CHOICE, TIME ALLOCATION, AND RESPONSE RATE DURING STIMULUS GENERALIZATION¹

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Six pigeons were trained to discriminate between two noise intensities using a procedure that assessed choice, time allocation, and response rate simultaneously and independently. Responses on the left or right key (R1 or R2) were respectively correct in the presence of two different intensities, S1 and S2. After a correct response, reinforcement became available for pecks on the center key. Reinforcement density for R1|S1 relative to R2|S2 was varied across experimental conditions. Generalization tests followed extensive training at each condition. As a function of stimulus intensity, proportions of initial choices of R2, of time spent in R2-initiated components, and of center-key responses emitted in R2-initiated components all yielded sigmoidal gradients of similar slope, which shifted slightly in location when relative reinforcement density changed. Changeovers were maximal where initial choice proportions approximated 0.5. Gradients relating the absolute number of center-key responses to stimulus intensity were also roughly sigmoidal, but were more sensitive to changes in reinforcement density. Gradients of momentary response rate also depended on reinforcement density. During training, large but transitory shifts in choice responding occurred when reinforcement density changed, while differences in momentary response rate developed slowly, suggesting separate control of choice and response rate by the contingencies of reinforcement.

Key words: stimulus generalization, choice, time allocation, response rate, multiple schedules, concurrent schedules, auditory intensity, key peck, pigeons

Studies of stimulus generalization that use different training procedures often report different gradient forms, and have given rise to diverse theoretical interpretations of the mechanisms underlying stimulus generalization. One common training procedure successively presents two different stimuli, with responding on one key intermittently producing food in the presence of one stimulus (S+), while food is never available in the presence of the other (S-). For example, Ernst, Engberg, and Thomas (1971) trained pigeons to discriminate between two light intensities, and then varied light intensity in a generalization test.

Gradient peaks shifted from S+ in a direction away from S-. Similar gradients are routinely obtained on qualitative continua such as wavelength (e.g., Hanson, 1959). Such gradients, with peaks shifted away from S+, are compatible with the Spence (1937) theory of stimulus generalization, which assumes excitatory conditioning to S+, inhibitory conditioning to S-, and generalization of both processes to adjacent stimuli. According to Spence, responding depends on the difference between excitatory and inhibitory strength at each value of the stimulus continuum.

An alternative successive discrimination procedure arranges reinforcement for two different responses, R1 and R2, in the presence of two different stimuli, S1 and S2. For example, Heinemann, Avin, Sullivan, and Chase (1969) trained pigeons to discriminate between two noise intensities in a forced-choice, discrete-trial procedure by reinforcing pecks on one key (R1) in the presence of one intensity (S1), and on a second key (R2) in the presence of a different intensity (S2). When noise intensity was varied in a generalization test, the resulting gradient relating the proportion

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of R2 responses to stimulus intensity was sigmoidal. Heinemann and Chase (1970) later obtained similar results with a wider range of stimulus intensities. The sigmoidal gradient is consistent with the theory of signal detectability, which assumes a distribution of sensory effects produced by each stimulus on the intensity continuum, and a response criterion such that R1 occurs if the sensory effect falls below the criterion, and R2 occurs if the effect exceeds criterion. (For a general review of signal-detection theory see Green and Swets, 1966; MacNicol, 1972. For discussions of signal-detection theory as it relates to stimulus generalization see Blough, 1969; Boneau and Cole, 1967; Heinemann *et al.*, 1969.) This theory does not assume any special excitatory or inhibitory effects accruing to S1 or S2. The effect of stimulus variation is confined to variations in the probability that a given stimulus will produce a sensory effect that exceeds the criterion, while differential reinforcement for R1 *versus* R2 determines only the location of the criterion.

