SECOND-ORDER SCHEDULES WITH PAIRED AUDITORY BRIEF STIMULI

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Pigeons were exposed to multiple second-order schedules of paired and unpaired brief stimuli in which responding on the main key was reinforced according to a fixed-interval thirty-second schedule by a brief stimulus (a tone in the paired schedule) and advancement to the next segment of the second-order schedule. In Experiment 1, a response on the second key was required during the tone in its fourth and final presentation to produce food. Responses during earlier brief stimuli indicated the extent to which the final brief stimulus was discriminated from preceding ones. Responding was comparable during all tones, extending prior findings with visual paired brief stimuli and weakening explanations of subjects' failure to discriminate between brief-stimulus presentations in terms of elicited responding. In Experiment 2 the number of fixed-interval segments comprising the second-order schedules varied from one through eight. Although main-key response rates increased across segments in both experiments, they increased much less sharply with a variable number of segments. These results suggest that the increase in main-key response rates across segments is due primarily to a degree of temporal discrimination not reflected on the second key. Main-key response rates were higher on paired auditory brief-stimulus schedules than on unpaired visual brief-stimulus schedules, especially in Experiment 2, thus further extending findings with visual brief stimuli to second-order schedules with auditory brief stimuli.

Key words: second-order schedules, brief-stimulus presentations, auditory brief stimuli, temporal discrimination, conditioned reinforcement, reinforcement omission, multiple schedule, key peck, pigeons

Second-order schedules are those in which the completion of some subordinate schedule is treated as a unitary response that is itself reinforced according to some superordinate schedule of primary reinforcement (Kelleher, 1966). For example, on a fixed-ratio 4 (fixed-interval 30-sec) [FR 4 (FI 30-sec)] schedule, such as that used in the first of the present experiments, the completion of each FI 30-sec component is treated as a unitary response that is itself reinforced according to an FR 4 schedule of primary reinforcement. Such schedules have been used in numerous studies to investigate the conditioned reinforcement effectiveness of various stimuli (cf. Gollub, 1977; Rose & Fantino, 1978). For example, it is possible to schedule the occurrence of brief stimuli at the end of each component. If such stimuli occur also at the completion of the component im-

mediately preceding food, they are known as paired brief stimuli and have putative conditioned reinforcement properties. If they occur at the end of each component except the one immediately preceding food, they are known as unpaired brief stimuli. A schedule consisting of unpaired brief stimuli may be used as a control condition against which the conditioned reinforcing potency of paired brief stimuli may be assessed. Indeed, Kelleher (1966) found higher response rates in paired than in unpaired schedules of brief stimuli as did several subsequent investigators (e.g., deLorge, 1971; Malagodi, DeWeese, & Johnston, 1973).

The interpretation became complicated, however, when Stubbs' (1971) extensive series of experiments found equivalent effects of paired and unpaired brief stimuli. Not only did both maintain comparable response rates for a wide range of stimuli and schedules but, within components, both paired and unpaired brief stimuli maintained a pattern of responding similar to that maintained by primary reinforcement. Stubbs (1971) also noted that

This research was supported by NIMH Grant MH-20752 to the University of California, San Diego. I thank Warren Meck, Jed E. Rose, and Paul Royalty for extensive help. Reprints may be obtained from Edmund Fantino, Department of Psychology, C-009, University of California, San Diego, La Jolla, California 92093.

several of the studies reporting conditioned reinforcement effects for paired brief stimuli did not control adequately for differences between the type and number of paired and unpaired brief stimuli used. Thus, the status of paired brief stimuli as conditioned reinforcers was in serious question.

Two of the studies which have controlled adequately for differences in the type and number of paired and unpaired brief stimuli also employed a multiple-schedule procedure, in which paired and unpaired brief-stimulus schedules alternated (deLorge, 1971; Rose & Fantino, 1978). Rose and Fantino cited Nevin's (1973) conclusion that multiple schedules often provide a greater sensitivity to the effects of independent variables than single-schedule comparisons. Both deLorge (1971) and Rose and Fantino (1978) found higher overall rates of responding and shorter postreinforcement pauses with paired brief stimuli relative to comparable unpaired brief stimuli in the same multiple schedule. This finding, plus others reported in Rose and Fantino, led the latter authors to conclude that at least some rate enhancement on schedules of paired brief stimuli arises from the conditioned reinforcing value of the paired brief stimuli.

