*SOME FACTORS THAT INFLUENCE THE
ACQUISITION OF COMPLEX, STEREOTYPED,
RESPONSE SEQUENCES IN PIGEONS*

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Two pigeons were required to peck six to nine illuminated response keys. A response on any one of the keys darkened that key. When each key had been darkened, a reinforcer was delivered. No specific sequence of key pecking was ever required. The keys were presented in various matrices: three by two, three by three, horizontal rows, and vertical columns. The keys either presented the same stimulus, white light; or each key presented a different stimulus, a color or form. The results indicated that although there were 720 to 362,880 different sequences that would produce reinforcement, each bird developed a particular, stereotyped sequence that dominated its behavior. Variability among the birds across phases yielded less than 60 sequences, .0001 to 6 percent of the possible sequences. The data suggest that a reinforcement contingency that includes "free choice" of response sequence will produce stereotypical response sequences that function as complex "units" of behavior.

Key words: response sequences, complex operants, response stereotypy, key peck, pigeons

Reinforcement schedules have frequently been shown to control the force, duration, latency, and topography, as well as the response rate, of several operants (e.g., Antonitis, 1951; Herrnstein, 1961; Millenson & Hurwitz, 1961; Notterman & Mintz, 1965; Skinner, 1938; Stebbins & Lanson, 1962). Most studies have also demonstrated that long-term training on a variety of reinforcement schedules yields reduced variability in the terminal performance relative to the behavior emitted during early training sessions (e.g., Antonitis, 1951; Ferster & Skinner, 1957; Notterman, 1959; Skinner, 1938; Vogel & Annau, 1973). Several recent studies have demonstrated that a reinforcer not only influences the response that produces it, but also the earlier responses that were never directly followed by reinforcement (Cattania, 1971; Hawkes & Shimp, 1975; Wasserman, 1977).

Other researchers have published data indicating that repetitive behavior often becomes

stereotypical. Eckerman and Lanson (1969) showed that the variability of the pigeon's key peck on a 10 in. wide by .75 in. high response area decreased with training. That is, the key pecks were predominantly emitted on a narrow area of the key although there was no specific contingency to do so. Similarly, the present study is concerned with the distribution of responses across several pecking keys upon which no particular sequence is required. Schwartz (1980, 1981) and Vogel and Annau (1973) employed similar procedures, which enabled pigeons to exhibit stereotypical response sequences not required by the contingencies in effect.

In the Schwartz studies, pigeons were confronted with two pecking keys and a 5 by 5 matrix of lights. Each trial began with the top left lamp illuminated. Pecks on the left response key extinguished the lamp and lit the one to its right. A response on the right response key extinguished the lamp and lit the one below it. To obtain reinforcement, the birds had to move the illuminated lamp from the upper left to the lower right position in the matrix. This required four responses on each pecking key. Of the 70 possible sequences on the two response keys, the birds typically emitted one sequence for the majority of the trials.

The present study was designed to further

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demonstrate that although variability is permitted (i.e., there are several thousand possible response sequences), each bird quickly produces a dominant stereotypical sequence. Schwartz (1980, 1981) and Vogel and Annau (1973) permitted their subjects to demonstrate stereotyped sequences across two pecking keys. The present study enabled pigeons to demonstrate subject-determined response sequences distributed across six to nine pecking keys. Ferster and Skinner (1957) demonstrated that the introduction of a novel stimulus disrupts or alters previously established stable behavior. For example, they trained a pigeon on a fixed ratio 50 (FR 50) schedule for 5000 reinforcements. The response key was changed to a novel color at the beginning of the next session. The stimulus change disrupted the typical FR 50 break-run performance and continued to produce an intermittently rough grain for another two sessions (Ferster & Skinner, 1957, p. 78). This example and several others in their book indicate that although the reinforcement contingency remains unaltered, novel stimuli influence behavior. Therefore, one purpose of the present study was to assess what effects various stimuli projected on the response keys and their spatial configuration would have on the establishment and maintenance of stereotyped response sequences.

Finally, the emergence of consistent response patterns could be viewed as support for the position that a group of discrete responses may collectively function as an operant (Shimp, 1976a; Wasserman, 1977).

METHOD

Subjects

Two adult male white Carneau pigeons were maintained at $80\% \pm 15g$ of their free-feeding weights. These pigeons had prior histories on the matching-to-sample paradigm.

