SUPERSTITIOUS BEHAVIOR IN HUMANS

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Twenty undergraduate students were exposed to single response-independent schedules of reinforcer presentation, fixed-time or variable-time, each with values of 30 and 60 s. The reinforcer was a point on a counter accompanied by a red lamp and a brief buzzer. Three color signals were presented, without consistent relation to reinforcer or to the subjects' behavior. Three large levers were available, but the subjects were not asked to perform any particular behavior. Three of the 20 subjects developed persistent superstitious behavior. One engaged in a pattern of lever-pulling responses that consisted of long pulls after a few short pulls; the second touched many things in the experimental booth; the third showed biased responding called sensory superstition. However, most subjects did not show consistent superstitious behavior. Reinforcers can operate effectively on human behavior even in the absence of a response-reinforcer contingency and can, in some cases, shape stable superstitious patterns. However, superstitious behavior is not a consistent outcome of exposure of human subjects to response-independent reinforcer deliveries.

Key words: superstitious behavior, response-independent reinforcers, fixed-time schedules, variable-time schedules, lever pulling, humans

The fundamental principle of operant conditioning is that occurrence of a reinforcer alters the frequency of the responses it follows. Responses immediately preceding reinforcer delivery may become more probable even though the availability of the reinforcer does not depend on them. The effects of such response-independent delivery of reinforcers were first investigated by Skinner (1948) in pigeons. He described the behavior shaped by these procedures as "superstition" or "superstitious behavior," by analogy with some kinds of human behavior. Subsequent research (Herrnstein, 1966; Skinner, 1953; Zeiler, 1972) addressed the properties of superstitious behavior, and Brown and Jenkins (1968) and Catania (1968) indicated that several classes of superstitious behavior can be distinguished in terms of procedures. Superstitious behavior in experimental studies has been treated mostly in terms of three kinds of responding: the altered rate of responding that occurs under response-independent schedules of reinforcer delivery;

unnecessary responding that occurs under concurrent schedules of reinforcement; and biased responding that occurs under stimulus control.

The first kind of superstitious behavior was demonstrated in situations in which frequent reinforcer deliveries were independent of behavior, as in Skinner's (1948) experiment. In these studies, however, a single response-independent schedule was rarely used from the start of the experiment. After Skinner's (1948) experiment, studies that used response-independent schedules were more concerned with the rate of established responses than with the emergence of idiosyncratic and stereotyped topographies of superstitious behavior. Consequently, almost all of the studies began by strengthening a selected response by response-dependent reinforcement and then shifting to a response-independent schedule. In animal studies, the typical finding is that when the schedule shifts from response-dependent to response-independent reinforcers, response rate decreases (Appel & Hiss, 1962; Lachter, 1971; Lachter, Cole, & Schoenfeld, 1971; Lattal, 1972, 1973, 1974; Skinner, 1938; Zeiler, 1968), but the decrement is not as large as after a shift to extinction (Herrnstein, 1966). Neuringer (1970) reported that much responding was maintained by response-independent schedules after only a few response-dependent reinforcers. Weisberg and Kennedy (1969), studying children's behavior, observed a dif-

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ference in responding between response-independent schedules and other schedules that was comparable to the differences typically seen in animals (see also Buskist, Miller, & Bennett, 1980).

The second kind of superstitious behavior was demonstrated using concurrent schedules of reinforcement, in which two or more spatially distinct responses were maintained by independent schedules. Catania and Cutts (1963) reported typical superstitious responding in these situations. Humans exposed to concurrent variable-interval 30-s extinction (VI 30-s EXT) schedules often responded rapidly on an extinction button that never produced reinforcers; reduction or elimination of this behavior required the introduction of a changeover delay (COD) that prevented temporal contiguity between responses on the extinction button and delivery of a reinforcer produced by a response on the variable interval button. Similar superstitious responding has been found in high school students (Bruner & Revusky, 1961) and in children (Zeiler, 1970).

