SENSORY SUPERSTITION ON MULTIPLE INTERVAL SCHEDULES

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Pigeons were exposed to multiple schedules in which an irregular repeating sequence of five stimulus components was correlated with the same reinforcement schedule throughout. Stable, idiosyncratic, response-rate differences developed across components. Components were rank-ordered by response rate; an approximately linear relation was found between rank order and the deviation of mean response rate from the overall mean rate. Nonzero slopes of this line were found for multiple fixed-interval and variable-time schedules and for multiple variable-interval schedules both when number of reinforcements was the same in all components and when it varied. The steepest function slopes were found in the variable schedules with relatively long interfood intervals and relatively short component durations. When just one stimulus was correlated with all components of a multiple variable-interval schedule, the slope of the line was close to zero. The results suggest that food-rate differences are not essential to engender response-rate differences among stimuli. Rate differences may be induced initially by different reactions to the stimuli and subsequently maintained by food.

Key words: sensory superstition, multiple schedule, variable interval, fixed interval, variable time, reinforcement rate, stimulus effects, key pecking, pigeons

When animals are exposed to reinforcement schedules, they may develop stable patterns of behavior that are not required by the contingencies of reinforcement. Such behavior is often termed "superstitious." Brown and Jenkins (1968) identified three arrangements that can yield superstitious behavior. First, a schedule such as fixed time may not require a hungry animal to make any particular response to obtain food; but the animal may, nevertheless, develop a relatively stable sequence of activities between food deliveries. This is response superstition, the first kind observed by Skinner (1948). Second, a stimulus may signal food that is independent of the animal's behavior; despite the absence of a response-food contingency, a response, such as pecking, may nevertheless be made to the stimulus. The best-known example of this stimulus-response "su-

perstition" is autoshaping (Brown & Jenkins, 1968). Third, two or more stimuli may be equally correlated with response-dependent food deliveries, but the animal may come to respond differently in the presence of the stimuli. This is sensory superstition, Skinner's second type.

The reasons for these stimulus-correlated differences are uncertain. Skinner originally explained the development of superstitious behavior by the concept of adventitious reinforcement: any response that was accidentally contiguous with a reinforcer would automatically be strengthened, would be more likely to recur and, thus, again be accidentally paired with the reinforcer. Subsequently, several objections have been raised to this idea as a comprehensive account of either response superstition or autoshaping (e.g., Staddon & Simmelhag, 1971).

Little is known about sensory superstition beyond what was originally reported by Morse and Skinner (1957). In their original experiment, two stimuli correlated with the same reinforcement schedule supported different rates of responding. Skinner presumed that the response-rate differences were due to accidental differences in the food-delivery rate in the two stimuli, but Morse and Skinner did not at-

This paper is based on a dissertation submitted to Duke University in partial fulfillment of the requirements for the PhD degree. These experiments were supported by a National Science Foundation Predoctoral Traineeship to Bettie C. Starr and by grants from the National Science Foundation to Duke, J. E. R. Staddon, principal investigator. We thank Evalyn Segal for editorial care beyond the call of duty. Requests for reprints should be sent to J. E. R. Staddon, Department of Psychology, Duke University, Durham, North Carolina 27706.

tempt to verify this experimentally. Although they suggested several variables that might influence sensory superstition, they studied the effects of only one reinforcement schedule and one stimulus duration.

The two experiments presented here delineate some of the factors that influence sensory superstition. We varied interfood interval, variability of food delivery (and hence the probability of accidental differences in the rate of food delivery), response contingency, stimulus duration, and nature of the stimuli.

EXPERIMENT 1

In their initial experiment, Morse and Skinner (1957) imposed once per hour an "incidental" stimulus of 4-min duration on a variable-interval (VI) 30-min baseline. Morse and Skinner attributed the resulting divergence in response rates to a self-perpetuating "sampling error," an accidental difference in the food-delivery rates during the baseline stimulus and the incidental stimulus. Initial accidental differences in food-delivery rate would induce differences in response rates in the two stimuli that would in turn tend to perpetuate the difference in food-delivery rates. This viewpoint implies that operations that equalize food-delivery rate in incidental and background stimuli should eliminate sensory superstition. Morse and Skinner suggested that the duration of the incidental stimulus relative to the background stimulus, and the nature and intensity of the incidental stimulus, might also affect the development of sensory superstition.

