SOME VARIABLES AFFECTING THE SUPERSTITIOUS CHAINING OF RESPONSES^{1,2}

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This study was based upon a repeated acquisition technique that systematically generated superstitious chains of responses. Several procedures were investigated in an effort to modify the amount of superstitious chaining. The effects of a large work requirement, a stimulus correlated with non-reinforcement after inappropriate responses, an equivalent time delay after inappropriate responses, and extensive training were examined. The presentation of a stimulus correlated with non-reinforcement was found to be the most effective technique for reducing superstitious chaining; the time delay was the least effective.

Reinforcement strengthens any behavior it happens to follow. When an organism makes a response that is not actually part of the reinforcement contingency but that is nevertheless followed by reinforcement, the behavior so strengthened can be described as superstitious and the reinforcement contingency as adventitious. A notable step toward understanding and analyzing experimentally such superstitious behavior was taken by Skinner in 1948. He arranged for a food magazine simply to operate automatically every 15 sec in the same chamber with a hungry pigeon. When he returned some time later, he found that the pigeons were performing such behaviors as turning, bowing, and hopping. The birds had apparently been conditioned by accidental coincidences between the behavior and reinforcement. Skinner noted the similarity between these behaviors in his pigeons and certain human superstitions, such as a card-player's rituals for changing his luck and a bowler's "body-English" for guiding the ball into the pins. These behaviors, too, were probably strengthened by an accidental coincidence between the ritual and a reinforcing state of

affairs, although a causal relationship was lacking.

Since Skinner's original work, a number of studies with a variety of experimental situations have implicated superstitious behavior. One example is the collateral behavior observed by Wilson and Keller (1953) to intervene between the lever-pressing responses on a differential reinforcement of low rate (DRL) schedule. They noticed that their rats developed stereotyped behaviors, such as grooming or nose poking, which occupied enough time so that the next lever press was often reinforced. Although it may have increased the probability of reinforcement of the next lever press, the collateral behavior can still be regarded as superstitious, since the behavior was not part of the reinforcement contingency. Analogous superstitious behaviors during DRL schedules have been found in various settings and with several species. Hodos, Ross, and Brady (1962) observed excessive licking and head jerking in monkeys restrained in primate chairs. Laties, Weiss, Clark, and Reynolds (1965) studied a rat that nibbled its tail in a stereotyped way between spaced responses. Bruner and Revusky (1961) and Randolph (1965) found that humans would operate extra pushbuttons before the response reinforced by the DRL schedule; Catania and Cutts (1963) made a similar finding with a variable-interval schedule. Kapostins (1963) discovered systematic patterns of intervening verbal behavior in an human experiment on word utterance. While they may have filled time, the various collateral behaviors in all of

¹Dedicated to B. F. Skinner in his sixty-fifth year. His pioneering work on superstition in 1948 formed the background for the present research.

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these studies formed no part of the actual reinforcement contingency.

Other examples of superstitious behavior have been observed with quite different procedures. Migler (1963) and Keehn and Chaudrey (1964) presented a shock that was automatically turned off after a fixed duration. Nevertheless, the rats in these experiments continued to press a lever during the shock as if the lever press terminated the shock. Migler also observed one rat to press a spare second lever during the shock, even though that lever had never had any effect. The superstitious escape behavior in these experiments was maintained by the accidental correlation of the response and shock termination. Accidental relationships may also arise in the sensory control of behavior. Morse and Skinner (1957) trained pigeons with food reinforcement delivered after variable intervals to peck a key in an orange light. Occasionally a blue light was presented independently of the reinforcement schedule. Pigeons that accidentally received a few reinforcements in the blue light began to peck at high rates in blue. Other pigeons that received no reinforcements in blue responded infrequently during the stimulus. Such superstitious discriminations can be explained in terms of adventitious reinforcement (or accidental failure to receive reinforcement) during the incidental stimulus.

An experiment particularly relevant to the present study was performed by Herrnstein and Morse (reported in Herrnstein, 1966). A pigeon was trained to peck a disk on a short fixed-interval schedule (FI 11-sec). Then the reinforcement contingency was removed, but the reinforcer was delivered every 11 sec regardless of the bird's behavior. The results over 21 daily sessions showed that a substantial rate of pecking (about one peck every 2 sec) was maintained, even though the reinforcement was purely accidental. This study departed from those discussed above in that the behavior was conditioned with a deliberate reinforcement contingency and then was maintained superstitiously.

