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CONTROL OF KEY PECKING BY THE DURATION OF A VISUAL STIMULUS[1]

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Pigeons' key pecks were brought under the control of the duration of a visual stimulus in one-key and two-key procedures. In the one-key procedure, pecks were reinforced after presentations of a long-duration stimulus but not after presentations of a short-duration stimulus. In the two-key procedure, left-key pecks were reinforced after the long-duration stimulus and right-key pecks after the short-duration stimulus. In both procedures, the long-duration stimulus was 10 sec, and the short-duration stimulus was increased from 1 to 8 sec in 1-sec steps. Discriminative control developed with both procedures, but with greater accuracy in the two-key procedure, in which a difference threshold was obtained at short-duration values between 7 and 8 sec, or about 2.5 sec shorter than the long-duration stimulus.

Duration is a property of exteroceptive stimuli that can control an organism's operant behavior, within certain limits. The exploration of these limits in a given species is interesting in its own right, as is any psychophysical study. Moreover, it provides data that might prove valuable in the analysis of temporally spaced responding under such reinforcement schedules as DRL (differential reinforcement of low rate). It has been asked whether an animal's ability to space its responses in time can be inferred from its ability to discriminate durations as a property of discriminative stimuli (Catania, 1970; Kramer and Rilling, 1970; Platt, Kuch, and Bitgood, 1973; Reynolds and Catania, 1962; Richelle, 1968; among others). Depending on contingencies, the temporal parameter may involve the time separating successive responses (exemplified by DRL schedules), the time since a preceding reinforcement (fixed-interval (FI) schedules), the duration of a response (Platt *et al.*, 1973), the latency between a stimulus and a response (Catania, 1970, Saslow, 1968, 1972), and differential responding to external stimuli of different durations. No *a priori* reason should lead one to expect an organism to adjust with equal accuracy to the same value of the temporal parameter across these various categories of contingencies. In fact, the sparse data available to date point to the contrary (see Richelle, 1972). Moreover, within any of the above categories, minor variations in training procedure, density of reinforcement, intertrial or intersignal intervals, and the like produce changes in the accuracy of temporal control. In pigeons, the inaccurate spacing of responses under DRL schedules with values longer than 20 or 25 sec is not correlated with the accuracy of discriminating the duration of visual stimuli. As was shown by Reynolds and Catania (1962) and Reynolds (1966), pigeons discriminate stimuli of 30-sec duration from shorter-duration stimuli. Stubbs (1968) provided further evidence using durations up to 40 sec. In a study in which different stimulus durations controlled different responses, Stubbs showed that accuracy is a function of the relative, rather than the absolute differences between stimulus durations. The Weber fraction approximated 0.25 in one of Stubbs' experiments. Stubbs also showed that accuracy was a function of the contingencies of reinforcement under which it was measured.

Stubbs' sophisticated method is analogous to the so-called Method of Constant Stimuli in psychophysics. The present study attempted to control the pigeon's key pecks by the duration of visual stimulus with a procedure analogous to the Method of Limits, and to compare the accuracy in two situations that involved different degrees of constraint exerted by the contingencies.

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METHOD

Subjects

Three experimentally naive, male homing pigeons lived in individual cages, and were maintained at 90% of their free-feeding body weights.

Apparatus

The experimental space was a standard Grason-Stadler pigeon chamber equipped with two keys separated by 9 cm and symmetrically located on both sides of the central axis of the front panel. Each key could be illuminated green, and was operated by a minimum force of 0.12 N. A red ceiling light was used to present durations as discriminative stimuli. It was centered between the two keys. In the one-key procedure, the (left or right) key was covered. The control circuits were Grason-Stadler solid-state silent units, located in an isolated compartment near the chamber. When neither the keys nor the red light was lit, the subject was maintained in dim light, contrasting with the visual stimuli involved in the contingencies. Access to the food magazine was the reinforcement.

Procedure

One-key schedule. Each pigeon was exposed, during each 2-hr session, to a random sequence of red-light stimuli of two possible durations, long and short. The long stimulus was 10 sec throughout the experiment. The short stimulus was increased from 1 to 8 sec by 1-sec steps: two sessions were run with 1 sec, four sessions with 2 sec, and six sessions with each value from 3 to 8 sec. The average intersignal interval was 40 sec, with values ranging from 25 to 62 sec. Equal numbers of long and short stimuli were presented. Responses emitted during the presentation of either duration stimulus terminated that presentation (red light off). In the absence of such responses, the long or short stimulus was followed by a 3-sec period during which the key was transilluminated green. A response on the key during green darkened the key and, if the preceding stimulus was long, produced food for 5 sec.

After shaping of the key peck, pigeons were trained with only the long stimulus, until they no longer responded during the temporal stimulus (red light). The short stimulus was then introduced progressively, beginning with a brief flash, and slowly increased to 0.5 sec. Only when the performance was perfect at this value was the duration increased to 1 sec, starting the program described above.

