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Ruth A. Heltzer

Stuart Vyse
Connecticut College, savys@conncoll.edu

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INTERMITTENT CONSEQUENCES AND PROBLEM SOLVING: THE EXPERIMENTAL CONTROL OF "SUPERSTITIOUS" BELIEFS

RUTH A. HELTZER and STUART A. VYSE
Connecticut College

Three groups of college students were asked to determine how points were earned in a task that allowed the assessment of response variability. All students received points for sequences of eight presses distributed across two keys (four presses on each key). One group received a point for each correct sequence, one group received points on a fixed-ratio 2 schedule, and one group received points on a random-ratio 2 schedule. There were no significant differences in nonverbal response variability across the three groups, and the fixed-ratio 2 and random-ratio 2 groups obtained equivalent point totals. However, participants in the random-ratio group were significantly more likely to write verbal descriptions of the task that made reference to performance-consequence relations that were not in effect. The results demonstrate that superstitious rule generation is more probable when consequences are random and not merely intermittent.

When people are exposed to operant contingencies without benefit of instruction, they frequently generate descriptions of the events they experience. A child playing with a new toy can soon articulate the principles of its use, and an experienced surgeon can suggest techniques that will improve the likelihood of a successful operation. Although this process of rule generation often leads to accurate descriptions of the environmental contingencies (or of behavior adapted to these contingencies), in some cases inaccurate rules result. Furthermore, if supported by the environment, inaccurate contingency statements can persist and control forms of responding that are poorly matched to the demands of the task (Leander, Lippman, & Meyer, 1968; Vyse, 1991).

When Skinner (1948) discovered that the regular presentation of food to a hungry pigeon, without reference to its behavior, produced

An earlier version of this article was presented at the annual meeting of the American Psychological Association on August 11, 1990 in Boston. Correspondence should be addressed to Stuart A. Vyse, Department of Psychology, Box 5621, Connecticut College, New London, CT 06320. Internet: savys@conncoll.edu.

stereotyped, idiosyncratic responding, he called such behavior "a sort of superstition" (p. 171) because "the bird behaves as if there were a causal relation between its behavior and the presentation of food" (p. 171). More recent research has challenged the idea that Skinner's pigeons exhibited operant superstitions (Killeen, 1977; Staddon & Simmelhag, 1971; Timberlake and Lukas, 1985); however, this controversy notwithstanding, several studies with human participants have demonstrated superstitious conditioning of nonverbal behavior (e.g., Ono, 1987; Wagner & Morris, 1987). Drawing on this earlier work, the present investigators have adopted the term *superstitious rule* to refer to a verbal statement of contingencies or performance-outcome relations that are not in effect.

A variety of environmental contexts are associated with the generation of inaccurate rule statements, ranging from restricted descriptions of the true contingencies (e.g., Schwartz, 1982; Vyse, 1991) to completely superstitious accounts of the environmental demands (e.g., Catania & Cutts, 1989). For example, superstitious rules and nonverbal responding are observed in many human participants under fixed interval (FI) schedules. Research in human schedule performance revealed two distinct patterns of FI behavior in language-competent participants. Although infants showed the familiar scalloped pattern universally found in nonhumans (Bentall, Lowe, & Beasty, 1985), adults typically responded at either a high, steady rate or a very low rate, often making only a single response per interval (Leander et al., 1968). Furthermore, in postexperimental interviews, low-rate responders reported that reinforcement was dependent on the passage of time; whereas high-rate responders, who frequently emitted hundreds of key presses per interval, expressed the belief that reinforcement was contingent upon a certain number of responses (Leander et al., 1968; Lowe, 1979).

Catania and Cutts (1963) demonstrated that both superstitious rules and superstitious nonverbal behavior could be produced through adventitious reinforcement. College students pressing buttons for points under concurrent variable interval (VI) extinction (EXT) schedules showed stable responding on the EXT button. In addition, most participants reported that the VI button produced reinforcement only after a certain number of presses on the EXT button. The introduction of a changeover delay eliminated both superstitious verbal and superstitious nonverbal behavior.

In a study of behavioral stereotypy, Schwartz (1982) found that when reinforcement was made available for any of 70 sequences of eight presses on two keys, college students adopted a single dominant sequence. Later, when asked how reinforcement was obtained, most participants reported that the sequence they had adopted was the only one that produced points. They had mistaken a sufficient solution for a necessary one.