Apparatus

The apparatus was a 35- by 35- by 37 cm (length, width, height) operant conditioning chamber enclosed in a sound-attenuating hull. Figure 1 represents the intelligence panel employed in this experiment. Other than the unusual number of pecking keys, labeled 1 to 11, the intelligence panel, 37 cm long by 35 cm

wide, employed standard dimensions and commercial components. Each pecking key was 2.7 cm in diameter (BRS/LVE model #121-16). The stimuli were projected onto the keys by Industrial Electronic Engineers Inline Projectors (model #1813-44). The operating force requirement of each key was approximately .16 N. The horizontal distance between the keys was 8.1 cm, center to center. The pecking keys were vertically separated by 6.4 cm, center to center. A 6 cm square feeder aperture was centered on the wall 10 cm above the floor.

The feeder (BRS/LVE model #114-10) provided 3-sec access to mixed grain at appropriate times. The houselight, a GE #1820 lamp, provided light before and after experimental sessions. During each daily session, illumination was provided only by the Inline projector mounted behind each response key and the feeder light during reinforcement. Response Keys 10 and 11 were never illuminated during the experiment. White noise delivered through the speaker and a ventilation fan provided masking of extraneous laboratory noise. Data recording and experimental events were controlled by an E and L Instruments MMD-1 Computer.

Fig. 1. The intelligence panel employed. The pecking keys are numbered 1 through 11. SP is the speaker that provided masking noise; H and SA represent the houselight and sonalert respectively.

Procedure

Because of a prior history of key pecking and eating from a food magazine, no preliminary training was required. The pigeons were run in daily sessions consisting of 50 trials. Figure 2 shows the response keys and stimuli employed in each phase of the experiment.

Phase 1. Phase 1 provided an opportunity for the birds to establish a stereotypical response sequence on six keys. Each bird was exposed to 20 sessions with the following contingency. At the beginning of each trial, response keys 1 to 6 inclusive were illuminated with white light. A peck on any of the six response keys darkened that key. When each of the six response keys had been pecked, and subsequently darkened, a reinforcer was delivered. A reinforcer consisted of 3-sec access to mixed grain. During reinforcement all lights in the chamber except the feeder lamp were extinguished. Each reinforcer was followed by a 3-sec intertrial interval (ITI). During each ITI all chamber illumination was eliminated. During this phase and the others outlined below, the basic contingency was the same. In order to obtain reinforcement, it was necessary to peck each of the lighted keys once.

Fig. 2. The response keys and stimuli employed in each of the 11 phases of the experiment. The stimuli employed included: (W)hite, (R)ed, (G)reen, (Y)ellow, (V)ertical Line, (H)orizontal Line, (C)ircle, and an "X." The number under each representation of the nine keys (1 to 11) indicates which phases these stimuli and response keys were employed. Filled circles indicate response keys that remained dark during a phase.

No specific response sequence was ever required. Additional key pecks on a darkened key had no programmed consequence. The independent variable altered across the remaining phases was the response keys employed and the stimuli projected on them.

Phase 2. Figure 2 indicates that for the next 20 sessions each of the six upper response keys presented a different stimulus. Keys 1 to 6 presented, respectively: red, blue, green, yellow, white, and a white vertical line on a black background. Phase 2 tested the possibility that a different stimulus present on each response key would strengthen, alter, or disrupt the sequence stereotypy emitted in Phase 1.

Phase 3. The same response keys and white stimuli employed in Phase 1 served in the 10 sessions of this phase. This manipulation tested whether changes in the dominant sequence produced in Phase 2 would be maintained when the conditions of Phase 1 were reinstated.

For the next ten sessions (Phase 4), Figure 2 indicates that response Keys 1, 3, 4, 6, 7, and 9 each presented white as their respective discriminative stimuli (S^D). This phase tested whether vertical columns of stimuli would produce more or less response stereotypy than the spatially horizontal conditions utilized in the first three phases.

The 10 sessions of Phase 5 provided rows of white stimuli in a horizontal plane that were spatially more separate than those presented in the first three phases.

