SUMMATION OF CONDITIONED SUPPRESSION¹RONALD VAN HOUTEN,² K. DANIEL O'LEARY,
AND STANLEY J. WEISSDALHOUSIE UNIVERSITY, STATE UNIVERSITY OF NEW YORK AT
STONY BROOK, AND THE AMERICAN UNIVERSITY

Four rats were trained to suppress responses in the presence of two separately presented stimuli that signalled shock in a conditioned-suppression paradigm. The two stimuli that signalled shock were then presented simultaneously to evaluate the effect of stimulus compounding on conditioned suppression. Two rats were tested by presenting the compound conditioned stimulus while conditioned suppression was being maintained to the individual conditioned stimuli. The other two rats were tested by giving them random presentations of the compound conditioned stimulus and the single conditioned stimuli during extinction of conditioned suppression. All four rats showed greater suppression to the compound stimulus than to either stimulus presented alone.

If a response is separately conditioned to each of two stimuli, the effect of the simultaneous presentation of the two stimuli on response frequency or magnitude is generally known as summation, when the response rate to the compound stimulus is higher than that to either stimulus presented separately (Weiss, 1967). This type of summation effect has been demonstrated in both operant and classical conditioning paradigms (Weiss, 1964; Pavlov, 1927).

Another kind of additive effect may exist in a conditioned-suppression paradigm where the response rate to either of two independent conditioned stimuli (CSs) is less than that of their baseline. Here, the tendency to suppress might summate to compounded CSs, producing a lower rate than to either stimulus alone. Hoffman, Selekman, and Fleshler (1966) trained pigeons to suppress responses to two separate auditory stimuli on the frequency dimension. A generalization test produced greater suppression in the region of the stimulus continuum where the separate frequency gradients overlapped than where they did not overlap. However, in the Hoffman *et al.* (1966)

study, the original CSs were never presented simultaneously. The present study sought to examine the effect of stimulus compounding of the original CSs after conditioned suppression had been demonstrated with the separate stimuli.

METHOD

Subjects

Four male hooded rats were maintained at 80% of their free-feeding weights. They were approximately 12 weeks old at the beginning of the experiment.

Apparatus

The experimental chamber was a Scientific Prototype A-102 rodent test cage housed in a ventilated, sound-proof enclosure. One CS, a 90-db, 1000-Hz tone, was delivered by an Eico signal generator through an overhead 8-ohm speaker affixed to the top center of the ceiling of the animal chamber. The sound-intensity measurement was taken with a General Radio 1551 Sound Level meter, scale C, with the microphone located 2 in. (50.8 mm) above the grid floor in close proximity to the response lever. The other CS, a 15-w light, was placed 14 in. (355 mm) above the floor of the apparatus. The ambient noise in the experimental chamber with the exhaust fan running was 69 db. The unconditioned stimulus (UCS) was a shock delivered to the grid through a scrambler by a Grason-Stadler Model E 1064 GS shock generator. Reinforcers were 45-mg Noyes rat pellets.

¹This research was supported in part by Grant MH-13495 from the National Institute of Mental Health, United States Public Health Service, to the third author. The authors are indebted to Drs. R. Rudolph and W. K. Honig for their critical readings of the manuscript.

²Reprints may be obtained from Ronald Van Houten, Department of Psychology, Dalhousie University, Halifax, Nova Scotia, Canada.

Procedure

The experimental procedure consisted of conventional magazine training and bar-press shaping, followed by variable-interval and conditioned-suppression training. Subsequently, all subjects were tested for summation of conditioned suppression on a stimulus compound-ing test. Two subjects were tested in extinction, the other two with a probe technique (Sidman, 1960).

Variable-Interval Training

Preliminary bar-press training consisted of approximately 50 reinforced bar presses on the first day. Subjects then received 80 reinforcements a session for three consecutive days according to the following schedules: Day 2, variable-interval 15 sec; Day 3, variable-interval 22 sec; Day 4, variable-interval 30 sec. After this preliminary training, all subjects received twenty-three 1-hr sessions on VI 30-sec, at which time response rate had stabilized for all subjects.