Using a similar matrix task, Vyse (1991) found that college students

who received random-ratio (RR) 2 reinforcement for some sequences through the matrix and fixed-ratio (FR) 1 reinforcement for others were more likely to describe contingencies that were not in effect (e.g., points are earned by executing a sequence of four paths through the matrix) than those not exposed to RR reinforcement. Building on this earlier work, the present investigation was designed as a direct examination of the effects of intermittent consequences on the accuracy of participants' descriptions of experimental task demands. To determine whether inaccurate rule statements were the result of random consequences or merely of intermittent ones, some participants were exposed to an RR 2 schedule of reinforcement and others to an FR 2 schedule. Because previous studies have implicated both externally provided instructions (Baron & Galizio, 1983; Hayes, Brownstein, Haas, & Greenway, 1986; Matthews, Shimoff, Catania, & Sagvolden, 1977; Shimoff, Catania, & Matthews, 1981) and self-generated rules (Leander et al., 1968; Vyse, 1991) in participants' insensitivity to prevailing schedules, a between-subjects design was chosen in which each participant was exposed to a single schedule of point delivery for nonverbal responding. Finally, in most previous investigations of rule discovery, only nonverbal responding has been reinforced, creating a motivational context that favors nonverbal behavior over the development of accurate contingency statements. As a result, in the present experiment participants were instructed to discover how points were earned and not to be concerned with the total number of points obtained. The primary dependent variable was the verbal behavior of the participants, and the independent variable was the schedule of consequences for nonverbal responding.

Method

Participants

Twenty-four students, 10 men and 14 women, from an introductory psychology course at Connecticut College were randomly assigned to one of three experimental groups. In exchange for their service, students received course credit, without regard for their actual performance.

Setting and Apparatus

The experiment was conducted in a 4-m x 4-m windowless room that contained a table, a chair, and an Apple Macintosh SE computer. The keyboard was placed directly in front of the monitor, as it might be arranged for normal use, but the computer's mouse was moved out of sight. During the session, a five by five matrix of 2-cm x 1.5-cm boxes was present on the screen, and a 1-cm diameter circle appeared in one of the boxes.

Procedure

Five self-paced sessions lasting between 5 and 10 min each were

conducted on a single day. Between sessions, participants left the room for approximately 3 min while the experimenter prepared the computer for the next session.

Upon entering the experimental room for the first time, the participant sat in front of the computer, and the experimenter read the following instructions:

> This is an experiment in problem solving. Using the "Z" key and the "/" key you will be able to earn points on the computer. The most important thing for you to do is to discover how points are earned. The total number of points you earn is not important. Try to come to as complete an understanding of the task as you can. When you are ready to begin, press the space bar.

The matrix was not visible at this time, but the message "When you are ready to begin, press the SPACE BAR" was displayed on the computer monitor. The experimenter answered any questions by merely rereading the relevant section of the instructions and left the room. No additional instructions were given on subsequent sessions.

When the participant initiated the session by pressing the space bar, the matrix appeared on the computer screen. At the beginning of each of the 50 trials per session, the circle appeared in the upper left-hand box of the matrix. A press on the "Z" key produced a tone and moved the circle down one box; a press on the "/" key also produced a tone but moved the circle to the right one box. Pressing any other key had no programmed effect. When a point was earned, the matrix disappeared, a feedback tone was presented, and during the 2-s interval the current point total was shown with the message "ADD ONE POINT." Points were earned for sequences of key presses that moved the circle from the upper left-hand corner to the lower right-hand corner: eight-press combinations that contained four left (Z) presses and four right (/) presses. A fifth press on either key would immediately produce a blank white screen and a 2-s intertrial interval.

At the end of the session, the screen displayed the total points obtained and the message, "END OF ROUND [session number] PLEASE SEE EXPERIMENTER. "

Experimental conditions. The three experimental conditions differed only in the schedule of point delivery. For those in the FR 1 group, participants earned a point for any sequence of four left and four right key-presses. In the FR 2 condition, a point was earned on alternate trips through the matrix, and in the RR 2 condition, a random 50% of sequences received a point. In each case, participants were exposed to the same contingency in all five sessions of the experiment.

Rule statements. Rule statements describing the matrix task were requested in the form of performance descriptions. Following the fifth session, the participant was given a pen and a piece of paper with the question "What do you have to do to earn points?" written on it. Participants

were given as much time as they needed to write an answer to the question. Verbatim transcriptions of these responses are presented in the Appendix.