Phase 6. The same six response keys used in Phase 5 now presented red, blue, green, yellow, white, and a vertical line for 10 sessions. This permitted assessment of the effects of greater vertical separation with the horizontally different stimuli presented as Phase 2. The next 10 sessions, Phase 7, presented the same conditions originally offered as Phase 2.

For the next three phases, five sessions each, the response keys and stimuli employed in Phase 7 were retained. In each phase, an additional response key and stimulus was added. Phase 8 provided the addition of response Key 8, which presented a white horizontal line on a black background. Phase 9 added an "X" on response Key 7. Phase 10 included a white circle on response Key 9. Phase 11 presented white light on response Keys 1 to 9 inclusive for five sessions.

Phases 8, 9, and 10 enabled the birds to demonstrate where they would insert each new response key in the dominant response sequence established in each preceding phase. In Phase 11, the nine different stimuli were replaced with white light. If the dominant response sequences established in Phases 7 to 10 inclusive were produced by employing nine different stimuli, then replacing those stimuli with nine white lights should alter or disrupt these sequences.

RESULTS

The data of main concern include: the number of different sequences emitted, the frequency of occurrence of the sequence that became dominant, the order of the keys that comprised the primary sequence, and the percentage of possible sequences that were actually emitted. Figure 3 shows the number of different response sequences emitted by each bird during the last three sessions of each phase of the experiment. There were several thousand potential response sequences. Only 150 of these could be produced, however, within the 150 trials depicted from each phase. Overall, the data show a remarkable degree of consistency over phases; i.e., with different numbers of keys, spatial arrangements, and stimuli projected on the keys. Across the last three sessions of each phase, the mean number of re-

sponse sequences emitted was 38.6 and 26, for Subjects B1 and B2, respectively. The standard deviation was 14.4 for Pigeon B1 and 12.0 for the other bird. The number of sequences emitted did not vary by more than 10% across sessions within each phase. The number of response sequences produced remained fairly constant after the second session of training.

The graph shows that Pigeons B1 and B2 produced 34 and 45 response sequences, respectively, during Phase 1. During Phase 2, when six different stimuli were introduced, Subject B2 halved the number of sequences (to 17) used, whereas Subject B1 showed a slight increase (35). In Phase Three, Subject B2 increased his sequence output (from 17 to 33), whereas Subject B1 decreased it (25). Both subjects emitted fewer sequences (23 and 10) when six vertical keys, separated by a column of dark keys, were introduced in Phase 4. However, when six horizontal keys separated by a row of dark keys were presented (Phase 5), both birds doubled the number of emitted sequences (from 23 and 10 to 45 and 41 for B1 and B2, respectively). The second time the different stimuli were introduced, as Phase 6, both subjects decreased the number of sequences emitted (to 36 and 13). Phase 7 removed the row of dark keys between the lighted stimuli. Subject B1 reduced the number of sequences emitted (to 26), whereas Subject B2 showed an increase (to 23 sequences). A comparison of Phase 4 with Phases 1, 2, 3, 5, 6, and 7 indicates that vertical columns of stimuli produced more response stereotypy than horizontal rows of stimuli. Phases 8 and 9, which introduced new stimuli, produced a slight decrease in response sequences by Subject B2 (20) and an increase by the other bird (from 26 to 36 sequences). Phase 10 yielded an increase in both subjects, about 20 additional sequences each, whereas Phase 11, nine white keys, showed an increase in sequences for Pigeon B1 (to 78) with a concurrent decrease to 17 sequences for Pigeon B2.

Figure 4 displays how the various response key configurations and stimuli affected the dominant response sequence produced during the last three sessions (150 trials) of each phase. The dominant sequence was defined as that sequence with the highest frequency of occurrence in each phase. The dominant sequence emerged within the first two sessions of Phase 1. The same dominant sequence for each bird

Fig. 3. The cumulative number of different response sequences emitted by each subject during the last three sessions of each phase of the experiment.

Fig. 4. The number of trials during the last three sessions of each phase during which the subjects produced the dominant sequence.

was emitted through all the phases that provided the response keys necessary to emit it. New dominant sequences emerged early in the first session of phases with novel spatial key arrangements, i.e., Phases 4, 5, and 6.