In contrast to Morse and Skinner's view, Lander (1968) found differential responding in two stimuli in a situation that precludes "sampling error." Lander trained his pigeons on a VI 3-min schedule correlated with a white key. One day out of six, the white key was replaced by red and green, alternating at 3-min intervals; no food was delivered on red-green days. Differential responding developed in red and green. Blue, Sherman, and Pierrel (1971) also found differential responding in a series of 3, 5, or 9 auditory-intensity stimuli, without differential food-delivery rate; responding was graded to stimulus intensity. The other suggestions of Morse and Skinner appear not to have been investigated.

The present experiment is a systematic examination of some of the factors that influence

differential responding in stimuli all of which are correlated with the same schedule of food deliveries. In five of the six phases of the experiment, the number of food deliveries in each stimulus was equated. In the sixth phase, the number of food deliveries per stimulus was allowed to vary, to assess the effect of small stimulus-correlated variations in daily food-delivery rate. We also investigated the effects of stimulus duration (12 vs. 120 sec), interfood interval (mean of 30 vs. 60 sec), and response contingency (VI vs. VT).

METHOD

Subjects

Ten White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. Eight pigeons, 46, 58, 70, 105, 106, 120, 126, and 127, were used in the experimental conditions. Two pigeons, 103 and 116, were used in the control conditions. All animals except 126 and 127, which were experimentally naive, had previous experience with fixed- and variable-interval schedules.

Apparatus

All subjects were run in the same custom-made variant of the standard, single-key operant chamber. A standard Grason-Stadler inline projector (stimulus set number 153) was used to project stimuli onto a translucent screen behind the transparent key. Effective key pecks produced a click from a feedback relay. The houselight was a 10-W lamp mounted in the ceiling of the box. A high-intensity lamp was mounted outside the box to provide additional illumination. During food delivery (3-sec access to mixed grain), houselight and keylight were extinguished and the grain magazine was illuminated. During blackouts, houselight and keylight were extinguished. Pecks during both food delivery and blackout were ineffective. White noise, a ventilating fan, and a styrofoam-covered wooden enclosure masked extraneous sounds. One end of the exterior enclosure contained a double Plexiglas window behind which was mounted a TV camera used for videotaping subjects. Recording and programming equipment was in an adjacent room. Data were recorded on digital counters and a cumulative recorder. Sample sessions were also recorded on an 8-channel punched paper tape in a data multiplexer that rounded

event times to 1/16th of a second. These tapes were analyzed using a PDP 8/L computer.

Procedure

The experiment was divided into five phases.

Phase 1. In all four conditions of Phase 1, five stimuli (three vertical lines on a white ground, horizontal dots, blue, red, a white triangle; these are numbered S1-S5 in Figure 1) were presented in blocks in which each occurred once, in random order. Blocks were separated by 6-sec blackouts. The duration of each stimulus within a block was, for different pairs of birds, either 12 or 120 sec. Food was presented to some birds on a VI (variable-interval) 30-sec schedule and to other birds on a VI 60-sec schedule. The shortest interfood interval for both schedules was 3 sec and the longest was 360 sec. Twelve food deliveries occurred per session in each stimulus, making a total of 60 food deliveries per session. After the 12th food delivery in a stimulus, no further food deliveries were made in that stimulus when it was presented in succeeding blocks. Each session terminated at the end of a block. Thus, each stimulus was presented the same number of times per session and was correlated with the same number of food deliveries, although there were local differences in food-delivery rate across stimuli. Birds were run for at least 28 days. If, during days 24 through 28, the rank order of the response rate associated with a stimulus changed by two or more places, or if there was a rank change of one place accompanied by a rate change of 10 responses per min or more, the bird was run for at least five more days. The four conditions in Phase 1, designated by schedule and stimulus duration, were: VI 30(12), VI 30(120), VI 60(12), VI 60(120). Each condition was studied with one pair of birds (see Table 1).

Phase 2. The conditions were studied with new pairings of the birds. For one bird in each of the Phase-2 conditions, the stimulus duration remained the same as in Phase 1, but the reinforcement schedule was switched. For the other bird in the condition, the reinforcement schedule remained the same as in Phase 1, but the stimulus duration was switched (see Table 1). The four conditions in this phase are designated by the subscript 2: VI 30(12)₂, VI 30(120)₂, VI 60(12)₂, VI 60(120)₂.

Phase 3. (Return to baseline). All birds were

returned to their Phase-1 condition. The conditions in this phase are designated by the subscript R (see Table 1).

Phase 4. (Stimulus change). Conditions were the same as in Phases 1 and 3, except that five new stimuli replaced the earlier set of five stimuli. The stimuli were a white circle, amber, vertical dots, green, and diagonal dots (numbered Stimulus 1 to Stimulus 5 in Table 2). Conditions in this phase are designated SC: VI 30(12)_{SC}, and so on (see Table 1).