In a study of the repeated acquisition of new behavioral chains (Boren and Devine, 1968), a large amount of superstitious behavior was observed. In that study, monkeys were trained with food reinforcement in a chamber containing four groups of three levers. During each session, the monkey's task

was to learn a new four-response chain by pressing in sequence the correct lever from each group. At the beginning of the session, the monkey pressed a random assortment of incorrect levers, as one might expect in the acquisition situation. However, by about the twentieth repetition of the reinforced chain, a semi-stable mixture of correct and incorrect responses usually developed. At this point, the same incorrect responses would often appear in the same sequence within the reinforced chain. For example, if the reinforced ("correct") sequence of levers was 1-4-8-12, the monkey might repeatedly press in the sequence 2-1-4-8-12. This elongated sequence was reinforced even though the press on lever 2 was irrelevant. The unnecessary lever press had apparently become chained adventitiously with the correct levers upon which the reinforcement was in fact contingent. Under appropriate conditions, new patterns of superstitious chaining were reestablished from session to session, so it appeared that the superstitious behavior was being systematically generated.

Using this superstitious behavior as a baseline, the purpose of the present study was to examine several variables that might change the frequency of such behavior. One variable was the amount of behavior required for each member of the chain. If the monkey could maintain a lengthy superstitious chain only by putting out a great deal of work, the amount of superstitious behavior might decrease. Other variables explored were: (1) the effects of a timeout stimulus (or S^{Δ} —a stimulus in the presence of which responses were not reinforced); (2) the effect of a time delay without a stimulus to determine if the delay alone could decrease superstitious chaining; and (3) the effect of extended training on one sequence to determine if (as suggested by Herrnstein, 1966) superstitious behavior would drift toward minimal forms.

METHOD

Subjects

Three rhesus monkeys (*macaca mulatta*) served. Their past history included more than 300 sessions in the apparatus described below, so their familiarity with the experimental environment and their pattern of relearning had reached a stable state. The monkeys were de-

prived of food for 24 hr before each session. Their major source of food was the 80 pellets (0.7-g D & G monkey lab chow pellets) delivered as reinforcers during the session. The only other food was an orange given to the monkeys several hours after the session.

The principles of laboratory animal care as promulgated by the National Society for Medical Research were observed.

Apparatus

The experimental environment was a metal chamber, 2 ft (0.6 m) in each dimension. Twelve levers, in four groups of three, were mounted on one wall, and above each lever was a pilot light. Behind each lever was a relay that produced an audible click when the lever was pressed. A pellet tray was mounted in the center of the wall below the levers.

The experimental procedure was scheduled automatically by relays, timers, pre-determining counters, *etc.* The clicks of the equipment were masked by white noise in the experimental room. Magnetic counters and a 20-pen event recorder automatically recorded the subjects' lever-pressing behavior.

General Procedure

The basic procedure was to train the monkey to learn or re-learn a four-response chain during an experimental session. As the monkey faced the 12-lever panel, the pilot lights were on over the first three levers on the left. When the monkey pressed the correct lever, the first three lights went out and the next three to the right came on. Next, the monkey had to press the correct one of levers 4-5-6 in order to advance the lights. Finally, when the correct one of levers 10-11-12 was pressed, the food-pellet dispenser operated. Then, the first three lights came on again to set the occasion for another response chain.

Several specific details of the basic procedure require comment. The food-pellet reinforcer was delivered after the completion of every second sequence, although the pellet dispenser operated (clicked) after each sequence. As another procedural detail, the monkeys were required to learn a new chain on alternate sessions. In other words, the second session of each pair was devoted to relearning the same response sequence as in the first session of the pair. Counterbalanced sets of six lever sequences were devised for the segments of the

study to be compared. An example of one such set is as follows: 3-4-9-11, 2-6-7-12, 1-5-8-10, 3-6-7-11, 1-4-8-12, and 2-5-9-10. The rules for constructing a set were: the same levers were not selected for the next sequence; repeated pairings of two lever sequences were not permitted; and each lever appeared equally often (twice) in each set. It has been found in this laboratory that the number of errors made in learning different sets constructed in this way do not differ substantially. Furthermore, in going through the same set several times, the monkeys make about the same number of errors each time. However, to avoid any small differences in the sets, a given set was always used in studying comparable conditions. Thus, for example, in studying one ascending-descending order of work requirements, the same set of lever sequences was used. Another set was used for the second ascending-descending order, *etc.* Each monkey served under all control and experimental conditions of the study.