These theories are difficult to bring into sharp opposition, in part because they have special relevance to different procedures. The theory of signal detectability is most appropriate to experiments in which two alternative responses are defined and reinforced during training (*i.e.*, a choice situation), whereas excitation-inhibition approaches are most appropriate to experiments in which only a single response class is defined and reinforced, *i.e.*, a go-no-go situation. The theory of signal detectability can account for peaked gradients in the go-no-go situation by assuming that responding and not-responding correspond to R1 and R2 in Heinemann's procedure, and that there is a second criterion above which responding does not occur. Conversely, excitation-inhibition theory can account for sigmoidal gradients in choice situations by assuming excitatory gradients for R1 and R2 centered about S1 and S2, respectively; inhibitory gradients for R1 and R2 centered about S2 and S1, respectively; and choice of R1 or R2 based on an algebraic combination of excitation and inhibition for each response at each value of stimulus intensity.

In an attempt to reconcile the various results of stimulus-generalization studies using different procedures, and in the hope of facilitating a unified account of performance during

stimulus generalization, we arranged a situation in which we measured both choices between two response alternatives and rate of responding after a choice as independent functions of stimulus intensity during generalization tests.

Although the theory of signal detectability is not explicit on this point, the detectability approach suggests that variations in stimulus intensity would affect only the probability of emitting R1 or R2; the rate of responding after a choice should be constant. Excitation-inhibition approaches to stimulus generalization, whether of the traditional sort originally proposed by Spence (1937) or the more recent variety proposed by Blough (1975), lead to the expectation that choices and response rates will both depend systematically on the frequency of reinforcement in the presence of a given stimulus and the physical similarity of other stimuli presented during generalization testing.

METHOD

Subjects

Twelve experimentally naive, male White Carneaux pigeons were maintained at $80\% \pm 15$ g of free-feeding body weights. In those cases in which performance was difficult to maintain, the subjects were kept at 20 g below 80% of their free-feeding weights until performance recovered. After 60 days of training, the six subjects with the lowest accuracy levels were dropped from the experiment.

Apparatus

The experimental chamber was constructed from a picnic chest. Three Lehigh Valley pecking keys, a houselight, and a Lehigh Valley grain feeder were mounted on a response panel. The keys were illuminated from behind by Lehigh Valley tri-color stimulus cue lights. A Utah 12-ohm speaker was mounted on the wall opposite the response panel.

The noise stimuli were produced by a Grason-Stadler noise generator, model 455C, connected in series to four Daven T-691 fixed attenuators of values 3, 6, 12, and 24 dB, a Grason-Stadler #E10589A impedance-matching transformer, and then to the speaker in the chamber. Nine auditory stimuli ranging from 68 to 92 dB re 20 μ N/M² and differing by 3-dB steps were used. The band-width of the noise

was specified by the manufacturer as flat from 0 to 20 kc, although inspection with an oscilloscope indicated that the higher frequencies within this range may have been attenuated. During the intertrial interval, as well as before and after an experimental session, a 5000-Hz, 80-dB tone was presented. The tone was produced by a Hewlett-Packard model 200B audio-oscillator. Calibrations were checked regularly with a Simpson #260 volt-ohm-milliammeter, and occasionally, with a General Radio #1551-C sound-level meter using scale CS.

Procedure

A. Final discrimination training procedure. The final procedure is diagrammed in Figure 1. Every training session consisted of 60 trials separated by 10-sec intertrial intervals. At the start of a trial, one of two noise intensities, S1 (74 dB) or S2 (86 dB), was presented and the two side keys were illuminated, the left red and the right green. The sequence of noise presentation was quasi-random (stimuli were arranged to occur no more than three times in succession). The noise stimulus and the side keys remained on for the duration of the trial. A peck on either side key illuminated the center key with a light of the same color. A response to the left key (R1) was designated as