Phase 5. (Variable-time schedule). Conditions were the same as in Phase 4, except that the response contingency for food delivery was removed. The four conditions were now: VT (variable time) 30(12), VT 30(120), VT 60(12), VT 60(120).

Phase 6. (Varying number of food deliveries). This phase was begun about six weeks after the end of Phase 5. The birds were returned to the VI 30- or 60-sec schedule, using the same stimuli and stimulus durations as in Phase 4, but now the number of food deliveries per session in each stimulus was not fixed. Sessions ended after 60 stimulus presentations (12 blocks). Over the 28 to 35 days of Phase 6, with a few exceptions approximately the same proportion of food deliveries occurred in each stimulus, but there was considerable intersession variability in number of food deliveries in each stimulus. The proportion of food deliveries occurring in each stimulus over the last five days of the experiment is shown in Table 2. The four conditions in this phase are designated by the subscript VN: VI 30(12)_{VN}, and so on (see Table 1).

Two additional birds were studied under control conditions. One bird (103) was run on VI 30-sec and another (119) on VI 60-sec, both with a green keylight throughout. The recording equipment recorded data as if the birds were being presented with five different stimuli of 12-sec or, on alternate days, 120-sec duration.

Procedure for determining changes in response-rate pattern. If during days 24 through 28 of any phase the rank order of the response rate in any stimulus changed by two or more places, or if there was a rank change of one place accompanied by a rate change of 10 responses/min or more, the bird was run longer. Any changes of this magnitude were designated as changes in the pattern of response rates. Across the averaging period, only data

Table 1

Average response rate (key pecks per minute) for each bird in each condition of Experiment 1.

<i>Phase</i>	<i>Condition</i>	<i>Bird</i>	<i>Average Rate</i>	<i>Number of Sessions</i>	<i>Condition</i>	<i>Bird</i>	<i>Average Rate</i>	<i>Number of Sessions</i>
1	VI 30(12)	79	223.3	33	VI 60(12)	126	55.1	36
		106	58.1	34		46	71.9	33
	VI 30(120)	120	60.6	33	VI 60(120)	58	54.3	28
		105	76.6	28		127	105.6	28
2	VI 30(12) _s	120	73.1	28	VI 60(12) _s	106	44.4	28
		126	49.5	28		127	112.6	28
	VI 30(120) _s	79	155.1	28	VI 60(120) _s	105	84.5	33
		58	60.3	28		46	84.1	28
3	VI 30(12) _R	79	175.1	28	VI 60(12) _R	126	67.2	28
		106	49.7	28		46	70.5	29
	VI 30(120) _R	120	57.0	33	VI 60(120) _R	58	63.4	28
		105	55.5	33		127	100.1	30
4	VI 30(12) _{SC}	79	146.1	28	VI 60(12) _{SC}	126	62.0	28
		106	41.4	28		46	72.9	28
	VI 30(120) _{SC}	120	56.7	33	VI 60(120) _{SC}	58	64.6	28
		105	62.1	29		127	94.1	28
5	VT 30(12)	79	101.1	28	VT 60(12)	126	43.2	28
		106	17.5	28		46	55.8	28
	VT 30(120)	120	5.3	33	VT 60(120)	58	12.5	28
		105	32.7	29		127	29.9	28
6	VI 30(12) _{VN}	79	118.1	33	VI 60(12) _{VN}	126	35.2	33
		106	51.6	28		46	57.4	34
	VI 30(120) _{VN}	120	60.7	33	VI 60(120) _{VN}	58	59.1	34
		105	54.5	33		127	76.2	35
Control	VI 30("12")	103	67.2	28	VI 60("12")	116	60.9	28
	VI 30("120")	103	67.3	28	VI 60("120")	116	60.9	28

from days having the same pattern of response rates were averaged together. When birds displayed more than one pattern of response rate, then the final averages graphed in the results section are averages weighted by relative frequency of occurrence.

The criterion for distinguishing among patterns is arbitrary, but a procedure for grouping data across days was essential. The alternative procedures of averaging the rates in each stimulus across days, or averaging the most divergent rates, the second most extreme rates,

Table 2

Average proportion of reinforcements per session for each bird over the last five days of Phase 6.

Condition	Bird	Stimulus 1	Stimulus 2	Stimulus 3	Stimulus 4	Stimulus 5
VI 30(12) _{VN}	79	.23	.22	.10	.24	.21
	106	.20	.21	.29	.20	.10
VI 30(120) _{VN}	120	.21	.19	.20	.20	.21
	105	.20	.24	.15	.21	.21
VI 60(12) _{VN}	46	.20	.19	.23	.13	.26
	126	.20	.22	.22	.15	.20
VI 60(120) _{VN}	127	.21	.20	.18	.22	.20
	58	.21	.18	.19	.21	.20

and so on, both had pitfalls. The first procedure masks changes in response rate patterns across days. The second procedure increases the apparent size of response-rate differences but does not reflect their stability or instability. Establishing criteria for distinguishing among patterns of response rate was a compromise designed to respect both the variability and the stability of behavior.