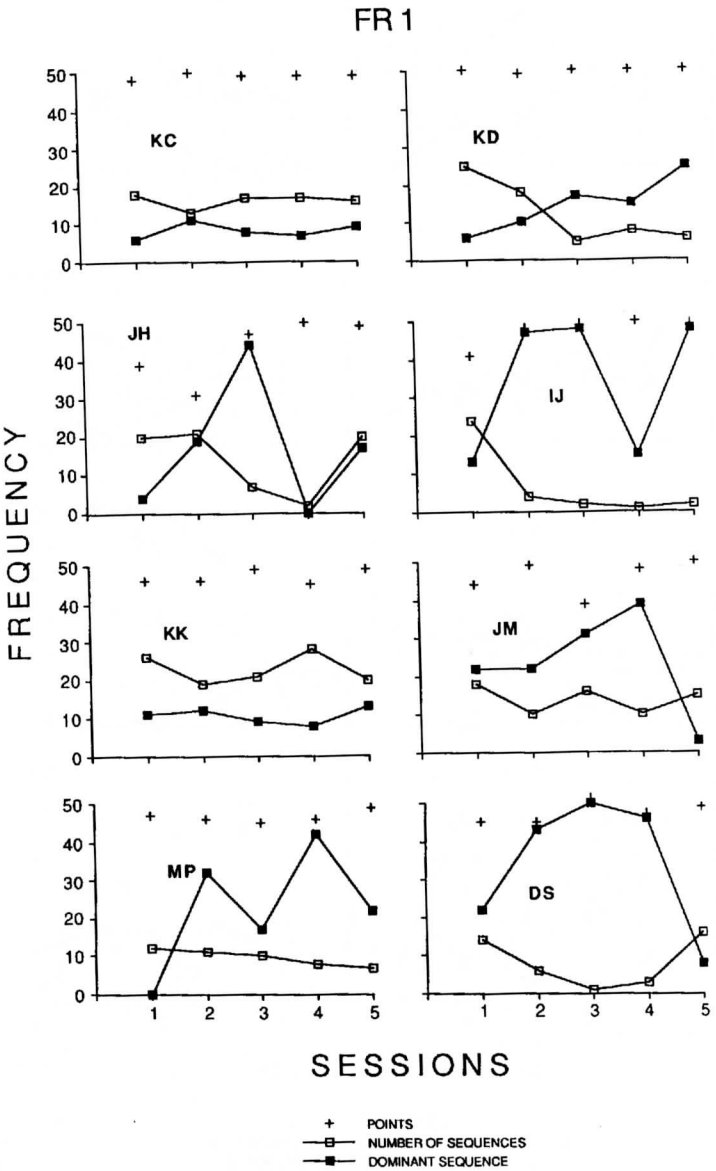

Figure 1. Individual plots of the key-pressing behavior of participants in the FR 1 group.