The third kind of superstition involves stimulus control. When the availability of response-dependent reinforcement is differentially correlated with selected stimuli, organisms respond differentially in the presence of those stimuli. Differential responding also occurs when a reinforcer does not depend on the stimulus even though it depends on responses. This phenomenon, investigated by Morse and Skinner (1957), is called "sensory superstition." Although sensory superstition does not produce as large a difference as when a discriminative stimulus is working effectively, it does occur in animals under various conditions (Blue, Sherman, & Pierrel, 1971; Kello, Innis, & Staddon, 1975; Kieffer, 1965; Lander, 1968; Starr & Staddon, 1982).

Thus, superstitious behavior has been studied and discussed by many researchers, but since Skinner's (1948) experiment very little has been reported about the properties of idiosyncratic and stereotyped superstitious behavior either in humans or in animals. On the contrary, Staddon and Simmelhag (1971) argued that repeated reinforcers presented independently of responses do not necessarily produce idiosyncratic and stereotyped superstitious behavior. They replicated most features of Skinner's (1948) experiment and found many kinds of "interim activities" just after

food delivery, but at the end of the interval they found almost exclusively key pecking, which they interpreted as an anticipatory consummatory response. Staddon and Simmelhag argued that "interim activities," their idiosyncratic and stereotyped properties notwithstanding, could not be regarded as superstitious behavior because these activities did not immediately precede and were not contiguous with reinforcers, as Skinner's interpretation required. Rather, they classified them as adjunctive behavior, as did Falk (1969, 1971). Recently, Timberlake and Lucas (1985) also examined the various patterns of superstitious behavior by combining the procedures of Skinner (1948) and Staddon and Simmelhag (1971). Their results were similar to those of Staddon and Simmelhag (1971), and they concluded that superstitious behavior under periodic delivery of food probably developed from components of species-typical patterns of appetitive behavior related to feeding.

The present study analyzed the behavior of humans exposed to response-independent schedules of reinforcer delivery. The experiment included three major components: First, it examined whether humans develop idiosyncratic and stereotyped superstitious behavior similar to that described by Skinner (1948); second, the development of sensory superstition was tested by introducing several uncorrelated stimuli into the experiment; and finally, effects of the types and values of the response-independent schedules were examined.

METHOD

Subjects

Twenty undergraduate students (6 males and 14 females), aged 19 to 24 years old, served as subjects. None had previously participated as subjects in a behavioral experiment.

Apparatus

The experimental booth, shown in Figure 1, was 500 cm wide and 250 cm deep, and was separated from the rest of the room by a partition. Three levers were placed at 120-cm intervals, center to center, on the 70-cm-high table. Each lever and its frame were made of steel. The frame was 28.5 cm wide, 36.0 cm

deep, and 34.0 cm high. A minimum force of 10 N was required to operate each lever, and effective responses on a lever were indicated by a red lamp mounted on its frame. On the wall facing the subject, a four-digit counter and a small red reinforcer indicator lamp were mounted 90 cm above the table. A signal light was mounted 5 cm below this lamp. A micro-computer (Z80/CPU®) and other scheduling and recording equipment were located in an adjacent room.

Procedure

Schedules were either fixed-time or variable-time, with values of either 30 s or 60 s (FT 30-s, FT 60-s, VT 30-s, and VT 60-s). Interreinforcer intervals in the VT 30-s schedule ranged from 3 to 57 s in 3-s steps; those in the VT 60-s schedule ranged from 25 to 95 s in 5-s steps. Independently of responding, at the end of each scheduled time period a point was added to the counter, accompanied by a flash of the reinforcer lamp and the sound of a buzzer. The initial phase of the experiment lasted 30 min, during which a subject received either 60 points (FT or VT 30-s) or 30 points (FT or VT 60-s).

After the initial phase, each subject was exposed to 10 min of extinction, which completed the 40-min experimental session. During the session, three different signal-light colors (red, orange, and green) were presented. Each was lit six to eight times in a random sequence. Total duration of each light and frequencies of reinforcement in their presence were both equal.

Before the experiment, subjects were randomly assigned to the four schedules (5 subjects per schedule). Each subject then received the following instruction, in Japanese, by tape recorder:

You may not leave the experimental booth or come out from behind the partition during the experiment. The experimenter does not require you to do anything specific. But if you do something, you may get points on the counter. Now try to get as many points as possible.