Two-key schedule. In the two-key procedure, both keys were transilluminated green for 3 sec after each stimulus presentation. A left-key peck was reinforced when the preceding red-light duration was long (standard 10-sec stimulus), and a right-key peck when the preceding red-light duration was short. Any pecks during red terminated the stimulus. Pecks on either key during green turned off both keylights. Finally, time of access to food was reduced from 5 to 3 sec because the number of opportunities for reinforcement was twice as large as in the one-key procedure.

Pretraining consisted of three successive steps. First, the pigeons were taught to peck both keys; then, 10-sec long and 0.5-sec short stimuli were randomly presented but with only the correct key lit green; finally, both keys were lit until an almost perfect performance was obtained on the 10-sec–0.5-sec discrimination (*i.e.*, after 13 sessions).

The experimental program started with a long stimulus of 10 sec and a short stimulus of 1 sec, and the short stimulus was then lengthened as in the one-key procedure. In this procedure, however, short stimulus values of 9 and 10 sec were added. In both procedures, probably because of the progressive training method, pecks practically never occurred during the intervals between signals, so that it was not necessary to provide consequences for such pecks.

RESULTS

One-key schedule. The left part of Figure 1 shows probabilities of responding in green after the long red stimulus (upper curve) as a function of the short stimulus value. Despite the fact that incorrect responses (*i.e.*, responses after the short stimulus) were not punished, all three pigeons discriminated between the 10-sec stimulus and stimuli of durations ranging from 1 to 5 or 6 sec, if responding with a frequency equal to or less than 0.25 is taken as criterion.

To simplify comparison with the results of the two-key procedure, the data are shown in the right part of Figure 1 (solid line) in terms of percentage of correct responses: pecks dur-