correct in the presence of S1 and a response to the right key (R2) was correct in the presence of S2. If the pigeon pecked the correct side key on a given trial, responding on the center key produced reinforcement (3-sec access to grain) under a random-interval (RI) schedule. All RI schedules used a time base of 10 sec, and the mean schedule values were varied by changing the probabilities of reinforcement (Millenson, 1963). If the subject pecked the incorrect side key, reinforcement was not available, although the center key remained illuminated for the duration of the trial. A trial lasted 30 sec after the initial side-key choice. At the end of the trial, scheduled reinforcers that had not been collected were cancelled. During the 30-sec trial, a response to the side key most recently pecked had no scheduled consequences. However, a peck to the other side key changed the center-key color and produced the reinforcement schedule appropriate to the newly pecked key. After a changeover, a 2-sec delay was imposed before reinforcement became available on the center key.

After 20 days of stable performance on this procedure, a series of generalization tests was administered, four series to each pigeon. Each series was separated from the next by 35 days of discrimination training with new reinforcement schedules for center-key responses. These schedules were RI 40-sec and RI 40-sec; RI 25-sec and RI 100-sec; or RI 100-sec and RI 25-sec; and again RI 40-sec and RI 40-sec in the presence of S₁ and S₂ respectively. The average rate of reinforcement remained constant across conditions, while the relative number of reinforcers in the presence of S₂ varied, taking on values of 0.5, 0.2, 0.8, and again 0.5. The schedule conditions are designated by the proportion of reinforcers in S₂, symbolized $p(S^R \cdot R_2 | S_2)$. For Birds 71, 73, and 81, the order of schedule conditions was 0.5, 0.2, 0.8, and 0.5; Birds 72, 74, and 79 experienced these conditions in the reverse order.

B. Shaping and pretraining. The subjects were trained to eat from the food magazine and then to peck the center key by the method of successive approximations. During pretraining, one or the other training stimulus (S1 or S2) was presented. The color of the center key was that associated with a correct response to the stimulus being presented. Reinforcement was available continuously for responses to the center key. Over a period of several days, the

Fig. 1. Schematic diagram of procedure. Arrows indicate particular responses and their consequences. Left and right columns indicate the presence of S1 or S2, respectively. See text for explanation.

availability of reinforcement was decreased until stable performance was obtained on an RI 40-sec schedule. The final discrimination training procedure described above then began.

C. *The correction procedure.* During the early stages of discrimination training, the program of stimulus presentation did not advance unless the subject had emitted one correct side-key response followed by at least one center-key response on the preceding trial. This correction procedure was instituted to disrupt the strong position biases that characterized the early stages of training.

D. *Maintained generalization testing.* A generalization series consisted of five consecutive daily tests. In each session, the first 10 trials included only the training stimuli, S1 and S2. The subsequent 60 trials were divided into four blocks, each containing nine test trials and six training trials. On each test trial, one of the following stimuli was presented: 92, 89, 86, 83, 80, 77, 74, 71, or 68 dB. (These include the values of S1 and S2.) Only during the training trials, in which either S1 or S2 was presented, was reinforcement available for correct responses. During testing, four measures were recorded: the choice of side key at the onset of a trial (initial choice), the number of center-key responses emitted given a prior occurrence of R1 or R2, time spent in the presence of red or green on the center key, and the number of changeovers from R1 to R2, or *vice versa*, that occurred in the course of a single trial.

RESULTS

At the completion of training, performance was under stimulus control for all six birds. Initial choices of the left or right key were usually correct. Few changeovers occurred, and these were evenly distributed across the training stimuli. Rates of responding on the center key were generally stable. During maintained generalization testing, performance was similar to that described above on training trials. This section considers the various measures of performance in relation to stimulus intensity during test trials. Only pooled data and the data of one representative bird are presented. Complete tables of individual data are given in Mandell (1973).