Experiment I

The first variable examined was the work requirement on each lever. Fixed ratios (FRs) of 1, 5, 10, and 20 presses on each correct lever were required to change the pilot lights and to advance the chain toward the terminal food reinforcement. Thus, with FR 10 and the sequence 1-4-8-12, the monkey must press lever 1 at least 10 times, then lever 4 ten times, and so on, until the tenth press on lever 12 operated the pellet dispenser (no pellet). When this entire sequence was completed the second time, the dispenser delivered a pellet. The fixed-ratio sizes were studied in an ascending and a descending order on two occasions. The exact order is also indicated in the figures to follow. The assumption behind this experiment was that the increased work imposed by the larger fixed ratios would reduce the superstitious chaining of incorrect levers because the maintenance of superstitious behavior would also involve increased work.

Experiment II

The second phase of the study was concerned with a manipulation of the consequences of the non-essential behavior. One such consequence was a stimulus (S^A) correlated with non-reinforcement. When the monkey pressed a lever that was not part of the required chain, an S^A was produced. More

specifically, after an incorrect response, the pilot lights over the levers and the houselights went out, and the levers did not produce food. After the S^A terminated, the pilot lights came on over the same levers where the error was made, and the monkey began again in the same part of the chain where it had previously made the inappropriate response. The work requirement on each correct lever was FR 1. Based upon a prior study of a range of S^A durations (Boren and Devine, 1968), S^A s of 1 sec and 15 sec were used. Any lever press during the S^A prolonged it, so that 1 sec or 15 sec of no responding was required to terminate the S^A period. In the prior study, an effect of error-produced S^A was to stop responding and to insert a delay between an incorrect response and a correct one. Thus, an S^A might well prevent adventitious reinforcement by the mechanism of inserting a temporal space between the incorrect response and the reinforcement produced by a correct one. To determine if the delay itself (rather than the delay plus the exteroceptive stimulus) could prevent the superstitious chaining, the stimuli making up the S^A were removed. In other words, when the monkey pressed an incorrect lever, a delay was scheduled but the pilot lights and the houselight remained on. All other conditions remained exactly the same, including the requirement of 1 sec or of 15 sec of no responding before the delay was terminated. The object was to compare the control over superstitious behavior exercised by the time delay alone with that exercised by the time delay plus the stimulus.

In all of the experiments described above, a given experimental condition was maintained for at least 12 sessions. This number of sessions was found to be sufficiently long for the monkey's performance to reach a stable state. Indeed, the performance usually changed within the first session of a new experimental condition.

Experiment III

The final phase of the study was directed at the question: "Can the superstitious chaining eventually be reduced by extended training?" The monkeys were permitted to relearn the same sequence of correct levers for five consecutive sessions. Four different sequences were scheduled for five sessions each. The work re-

quirement on each correct lever was held to the simplest schedule, FR 1.

RESULTS

Experiment I

The behavior treated quantitatively in this study was the number of times the monkeys pressed a lever that was not part of the reinforced response chain. Such lever presses will be referred to as nonreinforced, incorrect, and inappropriate responses, or more simply, as errors. The vast majority of the errors observed were of two types and were observed in two parts of a session. (1) The irregular, scattered "learning" error where the monkey hit various unreinforced levers in a non-systematic order. This type of error occurred at the beginning of a session while the monkey was learning a new response chain. (2) The systematic "performance" error which the monkey regularly included within the response chain. This type of error was typically observed later in the session while the monkey was rapidly performing the chain.

The two types of errors are illustrated in Fig. 1 with event records from the beginning and the middle of a typical session. The upper

Fig. 1. Event recordings from the beginning and the middle of a session. The reinforced sequence of lever presses was 2-5-9-10. The upper record illustrates the scattering of responses typical of the acquisition of a new response chain and the lower record illustrates a well-formed superstitious chain (levers 1-2-5-8-9-10).

record from the beginning of the session shows that the monkey scattered its responses over a variety of unreinforced levers. The variable performance might be expected because the monkey was relearning a new sequence of levers which it had not experienced for many sessions. A different picture is seen in the record from the middle of the same session. By this time the monkey was rapidly pressing the levers (2-5-9-10) upon which reinforcement depended. In addition, two non-reinforced levers (1 and 8) were included in the response chain so that the total chain was 1-2-5-8-9-10. Levers 1 and 8 were included far too frequently and repetitively to be considered non-systematic. Note that the extended sequence was reinforced even though the presses on levers 1 and 8 were irrelevant. The unnecessary lever presses had apparently become chained superstitiously with the correct levers upon which reinforcement was actually contingent. Such lever presses form the basic subject matter of the results.