Another major source of rate enhancement on second-order schedules of brief stimuli was identified by Squires, Norborg, and Fantino (1975). They noted that the salient brief stimuli—either paired or unpaired—in the early components resemble those prior to the start of the final component. Perhaps the organism fails to distinguish between them and thus responds in the early components at a rate more appropriate to the later components. Squires et al. assessed this possibility using a two-key procedure similar to the one to be described for the present experiments. The pigeon advanced through the second-order schedule by responding on one key (the main key) while brief stimuli occurred on the second key (the brief-stimulus key). A response to the final paired brief stimulus was required for primary reinforcement. Responses to brief stimuli occurring at the end of the earlier components were unnecessary, or in one experiment were punished. If subjects discriminated between components of second-order schedules they should not have made premature brief-stimulus key responses, especially when such

responses were punished. Instead, all subjects responded consistently to all brief stimuli (in the paired brief-stimulus condition), a finding replicated by Rose and Fantino (1978). Squires et al. suggested that the major source of rate enhancement on second-order schedules (relative to tandem controls which arrange no brief stimuli) is the poor discrimination between the component immediately preceding food and the prior components of the schedule. In other words, the brief-stimulus occurrences may weaken temporal control in second-order schedules, resulting in main-key response rates more appropriate to rates during the final component (cf. also Fantino & Logan, 1979, pp. 184-186).

The present experiments address two unresolved issues. Squires et al. (1975) and Rose and Fantino (1978) raised the possibility that responses on the brief-stimulus key in the paired conditions may have resulted from the tendency of stimuli that are differentially associated with food to elicit key pecking (e.g., Gamzu & Schwartz, 1973). The present experiments utilize a tone localized away from the hopper as the paired brief stimulus. Such stimuli would not be expected to engender elicited key pecks (Steinhauer, Davol, & Lee, 1977). Will responses still occur during brief stimuli terminating early components of the second-order schedule? If so, the Squires et al. (1975) and Rose and Fantino (1978) finding that pigeons do not discriminate between components of paired brief-stimulus schedules would be extended to auditory brief stimuli and would not appear dependent upon elicited responding. If not, an explanation of the prior finding in terms of elicited responding would gain plausibility.

The second unresolved issue concerns the increase in rates of responding on the main key across the components of the second-order schedule found by both Squires et al. and Rose and Fantino. Does this increase reflect primarily a degree of temporal control not evident in the response rates on the brief-stimulus key? Or does this increase reflect primarily the effects of successive omissions of reinforcement, signaled by the brief stimuli (Squires et al., 1975; Staddon, 1972)? In the second experiment the number of components comprising the second-order schedule is variable (ranging from one to eight) rather than fixed as in prior

studies. Since reinforcement is equiprobable after each component (excepting the eighth, after which it is certain) an increase in responding across components may reflect the effects of reinforcement omission rather than discrimination. If response rates are now more uniform across components, of course, the reinforcement omission explanation of increasing main-key response rates in second-order schedules will be weakened.

Finally, the present experiments are the first to investigate the effects of auditory brief stimuli in multiple second-order schedules of paired and unpaired brief stimuli [although Marr and deLorge (Note 1) reported in Marr (1969) studied a multiple second-order schedule in which a tone served as an unpaired brief stimulus]. It is of interest to determine whether the results are comparable to those from the many studies of second-order schedules with visual brief stimuli (e.g., deLorge, 1971; Gollub, 1977; Kelleher, 1966; Stubbs, 1971).

EXPERIMENT I

In Experiment I, second-order schedules consisting of paired or unpaired brief stimuli alternated in a multiple schedule. The goal was to establish whether or not the following characteristics of responding, found by Rose and Fantino in comparable schedules with visual brief stimuli, would also be observed when the paired brief stimulus was a tone: (1) no evidence of discrimination between paired brief stimuli across components on the brief-stimulus key (this was the primary goal of the first experiment); (2) rate enhancement on the main key for the paired brief-stimulus schedule relative to response rates in the unpaired brief-stimulus schedule; (3) an increase in rate of responding on the main key across components.

METHOD

Subjects

Three male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. All had extensive experience with second-order schedules, including participation in Rose and Fantino (1978) and in two experiments with tones as paired brief stimuli.