Conditioned-Suppression Training

On Day 28, conditioned-suppression training was initiated during the daily bar-press sessions. Four CS-UCS pairings were given. The CS alternated between light and tone with CS presentations occurring at random intervals during the sessions. Durations of CS, UCS intensity, and UCS schedule were manipulated to obtain intermediate levels of suppression.

The CS was originally presented for 3 min, terminating with shock onset. On the first day of suppression training (Day 28), each of the four 3-min CS presentations was followed by the onset of a 0.5-sec, 0.05-ma shock. Over Days 29 to 38, shock intensity was gradually increased to 0.5 ma. On Day 40, the CS duration was increased to 6 min. On Day 46, all subjects received shock after 50% of the CS presentations. On Day 54, Subjects 1B, 2A, and 2B were placed on 100% shock reinforcement. The 50% intermittent shock reinforcement schedule continued for Subject 1A because it seemed likely that 100% shock would completely suppress its responding.

Probe Test

When Subjects 1A and 1B showed stable intermediate rates of suppression, they were presented with a compound probe (Sidman, 1960).

In each test session there was a light-only presentation, a tone-only presentation, and two compound presentations, each terminating with shock. The compound probe test started with the presentation of one of the CSs, either tone or light, for approximately 2 min. Then, the other CS was added to the first for approximately 2 min. Finally, the added CS was turned off, leaving the first CS on for approximately another 2 min. These three stimulus conditions are respectively termed the pre-compound CS, the compound CS, and the post-compound CS, the post-compound CS terminating with shock onset. A schematic diagram of the probe test is presented in Fig. 1. The order of single and compound CS presentations was varied systematically.

Fig. 1. Schematic representation of compound probe testing. Upward deflections of a line indicate that the stimulus is on. An example of a compound probe with the tone as baseline is presented at (a) and an example of a compound probe with the light as baseline is presented at (b). The portions labelled (1) represent the pre-compound CS, those labelled (2) the compound CS, and those indicated by (3), the post-compound CS.

Extinction Test

When Subjects 2A and 2B showed stable intermediate rates of suppression, they were tested daily, each test consisting of ten 2-min presentations of tone alone, light alone, and the tone-light compound, all without shock. During these stimulus presentations, the VI baseline was still in effect. To isolate the three test stimuli, each stimulus was followed by 2 min of the VI baseline condition. The two subjects received a short warm-up on the VI baseline before each day's test. The order of the stimulus presentations during testing was determined by randomly selecting the six presentations of three, with each stimulus appearing in either the first, second, or third position of the test blocks.

After the first day of testing, both subjects received one session of conditioned emotional response (CER) training to reinstate suppression. Then, four more daily test sessions fol-

Subject 1A

Fig. 2. Cumulative records of Subject 1A during probe test Days 1 to 5. Every four segments indicate one day of testing consisting of two compound tests and two single stimulus presentations. Presentations of the tone alone are indicated by (T), and presentations of the light alone are indicated by (L). Compound presentations are indicated by (T + L). The cumulative records are arranged so that the CS presentations start at point A and terminate at point B contiguous with shock onset. Those segments with arrows only at A and B are presentations of the light alone or tone alone. The compound probes are indicated by two arrows between A and B. The lower-case letters at the left of the cumulative record segments indicate the following: (a) intermediate suppression to the tone presented alone; (b) intermediate suppression to the light presented alone; (c) summation of conditioned suppression with the tone as baseline; (d) summation of conditioned suppression with the light as baseline; (e) negative instances, i.e., the absence of additive summation. Diagonal marks on the records indicate food reinforcements.

Subject 1B

Fig. 3. Cumulative records of Subject 1B during probe test Days 1 to 5. Refer to Fig. 2 for an explanation of this figure.

lowed. No shocks were delivered during these test days for Subjects 2A and 2B.

RESULTS

Probe Testing

Cumulative records for the first five days of testing for Subjects 1A and 1B appear in Fig. 2 and 3. The data segments in Fig. 2 and 3 are arranged in chronological order, with the earliest results appearing in the upper left. The suppression to the CS alone on either side of the compound acts as a baseline for evaluating suppression to the compound.