Subjects were observed from the next room through a one-way mirror. After the experiment, each subject was given a questionnaire about how points were produced and was informed about the purpose of the experiment.

Fig. 1. Schematic illustration of experimental booth.

RESULTS

Table 1 summarizes the results for each subject. The order of the subjects' presentation is based on total lever-pull responses. The data include lever pulls and percentage of contiguous reinforcers during various periods of the experiment, and dominant response patterns. But the primary data of interest in this experiment are the specific patterns of superstitious behavior produced by response-independent reinforcers. While the time schedules operated, many examples of idiosyncratic and stereotyped behavior occurred. A description of these patterns is followed by discussion of transient superstitious behavior, sensory superstition, and other effects.

Persistent Superstitious Behavior

Two subjects developed persistent idiosyncratic and stereotyped superstitious behavior. During a session of FT 60-s, S5 emitted a pattern of lever pulls that might be called a topographical superstition (Catania, 1968). A representative pattern is shown in the event record of Figure 2. The pattern was simple: Several lever pulls (usually four) were immediately followed by lever holding. How was this idiosyncratic behavior acquired? Figure 3 shows S5's lever pulls and reinforcers during the first 9 min of the experiment. S5 began the session with short pulls or runs of short pulls on each lever. But after 60 s, the first reinforcer was presented while he was holding the middle lever after three short pulls. Thereafter he began to emit a long pull or a long pull after a few short pulls. The longer he held

Fig. 2. Representative record of topographical superstition produced by S5. Each displacement on the event record shows a pull and release of a lever.

the lever, the greater was the probability that a reinforcer would be presented during holding. Thus, almost all reinforcers were presented during a long pull that followed a few short pulls. By the 9th min of the session, his behavior had become stereotyped.

S15, who also developed persistent superstitious behavior, emitted several lever pulls early in the session (see Table 1), but for this subject the first and second point deliveries occurred 10 s after a lever pull. Her lever pulling then decreased and she began instead to

Table 1

Summary of results produced by each subject. Response patterns were classified as follows: A, persistent superstitious behavior; B, transient superstitious behavior; C, inconsistent lever-pulling behavior; D, inconsistent behavior other than lever pulling; E, stop of any movement. (PCR, percentage of contiguous reinforcers.)

Sub- ject	Schedule	Lever-pulling responses					PCR		Response pattern
		Total	RFR phase	EXT phase	Initial 30 s	Initial 5 min	Initial 5 min	Whole session	
S1F	VT30	2,873	2,215	658	24	236	100	100	A
S2M	FT30	2,547	2,018	529	24	280	90	88	B
S3F	FT30	1,851	1,461	390	3	47	30	85	BD
S4F	FT30	1,409	1,020	389	8	125	90	95	B
S5M	FT60	1,270	927	343	16	130	100	97	A
S6M	VT30	1,066	901	165	12	182	70	53	BE
S7F	FT30	1,008	800	208	1	98	100	83	B
S8F	VT60	971	754	217	4	160	60	67	B
S9F	FT60	793	636	157	9	111	60	70	C
S10M	VT30	717	488	229	1	51	60	72	B
S11F	VT60	656	478	178	5	68	40	73	B
S12M	FT60	455	367	88	8	76	60	53	B
S13F	FT60	350	273	77	1	48	80	43	B
S14F	VT30	177	135	42	3	19	20	33	CDE
S15F	VT60	143	94	49	1	22	10	7	A
S16F	VT60	135	98	37	2	9	0	33	CDE
S17M	VT60	43	41	2	0	1	0	20	CDE
S18F	FT30	24	19	5	0	5	0	10	CDE
S19F	FT60	24	22	2	0	11	0	3	CDE
S20F	VT30	0	0	0	0	0	0	0	DE

M: Male.
F: Female.

