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MAINTENANCE OF KEY PECKING BY RESPONSE-INDEPENDENT FOOD PRESENTATION: THE ROLE OF THE MODALITY OF THE SIGNAL FOR FOOD[1]

BARRY SCHWARTZ

SWARTHMORE COLLEGE

Three pigeons were exposed to a series of procedures in which periods of response-independent food presentation, on a variable-time schedule, alternated with periods in which food was never presented. The stimuli that signalled periods of food availability or non-availability varied from one procedure to the next, and were sometimes key colors, sometimes tones, and sometimes compounds of both. Key pecking was initiated and maintained when key color was a signal for food; key pecking was not initiated when a tone was the signal for food. However, control of key pecking that was already established could be transferred from key color to tone, and subsequently, initiated by the tone. It is suggested that for pigeons, pre-experimental relationships exist among food, visual stimuli, and pecking, and that a similar relationship, which includes auditory stimuli, must be induced in the laboratory.

A good deal of attention has recently been focussed on the effects of the delivery of food, independent of responding, on the initiation and maintenance of key pecking by pigeons. One group of studies, concerned primarily with the maintenance of key pecking, has shown that pigeons that have been trained to peck an illuminated key to produce food will continue pecking the key when food delivery is made response-independent (Appel and Hiss, 1962; Edwards, West, and Jackson, 1968; Herrnstein, 1966; Herrnstein and Morse, 1957; Lachter, 1971; Neuringer, 1970; Zeiler, 1968). This phenomenon has typically been explained as a corollary of the effects of response-dependent reinforcement (*e.g.*, Herrnstein, 1966). Food presentation reinforces whatever behavior precedes it. Thus, any behavior that a food-deprived organism displays at the time of food delivery is more likely to occur subsequently. If the next food presentation is soon forthcoming, there is an increased probability that the behavior in question will again precede it, and so on. In this way, response-independent food presentation can maintain pecking. The effect of pretraining is to ensure that the key peck will be the pigeon's most probable response, and thus, the one most likely to precede food delivery and be maintained.

A second group of studies, centered on the phenomenon of autoshaping, has been concerned with the effects of response-independent food presentation on the initiation as well as the maintenance of key pecking (Brown and Jenkins, 1968; Gamzu and Schwartz, 1973; Gamzu and Williams, 1971; 1973; Williams and Williams, 1969). Gamzu and his co-workers (Gamzu and Schwartz, 1972; Gamzu and Williams, 1971; 1973) have shown that in the absence of any response-reinforcer dependency, key pecking will be initiated and maintained only if the keylight is a differential signal for food.

In the Gamzu and Schwartz (1973) experiment, naive pigeons were exposed to a series of two-component multiple schedules of response-independent food presentation. A multiple schedule is one in which the component schedules are each correlated with a different external stimulus, and are presented either randomly or alternately. The component schedules were sometimes identical (non-differential procedures), *e.g.*, the key color alternated between red and green with food delivered at variable intervals averaging 33 sec in both colors, and sometimes different (differential procedures), *e.g.*, the key color alternated between red and green with food delivered at variable intervals averaging 33 sec in red only. Key pecking was established and maintained at

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high rates only in the differential procedures, and key pecking that was already established virtually ceased in all the non-differential procedures, although the frequency of food presentation in non-differential procedures was typically twice that in differential procedures. Gamzu and Schwartz argued that since key pecking occurred only in the differential procedures, and since only in those procedures was the keylight a differential signal for food presentation, the initiation and maintenance of pecking at the key was primarily a function of the differential stimulus-reinforcer contingency, rather than an adventitious response-reinforcer contingency (*e.g.,* Herrnstein, 1966).

The present study attempted to assess the generality of the Gamzu and Schwartz results. In the standard pigeon conditioning procedure, the differential signal for food and the response target share a common locus—the key. Furthermore, the visual stimulus is particularly well suited as a target for pecking (Fantz, 1957; Hunt and Smith, 1967; Rheingold and Hess, 1957). These features of the procedure may capitalize on a biological predisposition in the pigeon to peck at members of a particular class of stimuli, so that the emergence and maintenance of key pecking by response-independent food presentation may depend on both the locus and the modality of the stimulus that signals food. To examine this, pigeons were exposed to response-independent multiple and mixed schedules of food presentation, with signals that were sometimes auditory and displaced away from the key, sometimes visual and on the key, and sometimes compounds of both. To the extent that both the locus and modality of the stimulus are critical to the emergence and maintenance of pecking by response-independent food presentations, it was expected that pecking would not be initiated or maintained when the signal for food was auditory and displaced away from the key.