Figure 4 shows that the dominant sequence emitted by both birds increased in frequency during Phase 2 relative to Phases 1 and 3, indicating the influence of employing a different stimulus on each key. A response sequence was often a slight variation (only two keys reversed) of the dominant sequence (SVDS). For example, if the dominant sequence was 142356, sequences of 124356, 143256, or 142536 were often emitted. During the last three sessions of Phase 1, 99 (66%) of the response sequences of Pigeon B1 were a two-key variation of the dominant sequence. For B2, 63 (42%) of the sequences were SVDSs. During Phase 2, 108 (72%) and 134 (89%) of the sequences yielded by B1 and B2, respectively, were slight variations of their individual dominant sequence. When the six white keys were reintroduced in Phase 3, these SVDSs were reduced to 106 (71%) and 100 (67%) for B1 and B2 respectively. Figure 4 shows that the vertical columns of white stimuli, Phase 4, increased the strength of the dominant sequence, whereas

the horizontal rows of stimuli used in the next phase yielded a decrease in the emission rate of the primary sequence. The SVDS data reflect these results. During Phase 4, the SVDS values produced by B1 and B2 were 106 (71%) and 127 (85%), respectively. For the last three sessions of Phase 5, the SVDSs dropped to 52 (35%) and 61 (41%). The next six phases (6 to 11), which employed an increasing number of different stimuli and response keys, yielded a general increase in the occurrence of the dominant sequence (except Phase 10) used by Subject B2. Under the same conditions, the frequency of the dominant sequence used by B1 decreased. The SVDS values achieved by Pigeon B1 during Phases 6 through 11 were: 44 (29%), 112 (75%), 93 (62%), 51 (34%), 54 (36%), and 31 (21%). During the same phases Subject B2 yielded SVDSs of: 128 (85%), 114 (76%), 129 (86%), 110 (73%), 39 (26%), and 139 (93%). Figure 5 shows the cumulative number of trials during the last sessions (150 trials) of each phase that the five most frequently occurring sequences were emitted.

Fig. 5. The number of trials during the last three sessions of each phase during which the five most frequently occurring response sequences were emitted.

Some of these sequences were two-key reversals of the dominant sequence. Others were not. This graph is shown in order to present a more accurate depiction of the response stereotypy produced by each pigeon. The figure reveals that for the majority of the phases, these sequences were emitted during 50 to 90% of the trials. The figure reveals that when the "white" stimuli were replaced with distinctive colors and forms (Phase 2 and 6 through 11), the dominant response sequences initially increased in frequency. When "white" stimuli replaced the distinctive stimuli (Phase 3), the frequency of the dominant sequences decreased.

As before, several of the response sequences were slight variations, two keys reversed, of one of these five dominant response sequences (SVFDS). The SVFDS data closely reflect the trends shown in Figures 4 and 5. The mean of the SVDFSs for Pigeon B1 across the last three sessions of each phase was 115 (standard deviation = 20). The mean SVFDS for Pigeon B2 was 131 (standard deviation = 14). That is, 77% of the sequences emitted by Pigeon B1 during the last three sessions of each phase (1650 trials) were a slight variation of only five sequences. For Pigeon B2, these SVDFS sequences represented 87% of those emitted. The variability across phases is small relative to the large increase in the number of potential sequences that could be emitted in the last four phases.

The strongest case for the remarkable response stereotypy maintained by each pigeon is presented as Tables 1 and 2. Table 1 presents the frequency of the dominant sequence (X) and the probability that (X) occurred by chance, $P(X)$, as a function of the number of response keys used. The table indicates that as the possibility of response diversity increased (Y), due to the addition of more response keys, the actual amount of variability produced by both birds decreased. Table 2 shows the probabilities of the five most frequent sequences. The small values of $P(X)$ again indicate that the birds' behavior was remarkably consistent across phases (see Appendix).

Figure 6 presents the dominant response sequence emitted in each phase. The figure indicates that both birds produced similar but not identical sequences. Both birds emitted their dominant response sequences from left to right across the pecking keys. This pattern would maximize efficiency in terms of time and effort required to emit a sequence. Both birds always began their dominant sequence with Key 1 and frequently used the Sequence 1, 4, 2, as the first three responses of their predominant response sequence. These results are similar to data reported by Schwartz (1980, 1981). During each phase that presented response Keys 1 through 6 alone, or in conjunction with other keys, Subject B1 produced a stereotyped sequence (142356) on Keys 1 through 6 that persevered regardless of the

Table 1

The probability of the frequency of the dominant sequence occurring by chance. Data represent the last three sessions (150 trials) of each condition.