Apparatus

A standard experimental chamber was employed, measuring 31 by 31 by 38 cm. Two translucent Gerbrands response keys, 10 cm apart and 21 cm above the floor, were mounted on the front wall of the chamber. The left key could be illuminated red, green, yellow, or orange, and the right key white or blue. Either key could be operated by depressing it with a force of approximately .15 N. Also in the front wall of the chamber, and 5 cm above the floor, was a solenoid-operated hopper for grain presentation. The houselight was not illuminated except when it served as the unpaired brief stimulus, in which case the chamber was lighted with a miniature 6-W white lamp located on the chamber ceiling in the left rear corner. White noise was used to mask extraneous sounds. A tone consisting of a 1,100 Hz (sine wave) could be generated from behind the rear wall of the chamber, i.e., facing the front wall (EICO-Electronic Instrument Company, Audio Generator, Model 377; speaker mounted 30 cm above the chamber floor and 3 cm behind rear wall of chamber). The adjacent room contained standard relay programming equipment.

Procedure

Except during reinforcement both keys were illuminated throughout. The left (main) key was illuminated red in the unpaired brief-stimulus schedule and yellow in the paired brief-stimulus schedule. The right (brief-stimulus) key was illuminated white in both schedules. In both the paired and unpaired brief-stimulus schedules, responding on the main key produced, on a FI 30-sec schedule, a brief stimulus and advancement to the next component of the second-order schedule. After completion of four such components, a response on the brief-stimulus key during the brief-stimulus period resulted in darkening of the key lights, illumination of the food magazine and 4-sec access to grain; the brief stimulus—the tone—continued until its duration reached two seconds.

In the paired brief-stimulus schedule, the first three brief stimuli were identical to the brief stimulus paired with food, a 2-sec tone presentation. In the unpaired brief-stimulus schedule, the first three brief stimuli consisted

of a 2-sec houselight illumination, whereas the brief stimulus paired with food was the 2-sec tone presentation.

Brief-stimulus key responses during brief stimuli occurring in the first three components of either schedule or at any time when the tone was not on had no scheduled consequences but were recorded. If primary reinforcement was not obtained at the end of the fourth component—by a response on the brief-stimulus key during the 2-sec tone presentation—the component was repeated until food was obtained. (This occurred an average of once per session for Pigeon 1804, three times per session for Pigeon 6254, and 14 times per session for Pigeon 6448. Other data will show that Pigeon 6448 was under poor stimulus control of the auditory brief stimulus.) Sessions were conducted seven days a week with few exceptions, each session lasting until 20 reinforcers were obtained. The experiment was terminated when performance of all three subjects appeared stable upon visual inspection of their data. This occurred when subjects had been exposed to 35 to 40 sessions on this procedure.

RESULTS

The primary goal of Experiment I was to assess the degree of discrimination among paired brief stimuli across components on the brief-stimulus key. These data are presented in the top frames of Figure 1, which plot the proportion of brief stimuli with one or more pecks for each of the four components (in cases for which the final component recycled owing to a failure to respond, only the first opportunity per reinforcer is considered). These, and all subsequent data, are based on the final five sessions. Means and standard deviation bars are presented on the figure. An increase across components (filled circles) would constitute evidence for discrimination across components on the brief-stimulus key during the paired brief-stimulus schedule. Note that with one exception there is little or no evidence of such discrimination. The exception occurred for Pigeon 6448, which had a lower proportion of pecks during the first paired brief stimulus than during subsequent ones. Of the three subjects this one seemed least under stimulus control of the paired brief stimuli, however, as evidenced not only by its relatively low probability of responding dur-

ing the tone even in the final component but also by additional data discussed below.

A second measure of discrimination among brief-stimulus presentations is the proportion of brief-stimulus pecks (out of the total) as a function of the ordinal position of the brief stimulus. This measure gives comparable results to those shown in Figure 1. Specifically, the mean proportions were .20, .24, .30, and .26 (Pigeon 1804) and .26, .31, .29, and .14 (Pigeon 6254) for the first through fourth brief stimuli. By this measure also, Pigeon 6448 provided an exception during the first brief stimulus: its proportions across the four brief stimuli were: .05, .33, .34, and .27.