METHOD

Subjects

Three experimentally naive, Silver King pigeons were maintained at 80% of their free-feeding weights.

Apparatus

The center key of a three-key Lehigh Valley Pigeon Panel (Model No. LV1519C) could be illuminated with either red or green light. The feeder was located below the center key and the houselight was located above the key. Food was presented for 4-sec periods, during which time a light in the feeder was illuminated and the houselight and keylight were extinguished. A deflector directed the light from the houselight toward the ceiling of the chamber. A speaker for presentation of a 1000-Hz tone was located to the left of the feeder.

Table 1

Summary of Procedures

Procedure	*VT Stimulus*	*EXT Stimulus*	*Sessions*
I *mult* VT 33 EXT	Green	Red	24
II *mix* VT 33 EXT	Green	Green	15
III *mult* VT 33 EXT	Tone + Green	Green	9
IV *mult* VT 33 EXT	Green	Red	9
V *mult* VT 33 EXT	Tone + Green	Red	15
VI *mult* VT 33 EXT	Tone + Green	Green	18
VII *mix* VT 33 EXT	Green	Green	9
VIII *mult* VT 33 EXT	Tone + Green	Green	9
IX *mult* VT 33 EXT	Tone + Green	Tone + Red	6

Procedure

The pigeons were first trained to eat from the feeder. They were then exposed, with no prior key-peck training, to the series of multiple and mixed schedules of food presentation listed in Table 1. Each daily session consisted of 80, 30-sec periods in which the two components of the multiple, or mixed schedules were alternately in force. Each of the component schedules in a given multiple schedule was correlated with a different key color, or key color-tone compound. When the mixed schedules were in force, the response key was always green and the tones were absent. The component schedules were of two types: schedules in which food was presented, independent of responding, separated by variable intervals of time (VT 33-sec schedules), and schedules in which food was never presented (EXT). It is important to note that at no time during the experiment was food delivery dependent on the occurrence of a key peck.

The variable that differed across the procedures outlined in Table 1 was the nature of the stimulus that was a differential signal for food presentation. In procedures I and IV, only visual stimuli were presented, and green was a differential signal for food. In procedures II and VII, the mixed schedules, again only visual stimuli were presented. However, in this case, the key was always green and thus green was a signal for both the availability and the non-availability of food. The only differential signal for food in these procedures was temporal: food was available in every other 30-sec component. In procedures III, VI, and VIII, both visual stimuli and a 1000-Hz tone were presented. However, the key was again always green, so that only the tone was a differential signal for food presentation. In procedure IX, the reverse was true: the tone was always present and green was the differential signal for food. Finally, in procedure V, both tone and green were differential signals for food. The pigeons were exposed to each procedure until the response rate of at least two of the three pigeons showed signs of stability.

RESULTS

The results are presented separately for each pigeon in Figure 1, which plots responses per minute, averaged across blocks of three sessions, for all procedures. The procedures are separated by vertical lines and labelled at the top of the figure (see Table 1). In procedure I, with green as the differential signal for food, key pecking developed rapidly and was maintained at 10 to 15 responses per minute. Virtually no pecks occurred to the red stimulus, which was correlated with extinction. In procedure II, the mixed schedule, pecking declined to zero within nine sessions. When the tone was added as a differential signal for food in procedure III, no pecking occurred. In the early sessions on this procedure, all three pigeons were observed orienting toward the tone. However, this behavior diminished in frequency as the procedure continued. Similar evidence of orientation to the tone occurred in the first few sessions of each procedure in which the tone was presented, but soon abated.

Procedure IV was a replication of Procedure I and all three pigeons quickly resumed pecking on the green key. Virtually no pecks occurred on the red key. When the tone was reintroduced in procedure V, this time as a redundant differential signal for food (green was also a signal), key pecking continued at rates similar to those in procedure I. Procedure VI was a replication of procedure III. However, this time substantial key pecking was maintained. There are two other interesting features of the data from procedure VI. Early in the procedure, key pecking decreased markedly on the VT schedule and increased on the EXT schedule. This is precisely what happened on the mixed schedule (procedure II) and suggests that the key color, and not the tone had been the primary controller of key pecking in procedure V, and this control carried over into procedure VI. The subsequent gradual increase in VT responding and decrease in EXT responding suggests a gradual loss of control over pecking by key color. However, even later in the procedure, when the tone had clearly come to control key pecking, there was less pecking on the VT schedule and more pecking on the EXT schedule in procedure VI (with tone as the only differential signal for food) than in procedure V (with green as the effective differential signal for food).