RESULTS

The pigeons developed stable idiosyncratic patterns of response rate across the five stimuli. Rate differences were influenced by stimulus and interfood-interval durations. Because of the absolute differences in response rate within and among conditions, comparisons are most easily made using a response-rate-deviation measure. This rate-deviation measure uses the overall mean response rate of each animal as a baseline. (These overall means are shown in Table 1.) We first present data on response-rate deviations that demonstrate stable idiosyncratic patterns, and then show data on the effects of stimulus duration and interfood interval.

Figure 1 shows the deviation (in responses/min) from the overall mean response rate for each of the five stimuli for each bird in Phase 1. Each line represents one day's data. The number of days for which data are shown varies from bird to bird, depending upon whether the bird changed its pattern of response rates between days 24 and 28 (see Procedure). Birds tended to show stable idiosyncratic differences in their rates of responding in the various

stimuli over several days, in spite of the fact that they were receiving the same number of food deliveries in each stimulus. Three of the birds (127, 58, 105) showed a single pattern of rate deviations across the five stimuli. Four of the birds (106, 120, 79, 46) displayed two patterns across the last 10 days. Bird 126, one of the naive birds, was the least stable, shifting through three patterns of rate deviations in the last 10 days. For the days shown in Figure 1, deviations (from the overall mean) in particular stimuli were as large as 33 responses/min. More typically, a bird's most extreme rate deviated from the overall rate by 10 to 15 responses/min. There was no stimulus that always sustained the highest or lowest rates, although the hues (red, S4, and blue, S3) sustained the highest rates more frequently than did the other stimuli.

Similar results were obtained when the pigeons were switched to new stimulus-duration or reinforcement conditions, when they were returned to their original condition, when they were exposed to a new set of five stimuli, and when they were exposed to response-independent food deliveries (Phases 2 to 5). In each phase, the animals responded at stable different rates in the five stimuli. In fact, in these phases, rate differences were even more stable than in Phase 1. Most animals displayed only a single pattern of response rates within a phase, although a change in conditions was often accompanied by a shift in the pattern. Mean probability of a change in the rank of a stimulus in the last five days of a condition (number of rank changes/number of opportu-

Fig. 1. Differences in the rate of responding (responses per min) in each stimulus from the overall mean response rate for each bird in Phase 1 of Experiment 1. The data are from the last 5 to 10 days for each bird.

Fig. 2. Differences in the rate of responding (responses per min) in each stimulus from the overall mean response rate for each bird in each phase of Experiment 1. The stimuli are arranged along the abscissa in descending order, according to the rate of responding they supported. Data for each bird and averages for each condition are shown. Codes for birds in Phases 3, 4, 5, and 6 are the same as for Phase 1. Note different vertical vertical scale for Phases 4 and 5. The four lines with slope close to zero in the Phase-6 box are for the control condition.

nities for rank change) was .04, whereas the mean probability of a change in rank between conditions was .68. (Individual data for each of the last five days of Phases 2 through 5 are not shown.)

Figure 2 shows the effects on response-rate patterns of stimulus duration, interfood interval, change to a new set of key stimuli, removal of the response contingency, and varying the number of food deliveries per stimulus. In Figure 2, stimuli are arranged along the horizontal axis in rank order of the response rate they sustained. The stimulus occasioning a bird's highest rate was labeled 1, the stimu-

lus occasioning a bird's second-highest rate was labeled 2, and so on. Then, the response-rate deviations for the two birds in each condition were averaged together for each stimulus rank. The amount and direction of deviation from 0 indicates the mean deviation for that stimulus from the overall, mean response rate (Table 1). The X-axes in all graphs are identical, ordinal scales, so differences in slope of the lines reflect differences in response-rate deviations in the various conditions (except for Phases 4 and 5 where the large slopes for some animals necessitated a change in the vertical scale). A horizontal line indicates that all stim-

Table 3
Slopes of lines for each condition in Experiment 1

		Stimulus Duration			
		12 Seconds		120 Seconds	
30 sec.	Phase	Slope	Phase	Slope	
	1	-4.81	1	-3.78	
	2	-4.95	2	-3.37	
	3	-4.83	3	-4.80	
	4	-6.74	4	-4.29	
	5	-10.30	5	-2.25	
	6	-7.09	6	-3.63	
VI	Average	-6.35	Average	-3.69	
60 sec.	Phase	Slope	Phase	Slope	
	1	-4.78	1	-3.15	
	2	-2.12	2	-2.58	
	3	-9.20	3	-4.87	
	4	-10.30	4	-4.64	
	5	-11.91	5	-5.79	
	6	-5.06	6	-4.10	
	Average	-7.23	Average	-4.19	

uli supported about the same response rate. Since the plotted data were roughly linear, slopes were calculated for each line using the linear regression equation. The slopes are shown in Table 3.

