Stimulus generalization along dimensions of an active avoidance CS in young rats*

JAMES F. BRENNAN and DAVID C. RICCIO
Kent State University, Kent, Ohio 44240

Immature rats were trained in two-way shuttle avoidance and tested for generalization in extinction along the frequency and intensity dimensions of the CS. While symmetrical decrements in response strength around the original CS value were found when frequency was varied alone, marked dynamism effects emerged during intensity generalization. Concurrent variation of both dimensions resulted in increased stimulus control by frequency with higher intensity levels. Previous findings of aversively motivated stimulus generalization in young and adult rats were considered.

Previous studies of the generalization of fear in immature animals have been largely confined to situations in which the acquired behavior involved inhibiting, rather than emitting, responses (e.g., Frieman, Rohrbaugh, & Riccio, 1969; Rohrbaugh & Riccio, 1968). The major advantage of an inhibitory response requirement is that young Ss are not penalized for inferior motor development. However, it seemed of interest to determine if the relatively steeper generalization gradients, obtained from young rats in passive avoidance learning, would be found by using an active avoidance paradigm. In a recent study, Rohrbaugh, Brennan, & Riccio (1971) reported a procedure for obtaining control by dimensions of the auditory CS in two-way shuttle avoidance. Accordingly, the major purpose of this experiment was to replicate the Rohrbaugh et al study by examining the generalization of active avoidance behavior in immature rats.

A further question concerned the extent of stimulus control when both dimensions of the warning signal are varied during generalization testing. A number of experiments (e.g., Butter, 1963; Cross, 1965) have reported greater generalization decrements when test stimuli are varied along two dimensions compared with gradient slopes obtained when stimuli are changed along only a single dimension. An unusual aspect of the Rohrbaugh et al study of tonal frequency and intensity generalization was that these dimensions produced gradients of markedly different shape when varied separately. That is, symmetrical decrements in response speed around the value of the original CS were found when frequency was varied alone, whereas a clear dynamism effect

emerged when intensity was varied singly. Upon concurrent variation of both dimensions, might these two processes "cancel" each other, producing an intermediate gradient, or would one dimension become perceptually salient, masking the influence of the other dimension? While earlier work (Rohrbaugh et al) suggested that, in adult Ss, there was a synergistic rather than a canceling effect, it remained unclear whether a similar result would be obtained from immature Ss.

METHOD

The Ss were six male albino rats, purchased from Holtzman Co., approximately 18 days of age upon arrival in the laboratory. All animals were weaned at age 20 days, and training began at 21 days of age. During the entire experiment, Ss were maintained on an ad lib diet.

The apparatus used for the avoidance acquisition training and generalization testing was a double-compartment shuttlebox, 48.6 cm long x 14.2 cm wide x 22.9 cm high. Ss could move between compartments through a 14 x 7.6 cm opening in the center partition. The floor of the shuttle consisted of 1/5-cm steel shock grids spaced 1.4 cm apart. Hinged lids of acrylic plastic covered the shuttle. Photocells were mounted 15 cm from the door opening in each compartment. A Standard Electric Timer was activated with CS onset and terminated by interruption of a photocell, permitting measurement of response latency to 1/100th of a second. The unconditioned stimulus of a 175-V shock from a "matched impedance" (150-K ohm) source (see Campbell & Teghtsoonian, 1958) was delivered to the grids through a Foringer scrambler. Tonal stimuli were presented to the Ss through two Quam 6-in. 8-ohm permanent magnet speakers, one mounted on the side wall of each compartment. The training and testing tones of 1,000, 2,000, 3,000, 4,000, and 5,000 Hz were generated from a

Hewlett-Packard audio-oscillator, and a Hewlett-Packard attenuator provided intensity gradations of 0 (loudest), 7, 14, 21, and 28 dB attenuation from a standard tone (93 dB re .0002 dyne/cm²).

All Ss were initially given 3 days of avoidance training, 100 trials per day. On a given training trial, onset of the 3,000-Hz 14-dB CS was followed 5 sec later by the UCS, unless the appropriate response (i.e., running into the opposite compartment) occurred, which terminated the tone. If the S did not respond within 5 sec after CS onset, shock was delivered, and remained on with the tone until the S responded. Trials were separated by a variable interval averaging 20 sec. Intertrial crossings did not affect the avoidance contingency, since each interruption of a photocell deadened that beam until the beam in the opposite compartment was broken. Ss were discarded from the experiment for failing to make at least 25 avoidance responses on Day 2 of training. Three rats were eliminated under this criterion and replaced with naive pups. One of three different generalization tests were given on Days 4, 5, and 6: frequency generalization, intensity generalization, and concurrent frequency and intensity generalization. On a given test day, each animal was exposed to a warm-up acquisition training session until a criterion of five consecutive avoidance responses was met. The shock was then disconnected and the appropriate generalization test for that day began in extinction. When testing was along the frequency dimension, the generalization stimuli were tones of 1,000, 2,000, 3,000, 4,000, and 5,000 Hz, all attenuated 14 dB from the standard tone. In tests of intensity generalization, 3,000-Hz tones attenuated 0 (loudest), 7, 14, 21, and 28 dB (faintest) were presented. During both of these tests, the generalization stimuli were randomly presented, with the single restriction that each value occur once in a block of five trials. The third condition consisted of all combinations of 1,000-, 3,000-, and 5,000-Hz tones with intensities of 0, 14, and 28 dB attenuation. The nine generalization values were also randomly presented within blocks of nine trials. The order of testing was completely counterbalanced across test days and Ss. If the S failed to respond within 12 sec on any trial, the trial was automatically terminated. The testing session was ended if a S failed to respond on five consecutive trials or if 100 test trials elapsed, whichever occurred first.