Figure 2 presents three different measures of behavior, each calculated as a proportion re-

Fig. 2. Proportion of right-key (R2) initial choices, center-key responses following right-key responses, and center-key time following right-key responses, for three center-key reinforcement schedules, as functions of stimulus intensity. Pooled data and data from one representative subject are shown in left and right columns, respectively.

lating right-key (R2) responses, time following right-key responses (T|R2), and center-key responses following right-key responses (CK|R2) to total responses or time and plotted as a function of stimulus intensity. The data points are averages for the five generalization tests that comprise a single series. Both initial and recovered data at the 0.5 reinforcement-density condition are pooled. The three gradients represent the three reinforcement-density conditions (0.2, 0.5, 0.8). The high correlation between these three measures was not a necessary outcome of the procedure. For all three measures in all three conditions, roughly sigmoidal gradients were obtained. Deviations from this gradient form can be found in individual birds, but these are nonsystematic.

These gradients are quite similar to those obtained repeatedly by Heinemann and his associates (*e.g.*, 1969, 1970, 1973) in a simpler procedure that examined side-key choices in discrete trials. Heinemann *et al.* (1969) pointed

out that three parameters characterize the typical sigmoidal choice gradient: the slope of the gradient, the distance between the upper and lower asymptotes, and the location of the gradient along the abscissa. In no cases were systematic changes in the slopes of the gradients or the distance between asymptotes apparent in our data. The location of the gradients changes, however, as a function of the relative reinforcement density. Figure 2 shows that probability of R2 initial choices, relative time and relative center-key response rate were somewhat lower when $p(S^R \cdot R2|S2)$ was 0.2 than when it was 0.8, with data at 0.5 being intermediate. These effects, although small, were clearly evident for five of the six individual subjects, and were independent of order. According to Heinemann, the location of the gradient along the abscissa reflects the location of the response criterion, which depends on relative reinforcement. Thus, the sigmoidal gradient forms with constant slope, and the biasing effect of reinforcement scheduling, are consistent with the signal-detectability approach to discrimination and stimulus generalization.

The data on changeovers are also consistent with signal-detection notions. According to this theory, changeovers would be most frequent at stimulus values producing a distribution of sensory effects centered at or near the response criterion, because small changes in sensory effect would be most likely to fluctuate back and forth across the criterion under such conditions. Therefore, as the gradients of responding are shifted by changes in reinforcement density (see Figure 2), the value at which the mode of the changeover distribution occurs should shift correspondingly. This is shown in Figure 3, which plots the total num-

Fig. 3. Total number of changeovers as a function of stimulus intensity for conditions 2 and 3 $p(S^R \cdot R2|S2) = 0.2$ or 0.8 . Pooled data and data from one representative subject are shown in left and right columns, respectively.

ber of changeovers as a function of stimulus intensity. Only the data for 0.2 and 0.8 relative reinforcement conditions are shown because the choice gradients showed a clear separation in these two conditions, and because fewer changeovers were made in the 0.5 condition. The decrease in changeover frequency at stimulus conditions that favor strong preferences is also consistent with the findings of concurrent schedule research: Baum (1974) and Herrnstein (1961) have demonstrated that the rate of changeover responding is greatest when two concurrent variable-interval schedules have equal values, and the subject is approximately indifferent between them. Thus, the relation between changeover rate and degree of preference may be a general property of choice responding.

Figure 4 depicts the absolute number of center-key responses emitted at each stimulus intensity value, given the prior occurrence of R1 or R2. The upper asymptotes of these gra-

Fig. 4. Number of center-key responses given a prior occurrence of right-key (R2) or left-key (R1) responses, as a function of stimulus intensity for three center-key reinforcement schedules. Pooled data, and data from one representative subject are shown in left and right columns, respectively.

dients are positively related to the density of reinforcement. This effect was clearly evident for all six pigeons, and was independent of order of conditions.

These data are in only some respects consistent with previous research that emphasized rate of responding as a dependent variable in stimulus generalization. Other research has shown that normalized generalization gradients (which correct for the level of responding) become steeper as reinforcement becomes more frequent (Haber and Kalish, 1963; Hearst, Koresko, and Poppen, 1964). We did not confirm this observation; on the contrary, we observed remarkable constancy of the gradient form. A separate analysis indicated that all gradients were in fact multiplicatively related.