Generally, the shorter stimulus duration and the longer average interfood interval led to the largest differences among response rates in the various stimuli. The VI 60(12) schedule usually maintained the greatest response-rate differences across stimuli (without differential reinforcement). More specifically, for the conditions in which the number of food deliveries per stimulus was controlled, Figure 2 shows that:

1. In all phases except 1 and 6, the line for the VI 60(12) conditions had the steepest slope. The commonest slope ranking across conditions was VI 60(12), VI 30(12), VI 60(120), and VI 30(120), the same as the ranking of average slopes in Table 3.

2. This pattern was accentuated in the response-independent (variable-time) phase (Phase 5).

3. In three of the five phases (2 to 4), the biggest difference in slope was between the VI 60(12) conditions and all others.

4. In Phase 1, where behavior was most variable, the slopes of the lines for Conditions VI 30(12) and VI 60(12) were approximately the same and were slightly steeper than the slopes of the lines for the 120-sec conditions.

5. These results were not dependent upon a specific set of stimuli. The same pattern occurred in Phase 4 (which used a new set of stimuli) as in the preceding phases.

The data for the control animals are plotted in the lower right-hand graph of Figure 2, along with the data from Phase 6. The same procedure was used for plotting these data as for plotting the data of the other birds, except that there were no actual stimulus changes: a green keylight was on at all times but the recording equipment recorded data as if five different stimulus components were presented. There were essentially no differences in the response rate in the stimulus components. Even averaging the most divergent rates in a component for each of the five days, there was a deviation of only one or two responses/min from the average rate. The slopes of the rate-deviation lines for all the control conditions are approximately -4 .

In Phase 6, variable-interval schedules were in effect but the number of food deliveries per stimulus was allowed to vary. The main results from this phase, shown in Figure 2, were:

1. As in Phases 1 to 5, animals developed idiosyncratic patterns of rate differences during presentations of the five stimuli. The patterns tended to change more quickly than in the preceding phases, presumably in response to the (generally small) daily changes in food-delivery rate. Every animal showed changes in response-rate pattern over the last five days it was run.

2. As in Phases 1 to 5, the rate-deviation lines for Conditions VI 30(12)_{VN} and VI 60(12)_{VN} had steeper slopes than those for the other two conditions.

3. In this phase, VI 30(12)_{VN} had a somewhat steeper slope than VI 60(12)_{VN}.

Figure 3 shows the difference between the proportion of food delivered in each stimulus and the proportion of responses made during presentations of that stimulus, averaged across all days, for each condition in Phase 6. This measures the extent to which daily variation in response rate matched daily variation in the proportion of total food deliveries in each stimulus. The average difference between the proportion of food deliveries and responses did not exceed .08 during any presentation of a stimulus in any condition. Animals in condi-

Fig. 3. Absolute value of the average difference between proportion of food deliveries and the proportion of responses in each stimulus in Phase 6 of Experiment 1.

tions with 120-sec stimulus durations displayed smaller differences between food delivery and response proportions than did animals in the conditions with 12-sec stimulus durations; there was also less variability in the proportion of food delivered in the various stimuli in the 120-sec conditions than in the 12-sec conditions. The average difference between the stimulus correlated with the highest proportion of food deliveries and the stimulus correlated with the lowest proportion during the last six days (see Table 2) was .06 for the 120-sec conditions and .13 for the 12-sec conditions. This might account for some of the differences observed between the 120-sec and 12-sec conditions.

DISCUSSION

When pigeons are exposed to several stimuli correlated with the same variable-interval schedule, they develop different rates of responding in the presence of the stimuli. This occurs both when the number of food presentations per stimulus is allowed to vary from day to day and when it is held constant. When it is allowed to vary, daily variations in response proportion match fairly well to daily variations in food-delivery rate, the match being better with long (120-sec) stimulus durations. However, this match may mean either that variation in food-delivery rate produces variation in response rate, or that variation in response rate produces variation in food-delivery rate.