The top frame of Figure 1 also includes comparable data for the unpaired brief-stimulus schedule. Pigeons 1804 and 6254 made relatively few responses during the unpaired brief stimulus (mean proportions per component ranging from .02 to .08) but generally responded to the final (paired) brief stimulus (mean proportions of .90 for Pigeon 1804 and .82 for Pigeon 6254). Pigeon 6448 was again somewhat anomalous, responding on a somewhat higher proportion of trials during the unpaired brief stimuli (mean proportions ranging from .16 to .28) and on a somewhat lower proportion during the paired brief stimulus (mean proportion of .62) relative to the other two subjects.

The lack of evidence for discrimination across components on the brief-stimulus key during the paired brief-stimulus schedule raises the possibility that subjects were not attending to the tone, thereby undermining much of the rationale for the present experiment. In order to assess this possibility the rate of responding on the brief-stimulus key during the tone was compared with that in the absence of the tone. If subjects were not attending to the tone but occasionally made pecks at the brief-stimulus key these rates should be comparable. Instead, response rates during the tone and during its absence were sharply different for both Pigeons 1804 and 6254 (average response rate during tone, 43 and 34 responses per min, respectively; average rate in absence of tone 0 and 2 responses per min, respectively). These differences were significant beyond the $p = .001$ level for each subject as determined by a t -test). For Pigeon 6448, however, rates were not significantly different (16 responses per min during tone, 14

Fig. 1. Proportion of trials with one or more responses during the brief stimulus (top) and main-key response rates (bottom) for each of three subjects across the four components in both the paired and unpaired schedules of Experiment 1. Data represent averages over the final five sessions; vertical bars denote one standard deviation.

responses per min in absence of tone, $t = .2$, $p > .20$). Thus, these data suggest that two of the subjects—neither of which showed any evidence of discrimination across components on the brief-stimulus key during the paired brief-stimulus schedule—attended to the tone.

One secondary goal of this experiment was to determine if rate enhancement occurred on the main key for the paired brief-stimulus schedule relative to response rates on the unpaired brief-stimulus schedule. The lower panel of Figure 1 compares response rates on the main key for both the paired and unpaired schedules, in responses per minute, across components for each subject. The two subjects

which appeared to attend to the tone both gave some evidence of rate enhancement on the paired schedule, at least in the first two components, a finding comparable to those of Rose and Fantino (1978) with visual paired brief stimuli (for Pigeon 1804 the rate in the paired schedule was significantly higher in both components: $t = 4.6$, $p = .01$ for first component; $t = 7.2$, $p < .01$ for second component; for Pigeon 6254, however, the differences in response rates failed to reach significance: $t = 1.4$, $p > .20$ for first component; $t = 2.4$, $p < .10$ for second component). The third subject (Pigeon 6448) showed little difference in rates during the first two components, although it

had shown clear rate enhancement by paired visual brief stimuli in Rose and Fantino (1978). Indeed, this subject responded more in the unpaired schedule during the final two components though this difference failed to reach significance ($t = 2.1$, $p < .20$ in third component; $t = 2.6$, $p < .10$ in fourth component). Thus, the present experiment provides only modest evidence for rate enhancement.

More obvious is the answer the data provide to our final question: do response rates on the main key increase across components in second-order schedules with auditory brief stimuli as they do with visual brief stimuli? For each subject the lower panel of Figure 1 shows a clear increase in response rate across components.

DISCUSSION

The results with auditory brief stimuli are generally consistent with those found in prior studies using visual brief stimuli. In particular, subjects gave no evidence of discrimination between paired auditory brief stimuli across components on the brief-stimulus key, a finding consistent with those of Squires et al. (1975) and Rose and Fantino (1978). In Experiment 2 of their study Squires et al. showed that even when responses to the paired brief-stimulus key following the first component were punished, pigeons continued to make these responses at the same high rate. During the punishment procedure, all six pigeons continued to emit responses on the brief-stimulus key even though these responses prevented delivery of primary reinforcement. (Prior to the present Experiment 1, the subjects were exposed to paired auditory brief stimuli in a simple [i.e., nonmultiple] second-order schedule with a comparable punishment procedure. In this case also, subjects gave no evidence of discrimination between paired auditory brief stimuli across components on the brief-stimulus key. Data available on request.) This raised the possibility that these responses resulted from the tendency of stimuli differentially associated with food to elicit key pecking (e.g., Gamzu & Schwartz, 1973). If so, the auditory brief stimuli used in the present experiment should have permitted better discrimination across components on the brief-stimulus key since they would not be expected to engender as much, if any, elicited key pecking (Bilbrey