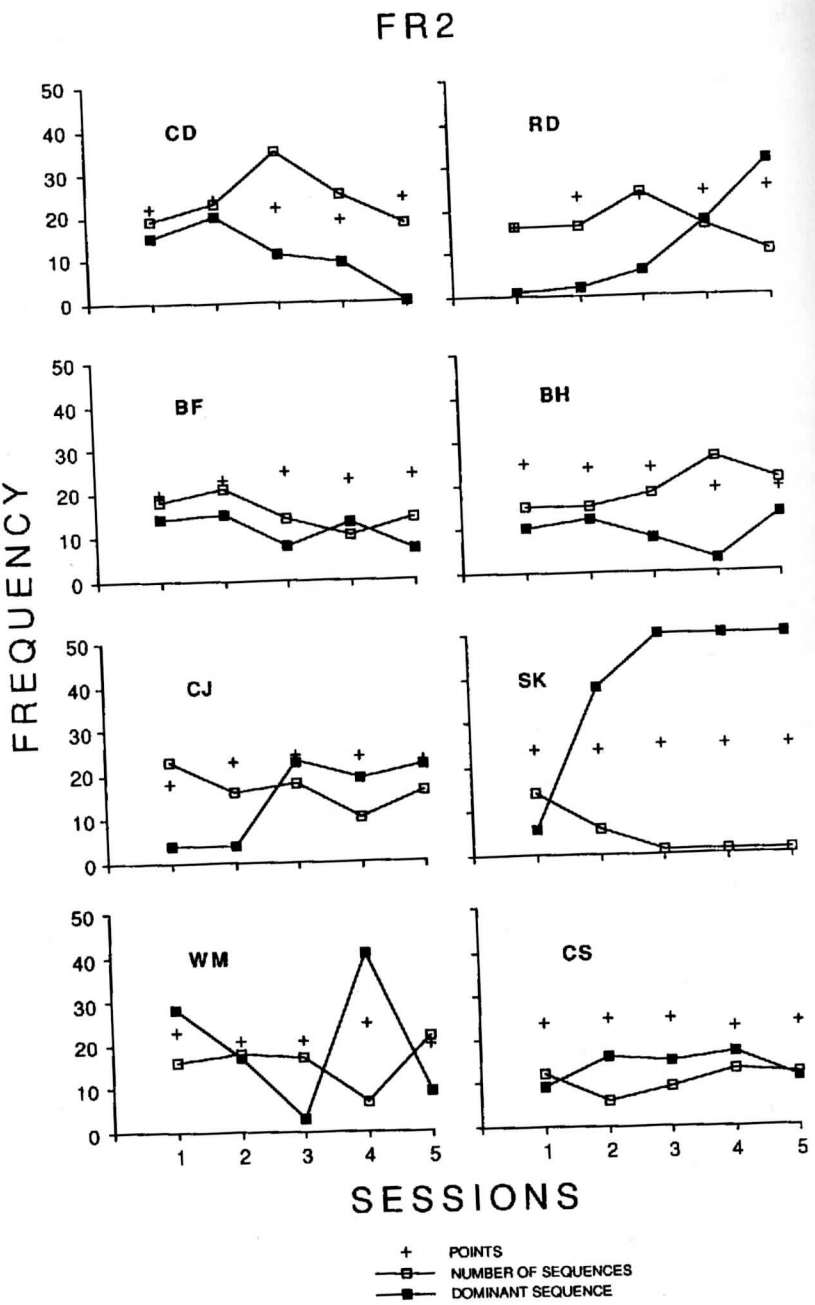

Figure 2. Individual plots of the key-pressing behavior of participants in the FR 2 group.