Phase	Number of Keys (K)	Frequency of the Dominant Sequence (x)		Value of (y) (y=K!)	Probability P(x) Subject	
		B1	B2		B1	B2
1	6	32	19	720	1.0409×10^{-66}	1.7088×10^{-86}
2	6	78	98	720	7.2063×10^{-177}	4.8212×10^{-887}
3	6	48	55	720	2.1075×10^{-96}	1.9307×10^{-118}
4	6	52	126	720	1.2378×10^{-106}	2.5580×10^{-830}
5	6	29	20	720	6.6640×10^{-50}	1.5567×10^{-80}
6	6	16	51	720	1.5698×10^{-28}	4.6748×10^{-108}
7	6	88	78	720	2.3188×10^{-806}	7.2063×10^{-177}
8	7	49	100	5040	1.8750×10^{-188}	5.7388×10^{-487}
9	8	28	98	40320	8.4669×10^{-96}	1.3796×10^{-406}
10	9	28	35	362880	1.4600×10^{-190}	1.7553×10^{-165}
11	9	10	116	362880	1.0713×10^{-35}	2.4165×10^{-606}

$$P(x) = \frac{N!}{x!(N-x)!} (1/y)^x \left(\frac{y-1}{y}\right)^{N-x}(y)$$

$N = 150$ (trials)

Table 2

The probability of the frequency of the five dominant sequences occurring by chance. Data represent the last three sessions (150 trials) of each condition.

Phase	Number of Keys (K)	Frequency of the Five Dominant Sequences ($x_1 \dots x_5$)		Value of (y) ($y=K!$)	Probability $P(x)$ Subject	
		B1	B2		B1	B2
1	6	32,31,14,14,8	19,16,10,9,9	720	1.0142×10^{-155}	4.4261×10^{-83}
2	6	78,9,9,6,6	98,25,4,4,3	720	2.3500×10^{-211}	3.5822×10^{-286}
3	6	48,20,20,12,6	55,18,16,6,5	720	1.6308×10^{-177}	9.6463×10^{-169}
4	6	52,30,14,14,8	126,8,4,3,2	720	2.2399×10^{-202}	5.3420×10^{-344}
5	6	29,12,11,10,8	20,19,19,16,10	720	9.1826×10^{-96}	1.3210×10^{-120}
6	6	16,15,12,10,9	51,37,19,17,14	720	1.9376×10^{-80}	3.1710×10^{-242}
7	6	88,12,8,4,3	78,21,10,7,5	720	2.0233×10^{-235}	5.5688×10^{-230}
8	7	49,28,14,8,7	100,23,3,3,2	5,040	5.2213×10^{-263}	2.9136×10^{-302}
9	8	28,25,22,14,11	98,13,6,5,5	40,320	3.8339×10^{-322}	9.0646×10^{-478}
10	9	28,20,10,5,5	35,15,9,7,7	362,880	1.5281×10^{-265}	1.8966×10^{-288}
11	9	10,8,8,5,5	116,11,5,2,2	362,880	5.0109×10^{-117}	2.9343×10^{-666}

$$P(x) = \left[\frac{N!}{(x_1)!(N-x_1)!} \cdot (1/y)^{x_1} \cdot \left(\frac{y-1}{y} \right)^{N-x_1} \cdot (y) \right] \cdot \left[\frac{N!}{(x_2)!(N-x_2)!} \cdot (1/y)^{x_2} \cdot \left(\frac{y-1}{y} \right)^{N-x_2} \cdot (y) \right] \cdot \dots$$

$$\cdot \dots \left[\frac{N!}{(x_5)!(N-x_5)!} \cdot (1/y)^{x_5} \cdot \left(\frac{y-1}{y} \right)^{N-x_5} \cdot (y) \right]$$