& Winokur, 1973; Steinhauer et al., 1977). Instead, pigeons continued not to discriminate across components on the brief-stimulus key. It might be argued that the subjects had developed elicited responding to the visual brief stimuli in their prior experiments and that control of this responding transferred completely to the tone. Although Schwartz (1973) was able to transfer control of elicited responding to a tone, based on his results one would not expect transfer in the present experiment. In his study key pecking was not initiated when a tone was made the only differential signal for food unless the level of key pecking prior to introduction of the tone was "substantial" (his Procedure III vs VI). In the present study the level of pecking to the white brief-stimulus key prior to introduction of the tone was virtually zero for at least two of the three subjects. It seems fair to conclude that the prior findings (i.e., Rose & Fantino, 1978; Squires et al., 1975) cannot be explained readily in terms of elicited responding.

The second unresolved issue following earlier work concerns the increase in rates of responding on the main key across components of the second-order schedule (Rose & Fantino, 1978; Squires et al., 1975). The first of the present experiments established that this rate increase occurs also when auditory brief stimuli are used (lower panel of Figure 1). The second experiment addressed the source of this rate increase.

EXPERIMENT 2

Although response rates on the brief-stimulus key in the prior experiment and in both Squires et al. (1975) and Rose and Fantino (1978) showed no evidence for discrimination across components, in all three sets of experiments rates of responding increased on the main key across components. Does this increase reflect primarily a degree of temporal control not evident in the response rates on the brief-stimulus key? Or does the increase reflect primarily the effects of successive omissions of reinforcement, signaled by the brief stimuli? Unlike prior experiments, in which the number of components comprising the second-order schedule was always fixed, the number of components in the present experiment was variable, ranging from one to eight, with reinforcement equiprobable after each

component (except the eighth, after which reinforcement was certain). If response rates on the main key continued to increase across components this increase could not be attributed to temporal discrimination. On the other hand, if response rates were now more nearly uniform across components the reinforcement omission explanation of increasing main-key response rates in second-order schedules would be weakened and the role of temporal discrimination underscored.

METHOD

Subject and Apparatus

The same subjects and apparatus were used as in Experiment 1.

Procedure

The procedure was the same as in Experiment 1 except for the number of components. Instead of the four FI 30-sec components used in Experiment 1 for both paired and unpaired brief-stimulus schedules, Experiment 2 used a variable number of FI 30-sec components comprising both paired and unpaired brief-stimulus schedules. The conditional probability that a response during the brief stimulus following the end of the n th component would be reinforced was one-eighth for each of the first seven components and was unity for the eighth component (as determined by a Lehigh Valley Electronics Model #1652 probability generator).

RESULTS

Main-key response rates across the second-order schedule are shown in Figure 2 for each subject for both the paired (filled circles) and unpaired (unfilled circles) brief-stimulus schedules. In each case there is an increase in response rates across components although most of the increase occurs between the first and second components.

Comparison of response rates in the paired and unpaired components reveals rate enhancement by the paired brief-stimuli as response rates in the paired schedule are consistently higher than in the unpaired schedule (filled circles higher in 21 cases, unfilled circles higher in two cases, with one tie). An analysis of variance shows this difference to be significant ($F_{1,2} = 98.2$, $p < .02$).

In order to better compare the increase in response rates across components on the main

Fig. 2. Main-key response rate for each of three subjects across the eight possible components in both the paired and unpaired schedules in Experiment 2. Data represent averages over the final five sessions; vertical lines denote one standard deviation.

key between Experiment 1 (fixed number of components) and Experiment 2 (variable number of components), Figure 3 plots these rates in a comparable fashion. For this purpose adjacent components from Experiment 2 have been combined in pairwise fashion so that each curve contains four points. As can be seen, in every case the increase in rate across components is more pronounced in Experiment 1 than in Experiment 2 (e.g., for each of the six parts of Figure 3, the curve for Experiment 1 begins below that for Experiment 2 but ends higher, in most cases by a wide margin).

As in Experiment 1 there was evidence that Pigeons 1804 and 6254 attended to the tone (average response rate on brief-stimulus key during tone, 89 and 88 resp/min respectively; average response rate on brief-stimulus key during absence of tone, 7 and 8 resp per min, respectively; for both pigeons this difference was significant beyond the $p = .001$ level as $t = 24.7$ for Pigeon 1804 and $t = 12.1$ for Pigeon 6254). For Pigeon 6448 there was again

no evidence that the tone controlled its responding on the brief-stimulus key (32 resp per min during tone, 30 resp per min during its absence; $t = .98$, $p > .20$).