That the tone had come to control key pecking in procedure VI is evident in the data from procedure VII, in which the tone was removed (a repeat of the mixed schedule of procedure II). Here, key pecking rapidly ceased in all three pigeons. When the tone was reintroduced in procedure VIII, the pigeons rapidly resumed responding at the levels observed in procedure VI. Finally, in procedure IX, when the differential signal for food was switched from tone to green (though both stimuli were still present) responding increased to the VT stimulus and ceased to the EXT stimulus.

In summary, the major results of this study were as follows: (*a*) Pigeons key pecked at substantial rates when the key color was a differential signal for food presentation (procedure I). (*b*) Key pecking ceased when the only differential signal for food was temporal (procedures II and VII). (*c*) When the pre-exposure level of key pecking was zero, key pecking was not initiated when a tone was made the only

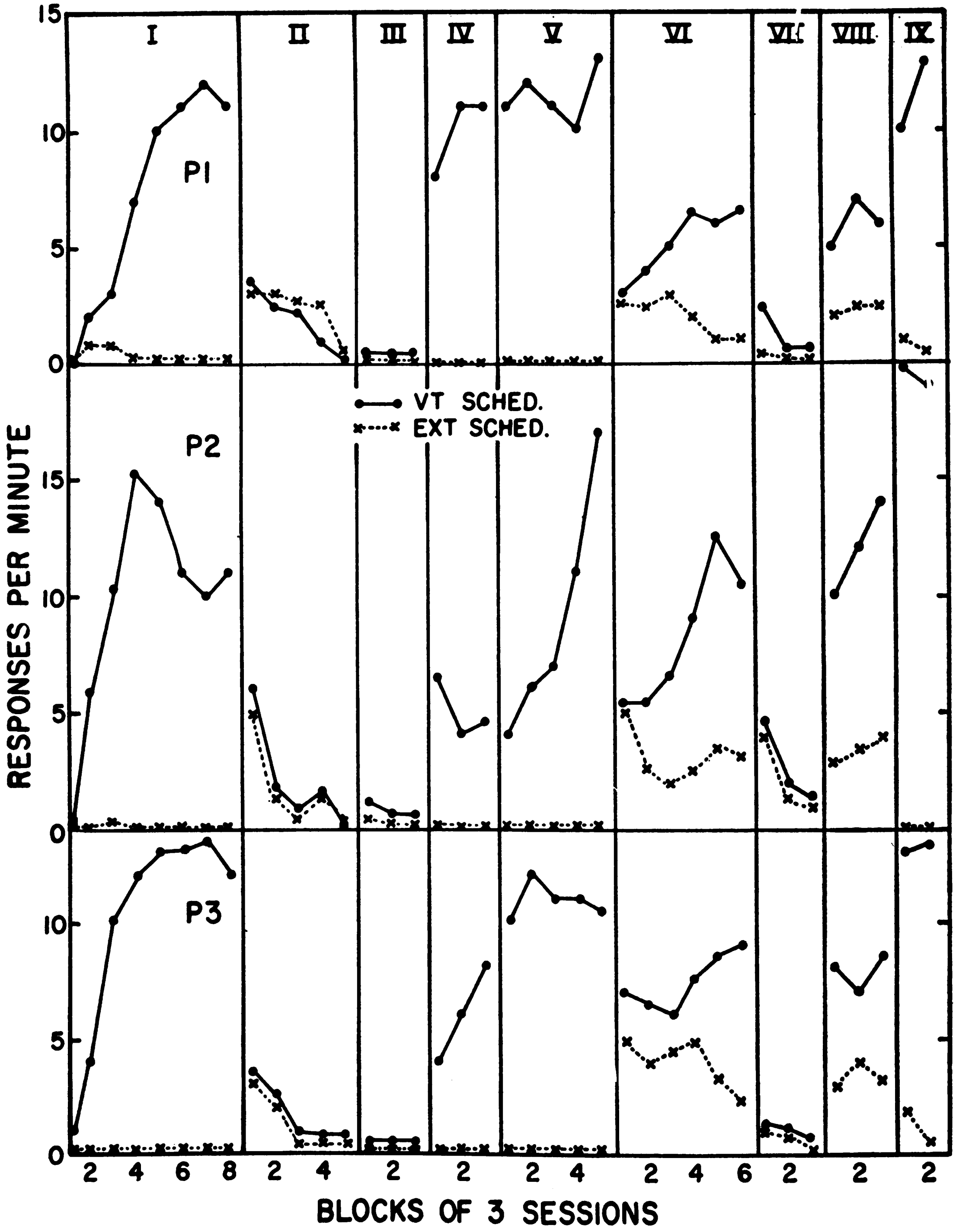

Fig. 1. Responses per minute, plotted separately, for VT and EXT schedules, and averaged across three-session blocks, for each pigeon in each procedure. The roman numerals at the top of the figure refer to the procedures identified in Table 1.

differential signal for food (procedure III). However, when the pre-exposure level of key pecking was substantial, key pecking was maintained when a tone was the only differential signal for food (procedure VI). Once the tone acquired control over pecking, it could generate and maintain pecking subsequently when the pre-exposure rate of key pecking was zero (procedure VIII). (*d*) The keylight acquired better control over pecking than the tone, *i.e.*, there was more responding on the VT schedule and less on the EXT schedule (procedures V and VI, procedures VIII, and IX).