The sizeable changes in absolute numbers of center-key responses in Figure 4, in conjunction with the rather small shifts in time allocation in Figure 2, suggest that the momentary rates of responding, defined as $CK|R1$ divided by $T|R1$ and $CK|R2$ divided by $T|R2$, depended on the ongoing schedule of reinforcement. The momentary rates are presented in Figure 5. Because both time allocation and absolute number of responses fell to low levels at stimulus intensities remote from those correlated with reinforcement for R1 or R2, momentary response rates were not always measurable. Accordingly, momentary $CK|R1$ rates are plotted only for stimuli equal to or greater than S1, and momentary $CK|R2$ rates are plotted only for stimuli equal to or less than S2. Moreover, no group data points are plotted at any stimulus intensity unless data were available for all six birds.

The average gradients of momentary center-key response rate after R2 were essentially flat when $p(S^R \cdot R2|S2)$ was 0.2 (top panel, solid line), while they were sloped when $p(S^R \cdot R2|S2)$ was 0.8 (bottom panel, solid line). Similarly, gradients of momentary center-key response rate were sloped when $p(S^R \cdot R1|S1)$ was 0.8 (top panel, dashed line) and flat when $p(S^R \cdot R1|S1)$ was 0.2 (bottom panel, dashed line). There was no clear effect at 0.5. The effect at 0.8 was evident for 11 of the 12 individual gradients. In other words, momentary rate depended on stimulus intensity only for responding that followed side-key pecks associated with the higher density of reinforcement. In addition, for any given noise intensity where measurable response rates were

Fig. 5. Momentary center-key response rate ($CK|R1/T|R1$ or $CK|R2/T|R2$) as a function of stimulus intensity. The relative probabilities of reinforcement for correct center-key responses in the presence of S1 and S2 are indicated in each panel. Data are plotted separately for the first and second exposures to relative reinforcement probability of 0.5 (designated 1 and 2). Pooled data and data from one representative subject are shown in left and right columns, respectively.

available following both R1 and R2, momentary rate on the center key was higher following the side-key response leading to the higher probability of reinforcement. This difference was observed in 42 of the 55 individual comparisons available at S1, S2, and the intermediate intensities, and was evident for all six birds when momentary rates were averaged across intensities. This analysis demonstrates that the momentary rate of pecking the center key was controlled jointly by noise intensity and by whether R1 or R2 had occurred as the previous choice response, when reinforcement densities were 0.2 and 0.8. These data are analogous to those of Haber and Kalish (1963) and Hearst *et al.* (1964), who found steeper gradients with more frequent reinforcement. An orderly, graded relation between momentary

rate and stimulus intensity has also been reported by Honig and Beale (1976), whose procedure was similar to ours in that it provided the subjects with control over the conditions in which they responded.

The finding that under some conditions momentary rate of responding was essentially constant and independent of stimulus intensity, parallels and extends those of Migler (1964) and Migler and Millenson (1969), who studied lever pressing by rats in settings that did not involve initial choice responses. Blough (1963, 1969) also reported that the momentary response rates of pigeons tend to be constant across stimulus values during generalization testing, especially for high rates (interresponse times in the vicinity of 1 sec or less). Such findings suggest that once an organism initiates responding to a stimulus, it continues responding at a constant tempo regardless of the value of the stimulus, or else it terminates responding altogether (*i.e.*, engages in some other behavior). Our results suggest that invariance of momentary rate during stimulus generalization may be obtained only under certain restricted conditions, including (a) the lack of an explicit choice response, and (b) relatively infrequent reinforcement.