By recording the errors made after the twentieth chain, one finds that the vast majority of the errors are of the systematic repetitive type. Considering the lack of any but accidental reinforcement contingencies, these errors will be referred to as superstitious.

Figures 2 and 3 show how the superstitious errors varied with changes in the fixed-ratio size. The measures plotted in these figures were derived by several steps. First, the number of presses on non-reinforced levers (errors) was recorded from the twenty-first to the one hundred-sixtieth chain, for the reason indicated in the previous paragraph. Next, the median number of errors per session was computed for an individual monkey based upon the last eight sessions (four pairs) under a given FR. The details of the computation were as follows: using the errors in the four initial learning sessions (where a given lever sequence was first scheduled), a median was computed. In the same way, a separate median was computed for the four relearning sessions where the same lever sequence was scheduled a second time. Finally, the value representing the median errors per session was divided by the size of the fixed ratio. This division was done because more errors should be expected from the larger fixed ratios. For example, on FR 20 the monkey must press an incorrect lever 20 times before any stimuli are available that

this lever is not part of the reinforced chain. On FR 1, the monkey need press only once. Thus, to correct for this factor, the number of errors was divided by the FR size. This computation yielded an error measure in terms of FR units.

Figure 2 shows how the error measure described above varied as a function of the fixed-ratio size. The data in the upper graph came from the initial sessions on a given lever se-

Fig. 2. Performance errors in FR units as a function of the fixed-ratio size (Monkey C). For convenience in plotting the error measure, the ordinate is on a logarithmic scale; to avoid zero, 10 has been added to each error measure. The first study of an ascending-descending order of FR sizes is plotted by round points; the replication is plotted by x's. The arrows on the lines indicate whether the FR was being increased or decreased. The data for the first time on a given lever sequence are shown in the upper graph, and the data for the second time on a sequence are in the lower graph.

quence and the data in the lower graph came from the second sessions on the sequence. Both functions show a systematic decrease in the error measure as FR increased. As might be expected, the two functions differ largely in that more errors were made during the initial sessions than during the second sessions.

Similar data for a second monkey are shown in Fig. 3. As in Fig. 2, the general trend of the functions was for the error measure to decrease

Fig. 3. Performance errors in FR units as a function of the fixed-ratio size (Monkey M). The construction of this figure is the same as for Fig. 2.

as the fixed ratio increased. However, examination of the order in which the points were determined reveals a certain lack of reversibility from one FR condition to another. For example, the errors for FR 10 tended to be lower when the previous condition was FR 20 than when it was FR 5. In spite of this tendency, however, the FR 1 condition always produced an elevation in the error measure. The data for the third monkey (Monkey S) demonstrated the same functional relation as in Fig. 2 and 3.

The inverse relation between FR size and superstitious errors does not reliably hold if the absolute number of errors is plotted, rather than errors in FR units as in Fig. 2 and 3. The reader can confirm this statement by multiplying the points above FR by 5, the points over FR 10 by 10, *etc.* Furthermore, although the evidence on resistance to extinction as a function of FR size (Mowrer and Jones, 1945; Boren, 1961) indicates that the consideration of errors in FR units is an approximation in the right direction, it may be argued that division by the FR size is somewhat arbitrary and probably inexact. In order to develop a less arbitrary measure of errors, the recordings were analyzed for the number of occasions an incorrect lever was pressed, regardless of how many times. An occasion was defined as one or more presses on an incorrect lever without interruption by a press on another lever. The usefulness of the "number of occasions" analysis was that the measure avoids the problem of FR size and of the number of lever presses made during an occasion. The behavior during the last 20 reinforcements was used for this analysis not only for simplicity but also because the superstitious chaining could be seen most clearly late in the session. The results of this analysis for Monkey C appear in Fig. 4. The function is a declining one. As the FR size increased, the number of occasions the monkey pressed an incorrect lever decreased.