Fig. 3. The first 9 min of the session of S5, showing the development of S5's superstitious behavior. Within each set of event records, the bottom one indicates point deliveries; successively higher records indicate responses on the right, middle, and left levers, respectively.

engage in other behavior. About 5 min into the session, a point delivery occurred after she had stopped pulling the lever temporarily and had put her right hand on the lever frame. This behavior was followed by a point delivery, after which she climbed on the table and put her right hand to the counter. Just as she did so, another point was delivered. Thereafter she began to touch many things in turn, such as the signal light, the screen, a nail on the screen, and the wall. About 10 min later, a point was delivered just as she jumped to the floor, and touching was replaced by jumping. After five jumps, a point was delivered when she jumped and touched the ceiling with her slipper in her hand. Jumping to touch the ceiling continued repeatedly and was followed by points until she stopped about 25 min into the session, perhaps because of fatigue.

Transient Superstitious Behavior

Response-independent reinforcers had temporary effects that may be referred to as transient superstitious behavior; that is, an accidentally reinforced response pattern was repeated for awhile. This type of superstitious behavior was seen in most subjects, and can be divided into several classes. Figure 4 illustrates such transient superstitious behavior.

Data from S4 and S7 show instances in which particular patterns of responding that were followed by point delivery were then repeated. Another class of transient superstitious behavior that occurred is that in which a response pattern across levers was repeated. S11 happened to pull the levers six times in the order left, middle, right, right, middle, left. Although a point delivery did not immediately follow this behavior, the next point was delivered just after she again pulled the levers in the same order. Thereafter she emitted the same response pattern three times. Data from S12 show an example of a transition from a rate pattern to a location pattern. Many other examples of transient superstitious behavior involved response topographies, such as the position held by the hand, the force or speed of pulls, the hand used to pull the lever, and so on. Thus, various transient superstitions were observed in the data of most subjects. But they were not maintained extensively, and they were replaced by other behavior because point deliveries rarely followed the same behavior pattern repeatedly.

Sensory Superstition

Subjects were exposed to the three colors of signal light that changed independently of both

Fig. 4. Examples of transient superstitious behavior, in which a response pattern reinforced accidentally is repeated a few times. Within each set of event records, the bottom one indicates point deliveries; successively higher records indicate responses on the right, middle, and left levers, respectively.

Fig. 5. Relative frequencies of pulls on each lever during each signal light.

Fig. 6. Development of S1's sensory superstition. Within each set of event records, the bottom one indicates point deliveries; successively higher records indicate responses on the right, middle, and left levers, respectively.

point deliveries and the subjects' behavior. Fewer than half of the subjects showed any biased responding concerning these color stimuli. But as shown in Figure 5, six subjects produced marked sensory superstitions, in that responding on particular levers increased notably during some colors of the signal light and decreased during others. In particular, S1 (Figure 5, top left) developed an almost perfect sensory superstition. During most of the experimental session, she responded on the left lever when the signal light was red, the middle lever when it was green, and the right lever when it was orange. Figure 6 shows details of the development of her sensory superstition. The relation between the signal lights and specific levers built up rapidly. When the red light first came on, she pulled the three levers in the order right, middle, and left, but because of an equipment failure, the first two points were delivered only after responses on the left lever. When the orange light came on, she obtained five points while responding on the middle lever. When the green light came on next, she responded only on the right lever, but no points were delivered for 40 s. After she changed to the middle lever, two points were delivered in succession. Thus, signal lights acquired discriminative properties for S1.

Other Behavioral Effects of Response-Independent Schedules

Differential effects of FT, VT, and their schedule values will be described first. Figure 7 shows total lever pulls of all subjects for each schedule during the initial 30 s and over the whole session. Although rates of responding during the initial 30 s were similar across all schedules (except for VT 60-s), as time passed the rates gradually diverged. In general, FT schedules produced more lever responding than VT schedules did, and 30-s schedules produced more lever responding than 60-s schedules did.

Table 1 shows the total lever responses of each subject during various periods of the experiment. Although no points were delivered during the first 30 s, the correlation coefficient between lever responses during the first 30 s and total lever responses was high ($r = .838$), as was that between lever responding during the first 5 min and total lever responses ($r = .864$). These data suggest that the frequency of lever pulls in these response-independent schedules was largely predictable from initial levels of responding.