All of the foregoing data were obtained when reinforcement was withheld during stimulus generalization test trials. The effects of changes in relative reinforcement density can also be assessed by examining the final training data. In Figure 6, the proportion of correct responses is evaluated as a function of reinforcement density. Each point represents average data for the last five days of training at a particular schedule and was determined by obtaining the number of correct responses given S2 and dividing by the total number of correct responses [*i.e.*, $R2|S2/(R1|S1 + R2|S2)$]. This was done separately for initial choice and center-key responses. In addition, amount of time was substituted for number of responses, and a similar proportion obtained. Finally, relative momentary rates of correct center-key responses were similarly computed.

All four measures are plotted as a function of relative reinforcement density for R2. If a matching relation obtained, it would be represented by a 45° line. When treated in this manner, the proportion of center-key responses approaches a matching relation most closely and, therefore, can be said to be most sensitive to

Fig. 6. Proportion of correct initial choices, center-key responses, center-key time, and momentary center-key rates given S2, as functions of the relative probability of reinforcement scheduled in the presence of S2. Ranges of proportions for individual subjects are indicated.

relative reinforcement density. Evidently, this function is the combined result of relative time allocation and relative momentary center-key response rate. The slope of the functions for overall correct center-key responses and momentary center-key response rates is greater than zero for all six pigeons; the slope for initial choice functions is greater than zero for five of the six and the slope of the function for relative time is not consistently different from zero.

The smallness of these effects is somewhat surprising in view of the pronounced effect of relative reinforcement density on response bias (*i.e.*, the tendency to emit one or the other response alternative) in other two-response successive-discrimination experiments (Commons, 1973; Hobson, 1970; Stubbs, 1968, 1976; Wright, 1972). There are indications, however, that by assessing bias at an earlier point in training, the results might be more similar to

those obtained in other experiments. Figure 7 presents the proportion of initial R2 choices (i.e., $R2|S2$ and $R2|S1$, equivalent to "hits" and "false alarms" in signal-detection terminology), over the course of training. The four panels represent the different reinforcement conditions, in order for the two subgroups. In most cases, response probabilities change substantially at the onset of a new reinforcement condition. When $p(S^R \cdot R2|S2)$ is 0.8, the probability of $R2|S1$ peaks at block 2 (Sessions 6 to 10) and gradually returns to near its former level. Symmetrical changes occur when $p(S^R \cdot R2|S2)$ is 0.2. Relative time and proportion of center-key response measures follow the same pattern.

These transient effects may be understood by considering the accuracy of performance established before the reinforcement schedules were varied. If the subjects are performing with high accuracy, as in the present experiment, any biasing variable that alters the overall tendency to make one or the other response must result in an overall loss of reinforcement.

Thus, the generalized effects of changing one reinforcement schedule work directly against the maintenance of overall rate of reinforcement. On the other hand, when accuracy is low, changes in the overall tendency to respond on the favored key regardless of stimulus value may produce a net increase in reinforcement. In the limit, if $S1$ and $S2$ are identical and accuracy is forced to chance, a durable dependency of response proportions on relative reinforcement would be expected.

Figure 8 presents the momentary rate of responding on the center key for $R1|S1$ and $R2|S2$ over the course of training. Unlike relative initial choice, momentary rates were about equal at the beginning of Conditions 2 and 3 and then diverged. There was considerable variability, but no consistent indication that these trends were transient.

The present schedule may be viewed as a multiple schedule in which $S1$ and $S2$ are discriminative stimuli signalling each component. Our subjects performed with high accuracy during the final sessions on each training con-

Fig. 7. Proportion of initial choices of the right key ($R2$) during successive reinforcement conditions for Groups I and II. Lines indicate averaged data. Individual points represent data from individual subjects.