The latter interpretation seems more parsimonious since daily variations in food rate are not essential for response-rate differences:

these difference occurred even when the number of food deliveries per stimulus was controlled. The finding confirms other observations (e.g., Lander, 1968) that response-rate differences can occur when there are no apparent differences in food-delivery rate. The current data also indicate that different stimuli must be present for this to occur. In the control condition with only a single stimulus, only small response-rate differences were detected among the various "components" of the schedule. On the other hand, rate differences do not depend upon a particular set of stimuli. Stable, differential-response-rate patterns emerged with two different sets of stimuli.

When food-delivery rate was controlled, the greatest response-rate differences across stimuli tended to occur in the conditions that used short stimuli (12 sec) and relatively long inter-food intervals. In Phase 6, also, where the number of food deliveries per stimulus varied, short stimulus durations supported the largest rate differences. However, there were larger rate differences in Condition VI 30(12)_{VN} than in VI 60(12)_{VN}. This may be because proportion of food deliveries during presentations of the various stimuli varied more for VI 30(12)_{VN} than for VI 60(12)_{VN}.

The presence or absence of a response contingency also influenced response-rate differences. Absence of the contingency accentuated response-rate differences in all conditions except VT 30(120), in which the rate differences diminished.

Within conditions, ranking the stimuli according to the size of response-rate deviations from the overall mean produced roughly linear response-rate-deviation functions. That is, the rate differences between any two adjacent stimulus ranks were often of similar magnitude. If there were only a single stimulus with a deviant response rate, J-shaped curves would result. If the stimuli, for example, fell into two groups, with each group supporting a different rate but stimuli within each group supporting similar rates, then a step-function would occur. Neither of these possible outcomes occurred. The significance of the linear relation remains to be seen.

These experiments indicate, then, that several factors influence the magnitude of response-rate differences among stimuli all correlated with the same reinforcement schedule. Daily variations in food-delivery rate are not

required for response-rate differences to emerge, but even when daily food-delivery rate did not vary, there were still local differences in food-delivery rate within daily sessions, which might be at least partly responsible for differences in response rates. To check this possibility, the next experiment correlated several stimuli with the same fixed-interval (FI) schedule, a procedure that minimizes local, as well as overall, differences in food rate.

EXPERIMENT 2

Two previous studies suggest that sensory superstition can develop on FI schedules. Kieffer (1965) trained rats on a multiple FI 2 FI 2-min schedule, with the presence or absence of a buzzer distinguishing the two components. The stimuli changed every five reinforcements. Rats developed higher response rates in the presence of the buzzer. Kello, Innis, and Staddon (1975), using pigeons, found a stable, persistent elevation in response rate in the presence of an "eccentric" stimulus (which differed from the normal baseline stimulus) when the eccentric stimulus was presented during the short component of a multiple FI schedule. Again, response-rate differences occurred in the absence of differences in food-delivery rate.

The present experiment used a five-component multiple FI schedule. Within a condition, the FI value was the same in all components, but the correlated stimuli differed. Four fixed-interval values (120, 60, 30, and 5 sec) were studied. In Phase 1, the correlated stimulus changed after every reinforcement. In Phase 2, the stimulus changed only after several food deliveries, as in Kieffer's study.

METHOD

Subjects

Nine White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. Eight pigeons, 28, 109, 110, 113, 119, 121, 129, and 131, experienced on interval schedules, were used in Phase 1 of the experiment. Bird 121 died 10 days after the conclusion of Phase 1 and was replaced by Bird 115 in Phase 2. Birds 28, 109, 113, 129, and 131 were also used in Phase 2.

Apparatus

All subjects were run in a custom-made, single-key operant chamber similar to the one

used in Experiment 1. A standard Grason-Stadler in-line projector (stimulus set number 156) projected stimuli onto a translucent screen behind the transparent key. A 10-W houselight was mounted outside the pigeon box. Data were recorded on digital and printing counters. All other details are the same as for Experiment 1.

Procedure

The experiment had two phases. In Phase 1, food delivery invariably signaled stimulus change. In Phase 2, several consecutive intervals were associated with the same stimulus, thus lengthening stimulus duration.

Phase 1. In all four conditions of Phase 1 (two birds per condition), five stimuli (a horizontal line, a white circle, green, a white square, and red) were presented in randomized blocks. Each stimulus occurred once in each block. Blocks were separated by 6-sec black-outs. Food was presented on either FI (fixed-interval) 120-sec, FI 60-sec, FI 30-sec, or FI 5-sec. Each pair of pigeons was exposed to only one interval duration. The duration of the stimulus in each condition was, of course, the same as the FI value. Sixty food deliveries occurred per session. Birds were run for at least 35 days. If, during days 31 to 35, the rank, by response rate, of any stimulus changed by two or more places or if there was a rank change of one place accompanied by a rate change of 10 responses per min or more, the bird was run for at least 5 more days. The four conditions in Phase 1, identified by FI value and the number of presentations of each stimulus within a block, were: FI 120(1), FI 60(1), FI 30(1), and FI 5(1). These conditions differed from those in Experiment 1 in two respects: (a) food presentations occurred at regular intervals; (b) stimulus changes always occurred after food presentations.