When a point was delivered within 1 s of a lever pull, that point was counted as contig-

Fig. 7. Total lever pulls averaged across the five subjects exposed to each of the four time schedules, during the initial 30 s and over the whole session.

uous with the response. The column labeled PCR in Table 1 shows these contingencies for the initial 5 min and for the whole session, calculated as percentages of total reinforcers. The percentage of contiguous reinforcers was high when the total response rates were high. The correlation coefficient between the percentage of contiguous reinforcers over the whole session and total lever responses was .829. The initial percentages of contiguous reinforcers of S1 and S5, each of whom showed persistent superstitious behavior, were both 100%. For S1, all point deliveries followed lever pulls within 1 s; for S5, only one point was separated from a lever pull by more than 1 s.

In this experiment, the three levers were set in a row. Figure 8 shows response counts on each lever during the reinforcer phase and during extinction. Many subjects accumulated more counts on the middle lever as a result of a back-and-forth pattern of lever pulls (left-middle-right-middle-left-middle and so on).

DISCUSSION

The production of superstitious behavior is a basic property of operant conditioning. The difference between superstitious behavior and other operant behavior studied in the laboratory is that the response preceding the reinforcer is not specified and not required in the case of superstitious behavior, whereas it is specified in advance by the experimenter and required for reinforcement in the case of operant behavior. Thus, superstitious behavior is defined as behavior produced by response-independent schedules of reinforcer delivery, in which only an accidental relation exists between responses and delivery of reinforcers.

Fig. 8. Response rate on each lever for each of the 20 subjects. Almost all subjects responded most on the middle lever.

The purpose of this experiment was to investigate the superstitious behavior of humans, and, in particular, idiosyncratic and stereotyped superstitious behavior comparable to the patterns that Skinner (1948) described in animals. The results were positive, in that idiosyncratic and stereotyped superstitious behavior was produced in human subjects by response-independent schedules. The response-independent schedules, however, did not always produce stable superstitious behavior. Only 3 subjects, S1, S5, and S15, showed such stable patterns; the others showed superstitious behavior only transiently.

The question is, then, why the subjects who showed persistent superstitious behavior developed such behavior while the other subjects did not. Before discussing this question, it is necessary to consider another basic feature of this experiment—that is, whether the point deliveries actually functioned as reinforcers. This may be a general problem in experiments using human subjects. In this experiment, a point delivery was accompanied by a flash of the red lamp and the sound of the buzzer.

These stimuli were important in getting the subjects to attend to the counter. But usually the effectiveness of reinforcers is demonstrated by increments in the frequency of responses that have preceded them. It is difficult to apply this criterion consistently in the present experiment because the responses preceding the reinforcers were not specified in advance. However, there was some evidence that the point deliveries actually functioned as reinforcers by this criterion. For example, persistent superstitious behavior developed only in cases in which the responses that had been immediately followed by point deliveries had increased in rate, and many subjects repeated particular responses as transient superstitions following point deliveries.

It seems that 3 subjects developed persistent superstitious behavior because the response-independent schedule had the same functional effect as a response-dependent schedule for these subjects. Four essential characteristics can be identified in the data of those subjects who showed persistent superstitious behavior: (a) The reinforcers were closely contiguous with certain responses, (b) the same responses were reinforced repeatedly, (c) other classes of responses were not reinforced, and (d) the reinforcers followed responses in an early stage of the session. For example, for S1 all 60 reinforcers were presented within 1 s of a preceding lever pull. Moreover, S1 reported in the questionnaire that a specific number of lever pulls was required for delivery of reinforcers. Thus, the behavior of S1 can be regarded as substantially equivalent to the behavior that would be maintained by a VR schedule with three discriminative stimuli. Similarly, S5 received 97% of all reinforcers within 1 s of individual lever pulls; only one reinforcer was not contiguous with such behavior. For S15, almost all reinforcers were delivered while she was engaged in her curious touching or jumping behavior. Thus, if the response-independent schedules had the same functional effects as response-dependent schedules for those subjects who showed persistent superstitious behavior, is it proper to call their behavior superstitious? The answer is yes, because superstitious behavior is defined not by sequences of events, but by procedures.