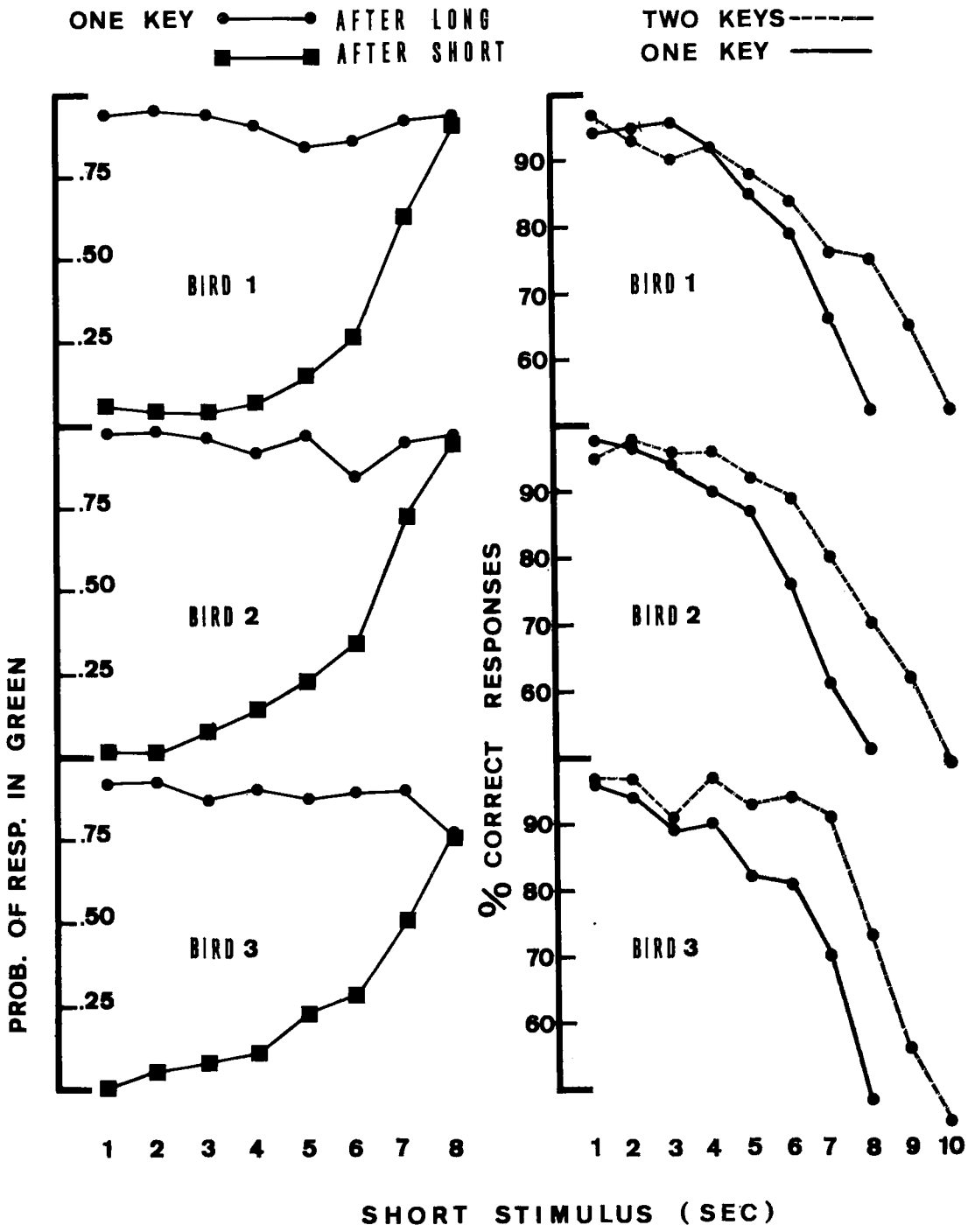

Fig. 1. Individual results under two types of contingencies in which key pecks were controlled by the duration of an exteroceptive stimulus. *Left:* probability of pecks in green after a long (10-sec) stimulus (upper curve) and after a short (1- to 8-sec) stimulus (lower curve) in a one-key procedure. *Right:* per cent correct responses as a function of the short-stimulus duration, in a one-key procedure (solid curve) and in a two-key procedure (dashed curve). Figures on the x-axis are durations of the short stimulus in seconds. See text for further details.

ing green after long stimuli and no pecks during green after short stimuli. Incorrect responses were therefore pecks during green after short stimuli and no pecks during green after long stimuli. Given these definitions, the per cent correct responses

$$\left(\frac{\text{correct responses}}{\text{correct responses} + \text{incorrect responses}} \times 100\right)$$

provides an index mathematically comparable to the one used in the two-key procedure.

Two-key schedule. Stimulus control was again measured in terms of per cent correct responses, *i.e.*, left-key pecks after long stimuli *plus* right-key pecks after short stimuli, divided by the total pecks on both keys after both durations. When key pecking is not controlled by stimulus duration, this index equals 50% and is not affected by biases for the right or left key.

The dashed line in Figure 1, right, shows the data as a function of the duration of the short stimulus. By the conventional 75% criterion, all three pigeons performed more accurately than in the one-key procedure: the 75% point fell between 7 and 8 sec.

DISCUSSION

Under both procedures in this experiment, the duration of a visual stimulus controlled pigeons' key pecks. The contingencies in the two-key procedure produced more accurate discriminative responding than the contingencies in the one-key procedure. In neither procedure was discriminative responding a condition for reinforcement: random responses on the key(s) during green would have been reinforced with 0.5 probability. In the two-key procedure, however, whether the pigeon received 50 or 100% of the available reinforcers depended on its accuracy: the contingencies did reinforce discriminative responding. But in the one-key procedure, pecking at each presentation of the green key, without regard to the duration of the preceding stimulus, would produce the maximal number of reinforcements. Compared with this optimizing strategy, discriminative responding could at best reduce the number of reinforcements. In fact, a slight reduction in pecking after long stimuli, *i.e.*, in reinforced pecking, was observed in some sessions with short-stimulus values between 3 and 7 sec for Pigeons 1 and 2, and of 8 sec for Pigeon 3. Why the organism should develop discriminative responding at all under the one-key schedule is a matter that deserves further attention; it is probably important that the short stimulus was introduced progressively. We hypothesize that the progressive training accounts for the strong control exerted by duration in both situations and in all three subjects.

Although the procedure was not designed to track a discrimination threshold, the two-key schedule provided a value of ±2.5 sec for a standard stimulus of 10 sec, confirming results obtained by Stubbs on the same species with a different procedure.

REFERENCES

Catania, A. C. Reinforcement schedules and psychophysical judgments: a study of some temporal properties of behavior. In W. N. Schoenfeld (Ed.), *The theory of reinforcement schedules.* New York: Appleton-Century-Crofts, 1970. Pp. 1-42.

Kramer, T. J. and Rilling, M. Differential reinforcement of low rates: a selective critique. *Psychological Bulletin,* 1970, **74,** 225-254.

Platt, J. R., Kuch, P. O., and Bitgood, S. C. Rat's lever-press durations as psychophysical judgements of time. *Journal of the Experimental Analysis of Behavior,* 1974, **19,** 239-250.

Reynolds, G. S. Discrimination and emission of temporal intervals by pigeons. *Journal of the Experimental Analysis of Behavior,* 1966, **9,** 65-68.

Reynolds, G. S. and Catania, A. C. Temporal discrimination in pigeons. *Science,* 1962, **125,** 314-315.

Richelle, M. Notions modernes de rythmes biologiques et régulations temporelles acquises. In J. de Ajuriaguerra (Ed.), *Cycles biologiques et psychiatrie.* Paris: Masson, 1968. Pp. 233-255.

Richelle, M. Temporal regulation of behaviour and inhibition. In R. A. Boakes and M. S. Halliday (Eds.), *Inhibition and learning.* London: Academic Press, 1972. Pp. 229-251.

Saslow, C. A. Operant control of response latency in monkeys: evidence for a central explanation. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 89-98.

Saslow, C. A. Behavior definition of minimal reaction time in monkeys. *Journal of the Experimental Analysis of Behavior,* 1972, **18,** 87-106.

Stubbs, A. The discrimination of stimulus duration by pigeons. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 223-238.

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