Instances of fairly stable intermediate suppression to the tone alone can be observed at all segments marked (a). Comparable results for the light alone can be observed at segments marked (b). For both subjects, suppression to the light was more variable than to the tone. Pausing in the presence of the light is evident at several segments for both subjects. Summation of conditioned suppression with the tone as the baseline can be seen at segments marked (c), and similar results with the light as the baseline can be seen at segments marked (d). Segments marked (e) indicate the absence of the summation effect to the compound.

The response rates during the probe test are presented for each probe in Fig. 4. The same data are presented with the light and tone

Fig. 4. Response rates for Subject 1A and Subject 1B during the first five days of testing. Each data point represents the response rate for one stimulus presentation. Both tone and light baseline conditions are presented together for each subject. The vertical lines connecting extreme data points indicate the range of the response rate to each stimulus and the horizontal slashes indicate the mean response rate to each stimulus.

baselines presented separately for each subject in Fig. 5. The post-compound rate did not fully recover in the light condition for Subject 1A.

In general, probe testing demonstrated reliable summation, but it should be noted that the effect decreased over sessions.

Extinction Testing

The results of extinction testing for the first four days are presented in Fig. 6 along with the average rate for the four days of testing. Each data point represents 10 presentations of the stimulus. The summation effect is very pronounced during compound test conditions for Subject 2A during Days 1 and 2. The effect diminished over the four-day period for Subject 2A, whereas no noticeable diminution occurred for Subject 2B. The reacquisition of conditioned suppression after Test Day 1 intensified the summation effect for Subject 2B

Fig. 5. Response rates for Subject 1A and Subject 1B during the first five days of testing. Each data point represents the response rate for one stimulus presentation. The results for the tone and light baseline conditions are presented separately for each subject. The vertical lines connecting extreme data points indicate the range of the response rate to each stimulus and the horizontal slashes indicate the mean response rate to each stimulus.

but not for Subject 2A. The summation effect also lasted longer for Subject 2B.

The results for Subject 2A on Day 1 (see Fig. 7) show a striking example of the magnitude of the effect for this rat. It is obvious that the summative suppression obtained was very reliable over test days and was not a function of averaging.

DISCUSSION

The effect of compounding two separate stimuli that individually control conditioned suppression was summative suppression. There was greater response suppression to the compound CS than to individual (CSs) in both the probe test with conditioned suppression maintained and during a test with conditioned suppression undergoing extinction.

The per cent of suppression to the com-

pound CS is predicted more accurately by the product than the sum of percentage suppression to the individual CSs. However, the prediction is not precise. The summation effect decreased for both subjects in the probe condition, and for one subject during extinction testing. The weakening of the summation effect of the CER during the extinction test may have been due to the general extinction of conditioned suppression. In the probe condition, on the other hand, the weakening may have been due to the formation of the discrimination that shock was never presented during the compound stimulus.

The possibility of a stimulus dynamism effect was not controlled for in this experiment. However, Weiss (1969) has demonstrated that this is not a factor in stimulus compounding experiments that result in an increase in rate.

Fig. 6. Average response rate in the presence of all stimulus conditions for Rats 2A and 2B during the four days of the extinction test condition. The points labelled 1-4 represent the average rate during each stimulus during testing.

Fig. 7. Response rate during 2-min presentations for Rat 2A on Day 1 of extinction testing.

REFERENCES

- Hoffman, H. S., Selekman, W. L., and Fleshler, M. Stimulus factors in aversive controls: conditioned suppression after equal training to two stimuli. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 649-653.
- Pavlov, I. P. *Conditioned reflexes*. (Trans. by G. V. Anrep.) London: Oxford University Press, 1927.
- Sidman, M. *Tactics of scientific research: evaluating experimental data in psychology*. New York: Basic Books, Inc., 1960. Pp 120-127.
- Weiss, S. J. Summation of response strengths instrumentally conditioned to stimuli in different sensory modalities. *Journal of Experimental Psychology*, 1964, 68, 151-155.
- Weiss, S. J. Free-operant compounding of variable-interval and low-rate discriminative stimuli. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 535-540.
- Weiss, S. J. Attentional processes along a composite stimulus continuum during free operant summation. *Journal of Experimental Psychology*, 1969, 82, 22-27.

Received 16 November 1968.