RESULTS AND DISCUSSION

Data from three generalization tests were collected from each of the six Ss,

*This investigation was supported by Grant GB-24220 from the National Science Foundation to the second author. Requests for reprints should be sent to David C. Riccio, Department of Psychology, Kent State University, Kent, Ohio 44242.

Fig. 1. Mean generalization speed for frequency generalization while intensity remained constant at 14-dB attenuation (Panel A), and mean generalization speed following intensity variation with frequency held constant at 3,000 Hz (Panel B).

making a total of 18 generalization tests. All tests were terminated prior to the 100-trial limit, with the number of trials during test sessions ranging from 25 to 80 trials. Latency to respond to each test stimulus was recorded and then converted to a speed score by calculating the reciprocal of response latency. Figure 1 shows the group gradients for frequency generalization (Panel A) and intensity generalization (Panel B) when each dimension was varied separately while the other remained constant at the original CS value. As Panel A indicates, when frequency alone was varied, the fastest speed occurred upon presentation of the original CS value (3,000 Hz), with reasonable decrements in response speed as the test stimuli differed from 3,000 Hz, although more pronounced decrements in responding emerged at lower frequencies than at higher frequency values. Analysis of the frequency results indicated that the effect of stimuli was a significant source of variance ($F = 6.30$, $df = 4/20$, $p < .01$). The apparent steepness of the slope following "single stimulus" training is probably attributable to an implicit interdimensional discrimination effect ($S+ =$ tone presence, $S- =$ tone absence). The frequency data are highly consistent with the generalization of auditory frequency in adults previously reported by Rohrbaugh et al (1971).

Interestingly, the group gradient obtained following intensity variation (Panel B) clearly shows a dynamism effect, with increasing response vigor as stimulus intensity increased. Statistical analysis of the data indicated a significant effect of stimuli

($F = 14.98$, $df = 4/20$, $p < .01$). Again, these data are very comparable to the dynamism effects in adults reported by Rohrbaugh et al. The basis for dynamism effects in shuttle avoidance is not yet clear. One reasonable model,

proposed by Perkins (1953) and Logan (1954), holds that dynamism is analogous to a peak shift effect and results from an implicit discrimination between a silent background ($S-$) and a more intense signal ($S+$). The Perkins-Logan hypothesis has found support from studies by Zeilinski (1965a, b, 1971), who examined intensity effects in both CER and barpress avoidance situations. By training Ss with various changes in white noise intensity during the ITI and CS periods, he reported evidence suggesting that the ease of intensity discrimination was a function of the direction of intensity change. Conversely, Brennan & Riccio (in press, a) found that dynamism effects in shuttle avoidance persisted even when the warning signal was softer than the background tone—a result that is not predicted from the Perkins-Logan discrimination view of intensity dynamism. The robustness of the auditory dynamism effects in rats under aversively motivated conditions may be related to faster rates of information processing with more intense signals (see also Grice, 1968). The functional role of dynamism might also be considered. If perceived

Fig. 2. Mean absolute response speed as a function of frequency with intensity as the parameter.

loudness ordinarily provides an important cue to the distance from a source (e.g., a predator), then an appropriate type of innate defensive reaction for a rat might well be to flee more quickly as the stimuli increase in loudness. In the wild, such a response might be elicited by novel or unlearned stimuli (cf. Bolles, 1970), but presumably the same mechanism could operate when the signal value of a stimulus is learned, as in the laboratory. Thus, once the avoidance response of running to the CS is established in the shuttle task, response vigor is enhanced as a function of stimulus intensity. The present findings are of particular interest because the process underlying intensity dynamism is apparently functional in rats as young as 25 days.