Phase 2. All details were as for Phase 1, except that, within a block, each stimulus was presented during several consecutive intervals. The four conditions (two birds per condition), designated by FI value and the number of consecutive intervals during which each stimulus was presented, were: FI 60(2), FI 30(4), and FI 5(12). Thus, at all FI values, each stimulus was presented for 120 sec, during which food occurred at 5-, 30-, or 60-sec intervals. Of the two phases in Experiment 2, Phase 2 was the more similar to Experiment 1, since food delivery

did not invariably signal a stimulus change. However, when a stimulus change did occur, it occurred after food delivery.

RESULTS

As in Experiment 1, the pigeons developed relatively stable, idiosyncratic patterns of differential response rates in the presence of the five stimuli. Response-rate differences across stimuli were influenced by interval duration. Because of the large response-rate differences across animals and conditions, comparisons can most easily be made with the regression-line measure, which uses the mean overall response rate of each animal as a baseline.

Table 4 shows the overall mean rate across all stimuli and the number of sessions for each bird in each condition in Experiment 2. Response rate in the FI 15-sec condition was generally much higher than in the other conditions.

Figure 4 shows the effect on average response-rate deviations of interval duration and stimulus duration. As for Figure 2 in Experiment 1, the stimuli are rank-ordered along the horizontal axis by the rate of responding

which they sustained, with the stimulus sustaining the highest response rate designated 1, and so on. This procedure was followed for each bird (and each pattern of response rates for a bird, if there was more than one) and then the rate deviations for each bird within a condition were averaged together. The mean deviations for each condition are designated by the lines in Figure 4. The slopes of the lines are given in the figure caption.

As in Experiment 1, different response rates developed in the five stimuli that were correlated with the same reinforcement schedules. Generally, the slopes of the lines for the FI 30 and 60 conditions were steeper than the slopes for the FI 5-sec and FI 120-sec conditions, with the FI 30 conditions having a slightly steeper slope than the FI 60 conditions. Whether a stimulus was correlated with one or several intervals in a row (i.e., was of relatively short or relatively long duration) seemed to have little effect. For two of the three interval values, there was a slight decrease in the steepness of the slope when a stimulus appeared for several intervals in a row. This would be consistent with the finding from Experiment 1 that longer stimulus durations were correlated with smaller response-rate differences across stimuli. However, the differences in slope were small and could have been due to an order effect, since all pigeons were exposed to the relatively short stimulus durations before being exposed to the longer stimulus durations.

Table 4

Average rate (key pecks per minute) for each bird in each condition of Experiment 2.

Condition	Bird	Average Rate	Number of Sessions
FI 120(1)	119	39.7	28
	110	47.1	33
FI 60(1)	109	21.1	33
	121	32.6	34
FI 30(1)	28	40.8	33
	129	42.2	28
FI 5(1)	113	64.3	30
	131	129.2	28
FI 60(2)	109	27.1	28
	115	36.9	28
FI 30(4)	28	35.3	33
	129	44.2	28
FI 5(12)	113	70.3	28
	131	141.0	32

DISCUSSION

These results show that even when there are no local differences in food-delivery rate animals will develop relatively stable differences in response rate in the presence of stimuli correlated with the same reinforcement schedule. In this experiment, response-rate differences developed in stimuli correlated with the same fixed-interval schedule. The differences in response rate were smaller in this experiment than in Experiment 1. Variability in the interfood interval, then, appears to increase differences in response rates but is not required to produce such differences. This confirms the implications of Experiment 1 and is consistent with Kieffer's (1965) experiment.

As in Experiment 1, the rate-deviation slopes depended to some extent on the reinforcement schedule in effect. Both the FI 5-sec

Fig. 4. Differences in the rate of responding (responses per min) in each stimulus from the average response rate for each bird in each condition of Experiment 2. Other details are the same as for Figure 2. Slopes of the average lines representing the conditions are as follows: FI 120, -1.96 ; FI 60(1), -3.21 ; FI 60(2), -2.46 ; FI 30(1), -3.50 ; FI 30(4), -3.38 ; FI 5(1), -1.79 ; FI 5(12), -1.90 .

and FI 120-sec schedules had low slopes. In the 5-sec case, the reason may be a ceiling effect; as Table 4 shows, response rates were always high and close to the maximum observed for pigeons. In the 120-sec case, the long component duration may be responsible.