$N = 150$ (trials)

stimuli present on those response keys. Subject B2 yielded a similar sequence (124536) only when response Keys 1 through 6 were employed alone. This difference between the birds can be explained by a closer examination of each bird's response patterns. Subject B1 established a response stereotype in Phase 1 and emitted it whenever given the opportunity, i.e., Phases 1, 2, 3, 7, 8, 9, 10, and 11. Subject B2 demonstrated that he responded to the pecking keys according to a spatial position. With the exception of Phase 5, the bird always pecked the keys by vertical columns. That is, the pigeon always pecked Key 1 first, then continued down the left column. It next pecked the middle column from top to bottom and then the right column in the same manner. When additional keys were added in Phases 8 through 11, Subject B2 modified its dominant sequence to always peck by vertical columns. During the same four phases, Subject B1 maintained the same response sequence on Keys 1 through 6 produced in Phase 1. The bird added the additional keys after emitting this sequence first. Furthermore, it always pecked Key 8 last. It responded to Key 7 and later Keys 7 and 9 before pecking Key 8. This may be due to the fact that Key 8 was located immediately over the feeder. For both subjects, the change from white stimuli to different stimuli did not affect the dominant sequences

when the response keys were adjacent to each other, i.e., Phases 1 and 2 and Phases 10 and 11. When the pecking keys were not adjacent, as in Phases 5 and 6, both birds altered their respective dominant sequences across these two phases.

DISCUSSION

The present experiment extended the findings of Schwartz (1980) and Vogel and Annau (1973). Specifically, when pigeons were reinforced for emitting a single response on each of six to nine keys, with no constraint on the order in which responses on the keys occurred, the pigeons produced specific, stereotyped, sequences, which occurred on over half the trials. Similar to Ferster and Skinner's (1957) results, the introduction of novel stimuli produced changes in the ongoing behavior. In the present study, however, the introduction of the six to nine novel colors and forms increased the frequency of occurrence of the dominant response sequences instead of disrupting the ongoing performances. The present data replicated the findings of Schwartz (1980) and Vogel and Annau (1973) by showing that after several thousand trials, the patterns of responding were not completely stereotyped. These results also differ from those of Schwartz (1980) in that his birds required 25 to 30

Fig. 6. The dominant response sequences produced by both birds during each phase of the experiment. The small digits in each panel represent the response keys. The arrows indicate the order in which the keys were pecked. The larger number at the bottom of each panel depicts the phase(s) in which the sequences were emitted.

sessions to decrease their response sequence variability. Furthermore, only one of his 12 pigeons emitted the same dominant sequence at the end of training that it produced during the early sessions. There are two procedural differences between the two studies that may account for the rapid emergence of response stereotypy in the present study. First, Pigeons B1 and B2 responded to the response keys that comprise the dominant sequence and received immediate feedback; the key went dark. The birds emitted only one response on each key. His birds responded to two keys and had to make observing responses to the light matrix for visual feedback and cues to switch keys. Second, his birds did not receive reinforcement on each trial. A fifth response on either key produced timeout (TO) and the next trial. The present study provided reinforcement on

each trial. Both birds consistently exhibited what Catania (1975) and Vogel and Annau (1973), among others, refer to as "freedom of choice." That is, when given the opportunity, pigeons maintain alternate routes to the same reinforcer. With the present procedure, however, the variability within some response sequences may indicate slight alterations of the dominant sequence. The lack of complete response stereotypy is not surprising. Of more interest is the emergence of the few response sequences relative to the thousands of possible sequences. Within the 110 sessions of the experiment, 5500 different response sequences could have been emitted. Both birds produced less than 100 different response sequences across all phases. Hawkes and Shimp (1975) demonstrated that a reinforcer that followed a "behavior pattern" a few seconds in duration could strengthen the entire pattern as a unit (operant). Their birds emitted specific "temporal" response patterns (FI scallops) on one key. The present study produced evidence of "spatial" response patterns functioning as a behavioral unit. Specifically, both procedures did not reinforce a single response but rather a pattern of behavior that the birds came to consistently emit. Other demonstrations of conditioning operants that involve two or more discrete responses include the selective control of response rates (Wasserman, 1977) and interresponse times (Platt, 1973). Those studies also manipulated emissions of the same response over time, i.e., control of temporal patterns of behavior. Grayson and Wasserman (1979) provided a demonstration of control of spatial patterns of behavior by requiring their pigeons to emit two responses in sequence on two response keys. Shimp (1976b) and Shimp and Moffitt (1974) showed that pigeons can remember three responses. The present study appears to extend these results by providing data showing that pigeons can maintain a six to nine discrete response spatial pattern of behavior.