DISCUSSION

The present data suggest that the locus and modality of the differential signal for food play a significant role in both the development and maintenance of key pecking by response-independent reinforcement. These data are consistent with those from a number of studies concerned with free-operant discrimination learning in the pigeon, some of which compared the effectiveness of visual and auditory stimuli in controlling key pecking, and some of which were concerned with the locus of the discriminative stimulus (*cf.* Terrace, 1966).

When the differential signal is a tone displaced away from the key, key pecking is not generated (procedure III) but is maintained (procedure VI). Once key pecking has been maintained in the presence of the tone, it subsequently can be generated by the tone (procedure VIII). A possible explanation of these phenomena is the following: the pigeon is predisposed to peck at visual stimuli, and in fact pecks at visual stimuli when they are differentially associated with food. On the other hand, the pigeon is not predisposed to peck at tones. When the tone is differentially associated with food, the pigeon does not peck the key (because the key is not a differential signal for food), does not peck the tone source (because pigeons do not peck at tones), and does not maintain an orienting response to the tone (because, as Staddon and Simmelhag (1971) suggested, food directly generates pecking, not orienting). What is necessary for the maintenance of pecking by the tone is to establish an association between the tone (as a signal for food) and the key (as a target for pecks). This is accomplished by procedure V. Once the tone has been associated with key pecking that is already maintained, it acquires the capacity to generate pecks when it is the only differential signal for food (procedure VIII). Thus, the fundamental difference between the tone and the key as signals for food is that it is necessary to establish in the laboratory a connection between the tone and pecking, while a tendency to peck at visual stimuli already exists. It should be noted, however, that even when control of pecking by the tone has been established, the keylight is still prepotent. This is evidenced by the responding that occurs in the EXT component of Procedures VI and VIII (in which the key is green in both VT and EXT components), and more clearly, by the immediate changes in responding that occur when the differential signal for food is switched from tone to green (procedures IV and IX). This result is puzzling in light of evidence reported elsewhere (Gamzu and Williams, 1971; Gamzu and Schwartz, 1973) that the key stimulus loses virtually all control over key pecking when it is no longer a differential signal for food.

The above argument attributes responsibility for both the acquisition and the maintenance of key pecking in this experiment to the stimulus-reinforcer contingency, and makes no mention of the possible effects of an adventitious response-reinforcer contingency. This omission requires justification, since the notion of adventitious reinforcement has played such a prominent role in other discussions of response-independent food presentation (Herrnstein, 1966). The Gamzu and Schwartz (1973) experiment, which is very similar procedurally to the present one, suggests that the applicability of adventitious reinforcement in accounting for the maintenance of pecking by response-independent food presentations may be limited, at least in procedures like the present one. In *mult* VT-EXT procedures, high rates of key pecking were maintained in the presence of the VT stimulus. If the key pecking were controlled by adventitious reinforcement, then a shift from *mult* VT-EXT to *mult* VT-VT (doubling the frequency of food presentation) would, if anything, result in an increase in key pecking. What occurs, however, is very sizable decrease in pecking—in some cases a complete cessation—which is consistent with an account in terms of differential stimulus-reinforcer contingencies. It is this result that suggests that adventitious reinforcement plays a negligible role in the present experiment. However, there is a complication. Rates of responding maintained on some procedures by response-independent food presentation (Gamzu and Schwartz, 1973; Gamzu and Williams, 1971; 1973) were considerably higher than response rates maintained by procedures that explicitly prevented possible adventitious reinforcement (Schwartz and Williams, 1972*a;* Williams and Williams, 1969). Thus, it is possible that adventitious reinforcement does contribute to the control of responding in this and similar experiments. It is possible that food delivery will adventitiously reinforce, and thus maintain, key pecks *only* if there is also a differential stimulus-reinforcer contingency controlling pecking, so that the efficacy of the response-reinforcer contingency depends upon the efficacy of the stimulus-reinforcer contingency. This possibility has been discussed in more detail elsewhere (Schwartz and Williams, 1972*b*) and requires further exploration.

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