In general, however, the varied behavior shown in this experiment should be discussed in terms of contiguities as sequences of events—

that is, the different contiguities that happen to be generated by response-independent schedules. These contiguities might be called "contiguities as event sequences," as opposed to "contiguities as operations or procedures" (a similar distinction about contingencies is made in Catania, 1968, pp. 330–331). The responses under response-independent schedules can change in different ways depending on these contiguities as event sequences. When the contingencies determine the temporal relations between particular responses and reinforcers (Herrnstein, 1966), there are four possible sequences; that is, a reinforcer is presented in temporal contiguity with a response ($R-RFR$), a response does not occur and a reinforcer is not presented ($\bar{R}-RFR$), a response is not temporally contiguous with a reinforcer ($R-\bar{RFR}$), and a reinforcer occurs that is not temporally contiguous with a response ($\bar{R}-\bar{RFR}$). When response-independent schedules are carried out as procedures, all four sequences can occur in various orders and combinations. Only one of these sequences is peculiar to response-independent schedules: A reinforcer can be presented without a preceding response ($\bar{R}-RFR$). But such a sequence will not occur if the organism continues to respond frequently. Instead, the other three sequences will occur in various combinations that cannot be distinguished from those produced by response-dependent schedules. For example, if only two relations ($R-RFR$, $\bar{R}-RFR$) occur during response-independent schedules, these sequences are equivalent to continuous reinforcement, and if three relations ($R-RFR$, $\bar{R}-RFR$, $R-\bar{RFR}$) occur, they are equivalent to intermittent reinforcement.

However, even though the same sequences occur, the response-reinforcer relations in response-dependent schedules and those in response-independent schedules are not equivalent, because the arbitrary response-reinforcer relations in response-independent schedules produce delays between responses and reinforcers that attenuate the effects of the reinforcers (see Sizemore & Lattal, 1978). In the present experiment, idiosyncratic responses might have decreased not because of the reinforcers that did not follow responses ($\bar{R}-RFR$) but because of delays of reinforcement. Catania and Keller (1981) conducted systematic research on the effects of delays of reinforce-

ment produced by both response-dependent schedules and response-independent schedules. Pigeons responded differently during response-dependent schedules with various delays than during VT schedules even though their distributions of response-reinforcer intervals were the same, and pigeons' behavior was also sensitive to delays as short as a few seconds. Killeen (1978) also noted the pigeons' sensitivity discriminating response-dependent stimulus change and response-independent stimulus change. Although these specific effects have not been demonstrated in humans, Wasserman and Neunaber (1986) found that response-outcome contiguity was a determinant of college students' ratings of causality, under a procedure in which their telegraph-key responses could postpone or advance (but could not produce or prevent) a gain or loss of points. The contiguity of response-produced outcome also was systematically related to the corresponding increases and decreases in responding. Verbal behavior surely plays a role in making events separated by long delays operate on human behavior as if they were contiguous. However, the results of Wasserman and Neunaber suggest that the relevant verbal behavior is differentially sensitive to discriminative control by contiguous events.

As long as the reinforcer is response-independent, temporal contiguity between a reinforcer and any particular response cannot be guaranteed in advance. However, whatever the species, as a particular response gains in frequency, the likelihood increases that response-independent reinforcers will be temporally contiguous with it, and that this will affect subsequent behavior. In everyday life, humans experience ambiguous situations in which the contingencies are unknown. In such situations, the behavior of humans may be directly affected by event sequences that are juxtaposed with their behavior. Therefore, even though the contingencies are those of response-independent schedules, the behavior of individuals who do not completely stop responding may be maintained indefinitely, because reinforcers without responses (R—RFR) will seldom occur as event sequences related to their behavior. This may be one reason that humans are likely to develop superstitious behavior in everyday life; another is that just a single response-reinforcer contiguity may sufficiently increase the frequency of the response to get

the process under way, as suggested by Skinner (1953, p. 87; 1978, p. 172).

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