The question arises concerning the possibility that these response sequences were maintained on a superstitious basis. With the superstition paradigm, the occurrence of reinforcers is independent and therefore not controlled by the organism's behavior (Skinner, 1948). The present study required six to nine discrete responses to produce a reinforcer. Therefore, the response keys were consistently

correlated with reinforcement. With the superstition procedure, reinforcement is contingent on the passage of time, and reinforcers are presented at regular intervals. In the present study, reinforcers were delivered only when a sequence was completed. The time between reinforcers varied because different sequences required differential amounts of time to complete them. The birds occasionally stopped pecking and engaged in "grooming" and "wing-flapping" behavior; both of which would increase the interreinforcement times. These factors make the likelihood of adventitious reinforcement or spurious stimulus control remote. The effects of the adventitious pairing of reinforcers and responses are often transient (Morse & Skinner, 1957). The present study revealed consistency of the dominant response sequences across sessions. In Skinner's (1948) paper, the behavior that was superstitiously maintained had a high operant level to begin with, i.e., head-bobbing, turning, and pecking toward the chamber floor. It is unlikely that the pigeon has a high operant level of emitting particular multiresponse sequences across several keys.

Several researchers have questioned the position that strict, response-reinforcer contiguity is necessary for conditioning to occur. Shimp and Moffitt (1974) speculated that reinforcers influence a number of stimulus-response associations that precede the response that produces the reinforcer. "Reinforcement might establish and maintain behavioral patterns several seconds in duration . . . behavioral patterns may be established as functional operants, i.e., operants, even though only a small fraction of the behavior in these patterns is contiguous with reinforcement" (p. 511).

"The reinforced response is followed promptly by the reinforcing stimuli; the preceding unreinforced responses are also followed by the reinforcing stimuli, though not quite so promptly. Indeed, the whole pattern of . . . responding is followed by the reinforcing stimuli and so, in a sense, is reinforced" (Dews, 1966, p. 578).

Or as Catania (1971) states the position, "There is no reason to assume that the effect of a reinforcer is restricted to the response that produces it" (p. 271).

The present study involved six to nine discrete responses emitted across as many sepa-

rate response keys over several seconds. The emergence of the dominant response sequences, which included several responses temporally removed from the reinforcer, supports the view that strict response-reinforcer contiguity may not be necessary for conditioning to occur. The present results lead this author to agree with Catania (1971) that "when we reinforce the last response of a sequence of responses we strengthen all of the responses in the sequence" (p. 286).

Zeiler (1977) defined a pattern of behavior as a functional response unit if (1) reinforcement is contingent on the occurrence of the unit and (2) the unit is more frequently emitted as a result of the reinforcers. In addition to lending support to this position, the present results indicate that experimenter-designated response units are not necessary for functional response units to emerge. Furthermore, the emergence of these pigeon-designated response sequences can be viewed as support for Shimp's (1976a) and Wasserman's (1977) position that operant contingencies can produce functional units of behavior. Lastly, the results indicate that these groups, compared to discrete responses, can function as a molar operant, even in the absence of experimenter-designated response-reinforcer contiguity.

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APPENDIX

The binomial formula predicts that the probability (P) of any event occurring x times in N trials is:

$$P(x) = \frac{N!}{x! (N-x)!} \pi^x (1-\pi)^{N-x}$$

Where π = probability of a particular event occurring during one trial, i.e., one divided by the number of possible events.

In the present case, $\pi = 1/y$ where y equals the number of possible sequences that can occur during any trial, i.e., $K!$, where K equals the number of available keys.

The probability of any dominant sequence occurring as often as it did, $P(x)$, is equal to the probability of the sequence occurring once $(1/y)$ raised to the power equal to the number

of trials it occurred multiplied by the probability of one of the remaining sequences occurring during the remaining trials:

$$\frac{y-1}{y} N - x_{(y)}$$

The final (y) is included because there is no restriction on the order in which sequences, dominant or otherwise, could occur.

The final equation

$$P(x) = \frac{N!}{x! (N-x)!} (1/y)^x \frac{(y-1)}{y} N - x_{(y)}$$

accounts for all possible events in a session, any dominant sequence as well as the remaining sequences.

The probability of the five dominant sequences (Table 2) represents the product of the probability of occurrence of each of the five most often occurring sequences.