In the FI 30- and 60-sec conditions, there were somewhat larger differences in response rate. In contrast to most of the phases in Experiment 1, the 30-sec interfood interval supported slightly larger response-rate differences than the 60-sec interfood interval. At least in the FI 30(1) and FI 60(1) conditions, this might have been due to the fact that the stimulus duration was shorter for the FI 30(1) con-

dition than the FI 60(1) condition. This difference, and the slight decrease in the size of the rate difference across stimuli from the FI 30(1) and FI 60(1) to the FI 30(4) and FI 60(2) conditions, suggests a small effect of stimulus duration, but the effect seems very weak in comparison to the effect in Experiment 1. Temporal cues in the FI schedule (cf. Staddon, 1974a, 1974b, 1975) may have overshadowed the effects of other stimuli.

GENERAL DISCUSSION

The present experiments suggest that the magnitude of response-rate differences across

presentations of stimuli signaling the same food reinforcement schedule ("sensory superstition" in pigeons) is mainly influenced by variability and mean duration of the interfood interval, with stimulus duration and presence or absence of a response contingency having lesser effects.

Two potential causes have been proposed for these effects: (a) variations in local reinforcement rate, which lead to self-perpetuating correlated response-rate differences, or (b) endogenous stimulus effects—either innately or because of past history, the pigeons just tend to respond faster or slower in the presence of some stimuli. These two accounts are not mutually exclusive: response-rate differences initiated endogenously will (under response-contingent reinforcement) produce reinforcement-rate differences that can act to perpetuate differential respondings. Either process could by itself produce sensory superstition, however. Hence the experimental question is the relative importance of these two processes.

Our results suggest that both reinforcement-rate differences and endogenous effects are involved—but the endogenous effects are more important. That endogenous effects are always involved is proved both by the Lander (1968) (see also Baron, 1965; Blue, Sherman, & Pierrel, 1971) experiment discussed earlier and by our finding of response-rate deviations with fixed-time schedules (no reinforcement-rate differences) in Experiment 2.

The smaller effects under fixed-time (Experiment 2) as opposed to variable-time or variable-interval (Experiment 1) schedules suggest a role for local reinforcement-rate differences as well. However, this difference between fixed and variable schedules cannot be taken at face value, for three reasons. First, we found negligible differences between the conditions where number of reinforcements per stimulus within a session was controlled (Phases 1 and 4, Experiment 1) and comparable conditions where it was not (Phase 6, Experiment 1). Second, the effect of shifting from variable-interval reinforcement (Phases 1, 2, 3, and 4 in Experiment 1) to variable-time reinforcement (Phase 5) produced if anything an increase in response-rate deviations (cf. Figure 2), even though this change abolishes any positive feedback relation between response and reinforcement rates.

Third, and most important, there is an alter-

native explanation for the smaller effects on fixed-time vs. variable-time schedules (which otherwise might seem to provide the best evidence for the importance of local reinforcement-rate differences to sensory superstition). When food is periodic, food delivery itself is the major controlling stimulus and the effects of key stimuli are correspondingly reduced. This shows up in the form of weakened contrast effects and a number of other differences between multiple FI and multiple VI or VT schedules (cf. Staddon, 1974a, 1974b). Thus there is no need to postulate any role for local reinforcement-rate differences in either the genesis or maintenance of the response-rate deviations we found.

The regular delivery of food may play a role in the stability of these deviations, however. Since key pecking is abolished in the absence of food delivery, this hypothesis is difficult to test and the evidence is necessarily indirect. For example, Kello et al. (1975) found that the normally transient increase in response rate produced by an infrequent novel-key stimulus presented during a fixed-interval schedule (and usually interpreted as some kind of disinhibition or generalization decrement) can be maintained indefinitely under conditions of high relative-reinforcement rate (cf. Staddon, 1975). The first of these conditions was satisfied in this experiment: since there were always five stimuli, each one occurred relatively infrequently. The effects of reinforcement rate in Experiment 1 (which showed the largest response-rate deviations) were weak and opposite to those implied by Kello et al., however: the longer VI value seemed to yield the larger rate-deviation slopes. But the Kello et al. experiment involved FI rather than VI schedules, as well as variable stimulus durations, so that it is not clear what aspects of those results should be expected to extend to the present situation. Future studies would do well to look at the effects of number and relative frequency of stimuli and a wider range of VI reinforcement rates.

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Received February 7, 1980

Final acceptance September 3, 1981