DISCUSSION

Response rates increased across components but did so much less sharply than they had in Experiment 1 which employed a fixed, rather than variable, number of components. As noted in the Introduction, to the extent that the rate increase across components was flatter in Experiment 2, these data provide evidence for a degree of temporal control in

Experiment 1 that was not evident in the response rates on the brief-stimulus key. It remains to explain only why some increase continued to occur across components even with a variable number of them. Data from Byrd and Marr (1969) suggest that some increase may be expected even when no stimuli are presented (and hence no reinforcement omission involved). In their study pigeons responded on a fixed-interval schedule reinforced under a variable-ratio of food reinforcement. They found some degree of acceleration in response rates between reinforcements not only when paired or unpaired brief stimuli accompanied the completion of each fixed-interval schedule but also in a condition in which no stimuli were presented (see their Figure 4). Apparently, some increase in rates of responding across components may be a characteristic of performance on second-order schedules. Thus, the increase in responding across components in the present Experiment 2 (variable number of components) may be an instance of this characteristic performance. The much sharper increase in responding across components in Experiments 1 (fixed number of components) probably reflects the additional effect of temporal control.

Finally, results in this experiment provide more clearcut evidence than those of the first experiment for rate enhancement by the paired brief stimuli: main-key response rates were higher on the paired brief-stimulus schedule than on the unpaired brief-stimulus schedule. This finding thus extends those of Rose and Fantino (1978) with visual paired brief stimuli to second-order schedules of auditory paired brief stimuli.

GENERAL DISCUSSION

Squires et al. (1975) showed that a major source of rate enhancement on second-order schedules is the poor discrimination between the component immediately preceding food and the prior components of the schedule. Resultant rates on the main key are thus more appropriate to rates during the final component. Squires et al.'s study and a subsequent one by Rose and Fantino (1978) left two issues unresolved. The first involved the possibility that responses on the brief-stimulus key in the paired conditions may have resulted from the tendency of stimuli that are differentially

Fig. 3. Main-key response rates compared for Experiments 1 and 2 for each of three subjects across components in both the paired and unpaired schedules. Response rates for Experiment 1 are the same as those from Figure 1, bottom. Response rates for Experiment 2 are arranged across pairs of the eight components, so that the rates may be more readily compared to those from Experiment 1. Data represent averages over the final five sessions; vertical lines denote one standard deviation.

associated with food to elicit key pecking. The first of the present experiments, using a brief stimulus not expected to engender elicited key pecking (a tone localized away from the food source), still found no evidence of discrimination on the brief-stimulus key, thus severely weakening an explanation of the prior finding in terms of elicited responding. The second unresolved issue concerned the source of the increase in rates of responding on the main key across the components of the second-order schedule (Rose & Fantino, 1978; Squires et al., 1975). The present Experiment 2 suggests that this increase reflects primarily temporal discrimination (not evident on the brief stimulus key).

The present results generally confirmed those of Squires et al. (1975) and Rose and Fantino (1978) and extended them to procedures using auditory paired brief stimuli. One subject, Pigeon 6448, seemed under poor stimulus control of the auditory brief stimulus, however. This was evidenced by its relatively low probability of responding during the tone, even in the final component, and by its comparable rates of responding on the brief-stimulus key both during the tone and during its absence. Following completion of the present experiments, Pigeons 6448 and four other subjects were exposed to a simple auditory discrimination task in which a VI 30-sec schedule, associated with a 2900-Hz tone, alternated with an Extinction period, lacking the tone; components were of 60-sec duration, while sessions terminated after 50 minutes. Pigeon 6448 acquired the discrimination after responding at chance level for the first eight sessions. It was the last of the five subjects to do so. Thus, while Pigeon 6448 was apparently capable of acquiring a simple auditory discrimination, it was not quick to do so.