The results of concurrent frequency and intensity generalization are shown in Fig. 2, which indicates that control by frequency increased with greater intensity levels. Statistical analysis revealed that the main effect of frequency only approached significance ($F = 2.93$, $df = 2/10$, $p < .10$); however, the effect of intensity was a significant source of variance ($F = 44.34$, $df = 4/20$, $p < .001$). That stimulus intensity affected frequency control was confirmed by the significant Intensity by Frequency interaction ($F = 2.95$, $df = 2/10$, $p < .05$). It is interesting to note that stimulus control is usually considered in terms of the steepness of a *decremental* gradient of response strength about the CS. However, if control "is measured as a change in response probability that results from a change in stimulus value [Terrace, 1966, p. 271]," then incremental dynamism gradients would also seem to qualify as an example of stimulus control. While Blue, Sherman, & Pierrel (1971) have noted that this terminology raises some awkward problems, it may be convenient to view concurrent frequency and intensity generalization in terms of

both continually tending to exert stimulus control in different directions. Considering the robustness of the intensity dynamism effects, one might anticipate that, at high intensities, the Ss would respond primarily to the onset of the signal, irrespective of its frequency, and produce flatter gradients to pitch. Under the loudest (0 dB) condition, the animals do respond more vigorously to each of the generalized stimuli than at lower intensities (see Fig. 2), but they also show a steeper frequency gradient. Thus, the dynamism effect is differential in that the greatest influence occurs at the original CS frequency value.

The results of this experiment are in substantial agreement with previous data obtained from adults in two-way active avoidance. The lack of pronounced age differences in the generalization of active avoidance behavior is consistent with data indicating comparable acquisition of active avoidance in young and adult rats (e.g., Feigley & Spear, 1970; Kirby, 1963). Furthermore, the present findings lend indirect support to the interpretation of steeper generalization gradients in young rats obtained in passive avoidance situations as attributable to response inhibitory deficits in immature Ss (see Brennan & Riccio, in press, b).

REFERENCES

- BLUE, S., SHERMAN, J. G., & PIERREL, R. Differential responding as a function of auditory stimulus intensity without differential reinforcement. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 371-377.
- BOLLES, R. C. Species-specific defense reactions and avoidance learning. *Psychological Review*, 1970, 77, 32-48.
- BRENNAN, J. F., & RICCIO, D. C. Persistence of auditory dynamism effects in rats following two types of differential training. *Learning & Motivation*, in press, a.
- BRENNAN, J. F., & RICCIO, D. C. Stimulus control of shuttle avoidance in young and adult rats. *Canadian Journal of Psychology*, in press, b.
- BUTTER, C. M. Stimulus generalization along one and two dimensions in pigeons. *Journal of Experimental Psychology*, 1963, 65, 339-346.
- CAMPBELL, B. A., & TEGHTSOONIAN, R. Electrical and behavioral effects of different types of shock stimuli on the rat. *Journal of Comparative & Physiological Psychology*, 1958, 51, 185-192.
- CROSS, D. V. Metric properties of multidimensional stimulus generalization. In D. I. Mostofsky (Ed.), *Stimulus generalization*. Stanford: Stanford University Press, 1965.
- FEIGLEY, D. A., & SPEAR, N. E. Effects of age and punishment condition on long-term retention by the rat of active and passive-avoidance learning. *Journal of Comparative & Physiological Psychology*, 1970, 73, 515-526.
- FRIEMAN, J. P., ROHRBAUGH, M., & RICCIO, D. C. Age differences in the control of acquired fear by tone. *Canadian Journal of Psychology*, 1969, 23, 237-244.
- GRICE, G. R. Stimulus intensity and response evocation. *Psychological Review*, 1968, 75, 359-373.
- KIRBY, R. H. Acquisition, extinction, and retention of avoidance response in rats as a function of age. *Journal of Comparative & Physiological Psychology*, 1963, 56, 158-162.
- LOGAN, F. A. A note on stimulus intensity dynamism (V). *Psychological Review*, 1954, 61, 77-80.
- PERKINS, C. C. The relation between conditioned stimulus intensity and response strength. *Journal of Experimental Psychology*, 1953, 46, 225-231.
- ROHRBAUGH, M., BRENNAN, J. F., & RICCIO, D. C. Control of two-way shuttle avoidance in rats by auditory frequency and intensity. *Journal of Comparative & Physiological Psychology*, 1971, 75, 324-330.
- ROHRBAUGH, M., & RICCIO, D. C. Stimulus generalization of learned fear in infant and adult rats. *Journal of Comparative & Physiological Psychology*, 1968, 66, 530-533.
- TERRACE, H. S. Stimulus control. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application*. New York: Appleton-Century-Crofts, 1966.
- ZIELINSKI, K. The influence of stimulus intensity on the efficacy of reinforcement in differential training. *Acta Biologicae Experimentalis*, 1965a, 25, 317-335.
- ZIELINSKI, K. The direction of change versus the absolute level of noise intensity as a cue in the CER situation. *Acta Biologicae Experimentalis*, 1965b, 25, 337-357.
- ZIELINSKI, K. Increase versus decrease in noise intensity as a cue in avoidance conditioning. *Acta Neurobiologicae Experimentalis*, 1971, 31, 331-340.