The same was true of Monkey M, as shown in Fig. 5, with somewhat less non-systematic variability. The carry-over from one fixed ratio to another, already noted in Fig. 3 for Monkey M, is apparent here. This partial irreversibility is especially clear because it occurred both times the fixed ratio size was increased and decreased. The main effect, however, shows that if a monkey must emit a number of responses to maintain a superstitious chain, it will do so

Fig. 4. Number of occasions an incorrect lever was pressed as a function on the fixed-ratio size. The data are for Monkey C.

on fewer occasions than if it must emit only one response. Thus, by this measure, as by the measure in terms of FR units shown in Fig. 2 and 3, the results are in agreement. When the monkeys were coerced by a large FR to put out large amounts of work to perform the superstitious behavior, then the superstitious behavior was less well maintained.

In a final analysis, the data of Exp. 1 were examined to determine the location of errors within the four-response chain. Because of the large volume of data and because of the variability, only representative data are shown in Table 1. The data are for the initial sessions

Fig. 5. The number of occasions Monkey M pressed incorrect levers at the various fixed-ratio sizes. This figure was constructed in the same way as Fig. 4, except that the data are for Monkey M. Note that the number of errors (especially for FR 10) depended partly on whether the previous FR was larger or smaller.

on lever sequences for FR 1 and FR 20 (two replications each). The median and the range of errors for four sessions are presented. Inspection of Table 1 reveals a great deal of variability. Nevertheless, Monkeys C and M tended to make fewer errors on the part of the chain (levers 10-11-12) closest to primary reinforcement. The variability makes other com-

Table 1

The frequency of errors in different parts of the response chain.

Levers	FR 1		FR 20	
	Mdn	Range	Mdn	Range
<i>Monkey C</i>				
1-2-3	266	167-863	3026	588-9247
4-5-6	196	142-297	2389	1950-3038
7-8-9	140	70-214	2516	882-5098
10-11-12	45	29-73	959	235-1425
1-2-3	440	244-588	1900	1468-5250
4-5-6	174	94-192	1638	503-2819
7-8-9	226	135-268	1491	11-2588
10-11-12	44	21-77	741	417-1273
<i>Monkey M</i>				
1-2-3	151	23-265	2540	108-2849
4-5-6	308	14-601	734	646-2168
7-8-9	150	44-258	1450	1142-1615
10-11-12	20	5-101	546	314-803
1-2-3	152	2-317	1695	1163-2603
4-5-6	20	10-360	1405	122-2295
7-8-9	78	51-188	712	326-1336
10-11-12	16	14-17	810	427-1119
<i>Monkey S</i>				
1-2-3	12	0-60	1170	454-2240
4-5-6	68	21-73	925	500-1292
7-8-9	23	6-36	935	186-1150
10-11-12	31	13-44	459	216-788
1-2-3	30	0-103	304	83-762
4-5-6	35	6-57	225	104-443
7-8-9	39	11-57	336	141-582
10-11-12	38	33-40	147	64-234

parisons difficult, a difficulty probably arising from the superstitious nature of the errors.

Experiment II

In this experiment certain consequences were made contingent upon the superstitious behavior. In a previous study (Boren and Devine, 1968), a response on an incorrect lever was followed immediately by a stimulus correlated with non-reinforcement (an S^A). This procedure effectively reduced the superstitious behavior, although it was not clear whether the stimulus *per se* was critical in producing the effect or whether the time delay was the major factor. The object of Exp. II was to extend the previous observation and to compare the effect of the S^A with the effect of an equivalent delay minus the stimulus.

Figure 6 shows the median errors of Monkey M under the various conditions of the experiment. Since a given sequence of reinforced lever presses was scheduled in two consecutive

sessions, the data for the first and second times on a sequence are shown in Fig. 6. As in Fig. 2 to 5, the two times on a sequence can be considered partial replications which permit estimates of the reliability of the effect within a subject.

In Fig. 6, a comparison of the errors under S^A conditions with the errors under delay conditions shows that the S^A were much more effective in reducing errors. It was of little consequence whether the S^As were 1 sec or 15 sec; they were about equally effective, thus confirming the previous study (Boren and Devine, 1968). Although the delays produced considerable variability (compare the two times a 1-sec delay was studied), the delays *per se* were relatively ineffective in reducing errors. For example, if the equivalent delays and S^As are compared, the S^A errors are 2% or less of the delay errors.

In Fig. 7, the data for another subject, Monkey C, show similar main effects. In every

Fig. 6. Median performance errors of Monkey M under the various S^A and delay conditions of Exp. II. The order of studying the conditions follows the order on the abscissa.