Fig. 8. Momentary center-key response rates in the presence of S_1 and S_2 during successive reinforcement conditions for Groups I and II. Lines indicate averaged data. Individual points represent data from individual subjects.

dition, so that nearly 100% of every S_1 trial was spent in the presence of red on the center key, which signalled one schedule of reinforcement, while nearly 100% of every S_2 trial was spent in the presence of green on the center key, which signalled an independent schedule of reinforcement. Studies of differential responding in the components of a multiple schedule have uniformly obtained a positive relation between relative responding and relative reinforcement (*e.g.*, Lander and Irwin, 1968; Reynolds, 1963). Thus, our finding of a reliable, durable effect on the relative momentary rates of center-key pecking (Figures 6 and 8) is entirely in accord with the multiple schedule literature.

In summary, relative measures of performance, such as the proportion of responding on one key or the proportion of time spent on one key, exhibited rapid transient changes in response to asymmetrical shifts in reinforcement

density. An absolute measure such as the momentary rate of responding, however, exhibited durable changes developing slowly after shifts in relative reinforcement density.

DISCUSSION

A brief summary of the procedure and results may be useful at this point. Pigeons confronted three response keys, where pecks on one side key (R_1) were correct and made reinforcement available on the center key in the presence of one noise intensity (S_1), while pecks on the other side key (R_2) were correct in the presence of a different intensity (S_2). The procedure permitted separate measurement of initial side-key choices; time spent responding on the center key after a choice; rate of responding on the center key after a choice, computed either on the basis of overall trial time, which we have termed overall response rate, or

on the basis of actual time spent responding after a particular choice, which we have termed momentary response rate. In addition, changeovers from one side key to another were recorded. These measures were examined during discrimination training and maintained stimulus-generalization testing under three different schedules of center-key reinforcement. The major results were that (1) initial side-key choices, relative time spent responding after a choice, and relative overall center-key response rate were related to stimulus intensity by sigmoidal functions, which were shifted slightly in location by relative reinforcement conditions; (2) the level of overall center-key responding depended on rate of reinforcement, but the forms of generalization gradients for overall response rate in relation to stimulus intensity were the same under all three conditions of reinforcement; (3) momentary response rate depended on both stimulus intensity and the ongoing reinforcement schedule; (4) changeovers were most frequent at those stimulus intensities where initial choices of a side key had a probability of approximately 0.5; and (5) initial choices were most dramatically affected by the schedules of reinforcement immediately after a transition from one schedule condition to another, while differences in momentary center-key response rate developed gradually over the course of extended training.

Considered in their totality, our data replicate and extend a number of findings in the study of stimulus and schedule control of responding. No single theoretical account integrates all the findings reported. Our data on initial choices in relation to stimulus intensity, the distribution of changeovers, and the transient effects of changes in reinforcement scheduling are consistent with signal-detectability theory when considered in relation to the contingencies of reinforcement. Our data on momentary rates of responding, which were measured independently of choices, show that differences in momentary rates developed only gradually when reinforcement schedules were changed, unlike choice responding. This dissociation of choice and rate measures in response to changes in relative reinforcement, although consistent with expectations based on multiple and concurrent schedule research, has certain implications for the signal-detectability approach to stimulus control. If changes in mo-

mentary response rate are taken to be indicative of the "expected value" of responding to a stimulus (*cf* Boneau and Cole, 1967), then shifts in the response criterion for choice should covary with changes in momentary response rate. This was clearly not the case. Moreover, nothing in the theory of signal detectability suggests that momentary rate of responding might depend on stimulus intensity under some parametric conditions. A possible account of differential responding to different successive stimuli during generalization is that two processes are involved: first, choice of one response class *versus* another (R1 *versus* R2, or responding *versus* not-responding) according to the general signal-detectability scheme proposed by Heinemann and his associates (1969, 1970, 1973), Blough (1969), and Boneau and Cole (1967); and, second, emission of responses at a rate that depends on relative frequency of reinforcement, according to a relation of the sort proposed for multiple schedules by Herrnstein (1970). In any given experiment, one or the other of these processes may predominate depending on factors such as frequency and contingencies of reinforcement, and duration of training. The separate measurement of choice and response rate is essential to a coherent account of the diverse findings of research on stimulus generalization.

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