In summary, pigeons responding on second-order schedules with auditory paired brief stimuli do not appear to discriminate between components when responding on the brief-stimulus key, extending prior findings with visual brief stimuli and weakening thereby explanations of this finding in terms of elicited responding. At the same time, however, responding increases across components on the main key. The present experiments suggest that this increase is largely due to temporal discrimination rather than to the effects of successive reinforcement omissions. The different

pattern of results on the main and brief-stimulus keys can be interpreted in at least two ways: in terms of differential discrimination and/or in terms of differential response strength. In the first case, different measures of the same discrimination do not necessarily agree (cf. Mackintosh, 1974, p. 558). In the second case, the tendency to respond on the brief stimulus key may be sufficiently strong to resist weakening by temporal cues associated with the early components (and with nonreinforcement), whereas responding on the main key is less resistant to the effects of such cues. This analysis is consistent with the view that responding in the initial links of a chain is less resistant to change than responding in the terminal links (e.g., Mandell, 1980; Nevin, Mandell, & Yarensky, 1981), since the main-key schedule in the present experiment is analogous to the initial links of a chain (effective responses light the brief-stimulus key) while the brief-stimulus schedule is analogous to the terminal links of a chain (effective responses produce food).

REFERENCE NOTE

1. Marr, M. J., & deLorge, J. O. Maintenance of behavior: Conditioned reinforcer vs. a neutral stimulus. Paper presented at Southeastern Psychological Association meetings, New Orleans, Louisiana, April, 1966.

REFERENCES

- Bilbrey, J., & Winokur, S. Controls for and constraints on auto-shaping. *Journal of the Experimental Analysis of Behavior*, 1973, **20**, 323-332.
- Byrd, L. D., & Marr, M. J. Relations between patterns of responding and the presentation of stimuli under second-order schedules. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 713-722.
- deLorge, J. The effects of brief stimuli presented under a multiple schedule of second-order schedules. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 19-25.
- Fantino, E., & Logan, C. A. *The experimental analysis of behavior: A biological perspective*. San Francisco, Calif.: W. H. Freeman, 1979.
- Gamzu, E., & Schwartz, B. The maintenance of key pecking by stimulus-contingent and response-independent food presentation. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 65-72.
- Gollub, L. R. Conditioned reinforcement: Schedule effects. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, 1977.
- Kelleher, R. T. Conditioned reinforcement in second-order schedules. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 475-485.

- Mackintosh, N. J. *The psychology of animal learning*. London: Academic Press, 1974.
- Malagodi, E. F., DeWeese, J., & Johnston, J. M. Second-order schedules: A comparison of chained, brief-stimulus, and tandem procedures. *Journal of the Experimental Analysis of Behavior*, 1973, **20**, 447-460.
- Mandell, C. Response strength in multiple periodic and aperiodic schedules. *Journal of the Experimental Analysis of Behavior*, 1980, **33**, 221-241.
- Marr, M. J. Second-order schedules. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Ill.: Dorsey Press, 1969.
- Nevin, J. A. The maintenance of behavior. In J. A. Nevin & G. S. Reynolds (Eds.), *The study of behavior*. Glenview, Ill.: Scott, Foresman, 1973.
- Nevin, J. A., Mandell, C., & Yarensky, P. Response rate and resistance to change in chained schedules. *Journal of Experimental Psychology: Animal Behavior Processes*, 1981 (in press).
- Rose, J. E., & Fantino, E. Conditioned reinforcement and discrimination in second-order schedules. *Journal of the Experimental Analysis of Behavior*, 1978, **29**, 393-418.
- Schwartz, B. Maintenance of key pecking by response-independent food presentation: The role of the modality of the signal for food. *Journal of the Experimental Analysis of Behavior*, 1973, **20**, 17-22.
- Squires, N. K., Norborg, J., & Fantino, E. Second-order schedules: Discrimination of components. *Journal of the Experimental Analysis of Behavior*, 1975, **24**, 157-171.
- Staddon, J. E. R. Temporal control and the theory of reinforcement schedules. In R. M. Gilbert & J. R. Millenson (Eds.), *Reinforcement: Behavioral analyses*. New York: Academic Press, 1972.
- Steinhauer, G. D., Davol, G. H., & Lee, A. A procedure for autoshaping the pigeon's key peck to an auditory stimulus. *Journal of the Experimental Analysis of Behavior*, 1977, **28**, 97-98.
- Stubbs, D. A. Second-order schedules and the problem of conditioned reinforcement. *Journal of the Experimental Analysis of Behavior*, 1971, **16**, 289-313.

Received November 24, 1980

Final acceptance June 23, 1981