Fig. 7. Median performance errors of Monkey C under the various S^A and delay conditions of Exp. II.

case, the S^A s reduced the frequency of inappropriate responding much more than did the delays. The average errors under S^A conditions were about 6% of the errors under the equivalent delay conditions. It is clear from both Fig. 6 and 7 that merely inserting a temporal space between an incorrect response and reinforcement is a relatively ineffective way to attenuate superstitious chaining of responses.

Why was the delay relatively ineffective in comparison with an S^A ? One reason is that the delay made poor contact with the inappropriate behavior. After the monkey pressed the wrong lever, no discriminable change occurred. When the error produced an S^A , on the other hand, the lights went out immediately. The clear and immediate stimulus change, indicating that the monkey no longer had access to reinforcement, exercised effective control.

A second factor was also present. Once a delay period without stimuli was started, the monkey often pressed other levers, thus pro-

longing the delay. During this time, both correct and incorrect levers could be pressed, but in either case nothing in the monkey's environment changed. Thus, many incorrect responses were without consequence, and many correct responses went unreinforced. In contrast, the S^A procedure was much more exacting. In correct responses were immediately followed by an S^A . Furthermore, since the monkeys did not respond during the S^A , correct responses were always reinforced, either by the pilot lights or by the food pellet. This set of exact contingencies arising from the S^A procedure and its associated delay seems to account for much of its relatively greater effect.

The changeover delay used by Catania and Cutts (1963) to separate the superstitious response from reinforcement was considerably more effective than the post-error delay of the present study. One reason may be that the two delays were scheduled differently. The changeover-delay interval was reset only by another superstitious response, whereas the delay of the present study was reset also by correct responses. Nevertheless, in partial agreement with the present study, Catania and Cutts found that the changeover delay varied considerably in its effect and that some subjects continued to respond superstitiously in spite of it.

Experiment III

The problem of the final experiment was to determine whether extended training on a given sequence would reduce the superstitious chaining to negligible amounts. The problem was approached by training the monkeys on the same sequence of correct levers for five consecutive sessions. This was done with four different sequences. The work requirement on each correct lever was FR 1, which in Exp. I had proved most likely to generate superstitious behavior.

The number of errors was recorded for each of the five sessions on a given lever sequence. Then, using the error values for the first session (Day 1) on each of the four lever sequences, a median was calculated. In the same way, a median was calculated separately for the second, third, fourth, and fifth sessions on a sequence.

A session-by-session plot of these median errors per session is shown in Fig. 8. With all three monkeys, the number of errors declined

systematically with repeated training. The curves were negatively accelerated with the bulk of the errors (an average over the three monkeys of 77%) occurring in the first two sessions. By the fifth session, all monkeys were making relatively few errors, and an extrapolation of the curves suggests that the errors would probably have decreased further with additional training.

Fig. 8. The reduction in errors caused by retraining the monkeys on one sequence of lever presses. Each curve shows the performance of one monkey.

In summary, extended training on the same sequence of levers reduced the amount of superstitious chaining. This result is consistent with Herrnstein's (1966) proposal that superstitious behavior should drift toward minimal forms. The findings in Fig. 8 may have been due to one or both of the following processes: (1) consistent and repeated reinforcement may have strengthened the correct lever presses, while (2) the delays and extra responding inherent in superstitions may have weakened the superstitious behaviors.

DISCUSSION

There is every reason to believe that superstitious behavior obeys the same laws as other behavior. Herrnstein (1966), in an excellent review of this question, found no exception. In the present study, the superstitious behavior included within the reinforced response chain seemed to be determined by an accidental reinforcement contingency, in the same way as the non-superstitious behavior was determined by an actual reinforcement contingency. While neither a new theoretical analysis nor a new set of principles is required, there remains the technical problem of how to

control such behavior. The problem is especially difficult because the adventitious reinforcement that maintains the superstition may still be present and may counteract efforts at control.

This study has investigated three ways of decreasing superstitious behavior. One way is to increase the response cost of the superstition. When the number of responses required to maintain the superstition was increased, the superstitious behavior was attenuated, at least if the appropriate correction for FR size or the number of occasions was considered. A second way to decrease superstitious behavior is to follow such behavior with an S^A . The use of an S^A is a simple and highly effective means of control. In comparison, interposing a delay between the superstitious response and the reinforcement was both behaviorally complex and relatively ineffective. The third way explored in this study was repeated training. When a number of sessions was devoted to training the desired responses, the superstitious responses were gradually reduced. Of the variables studied, however, the use of an S^A was the most immediate, reliable, and effective means to control superstitious chaining.

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