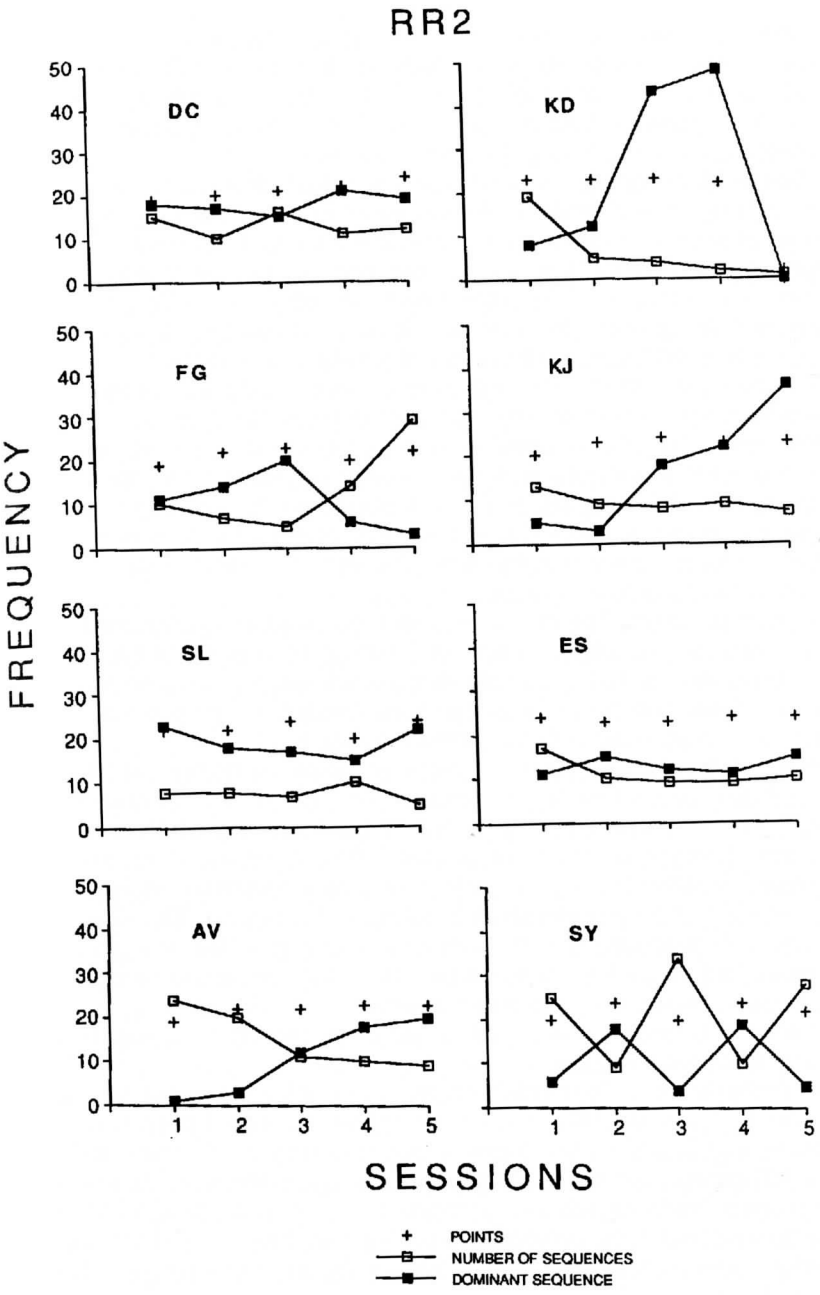

Figure 3. Individual plots of the key-pressing behavior of participants in the RR 2 group.

Results

Nonverbal behavior. Figures 1, 2, and 3 show individual graphs of the nonverbal behavior of participants in the FR 1, FR 2, and RR 2 conditions. The frequency of the dominant sequence adopted by each participant is indicated, as well as the total number of sequences used in each session and the total points per session.

Single factor analyses of variance revealed that participants in the three experimental conditions did not differ in either the total number of sequences used (summed across the five sessions) or the total frequency of participants' dominant sequences. This result indicates that the levels of behavioral variability and stereotypy in each group were equivalent. In addition, the number of points earned by participants in the FR 2 and RR 2 conditions were not significantly different.

Despite the lack of group differences, individual participants differed markedly in their levels of behavioral stereotypy. For example, in the FR 1 condition, IJ and DS showed relatively high levels of stereotypy, using their dominant sequences in over 80% of the trials of three sessions. In contrast, KC, JM, and especially KK showed relatively high levels of behavioral variability as indicated by higher numbers of sequences used in each session. Similar individual differences in stereotypy/variability can be seen in the other groups.

Verbal behavior. The students' written answers to the question "What do you have to do to earn points?" were categorized as either superstitious or nonsuperstitious. To be considered superstitious, a rule statement had to include at least one of the following characteristics: (a) mention of specific sequences or paths through the matrix that had to be used to earn a point, (b) mention of specific squares or areas of the matrix board that had to be entered, passed through, or avoided, or (c) mention of some other unprogrammed contingency (e.g., "you have to do pattern A on the first trial, then pattern B on the next one"). Based on these criteria, one participant from the FR 1 group (MP), two participants from the FR 2 group (CD and CS) and six participants from the RR 2 group (DC, FG, SL, AV, ES, and SY) produced superstitious rule statements. The specific results are presented in the Appendix. Verbal responses are labeled superstitious or nonsuperstitious, and superstitious statements are marked a, b, or c to indicate which criteria were met. In addition, the specific superstitious statements appear in italics.

A Fisher's Exact Test indicated that the number of superstitious rule statements in the two FR groups were not significantly different ($p = .40$); however, significantly more superstitious rule statements were observed in the RR group than in the FR groups ($p = .012$). Participants in the RR group also were significantly more likely to make statements of uncertainty about their solutions (e.g., "I never fully figured out when it would give me points") than participants in the other groups ($p = .013$).

Discussion

Using a task similar to the one used in this study, Schwartz (1982) found that reinforcement created behavioral stereotypy, which in turn was associated with inaccurate descriptions of the experimental contingencies. Several participants in the present investigation showed behavioral stereotypy (e.g., IJ, DS, SK, and KD), but in this case, stereotyped nonverbal behavior was not correlated with superstitious rule statements. Indeed the opposite relationship was seen in the RR group: Participants who produced nonsuperstitious rule statements had significantly *higher* levels of behavioral stereotypy (higher frequencies of dominant sequences), $t(6) = 3.50$, $p < .05$, $\omega^2 = .58$.

Consistent with the results of an earlier investigation (Vyse, 1991), the present study has shown that, when a problem solving task allows for behavioral variability, random consequences can engender superstitious descriptions of the environmental demands. The different results observed in the FR 2 and RR 2 conditions suggest that this effect is created by the inconsistency of consequences and not merely by their intermittency. Furthermore, these results were obtained under conditions in which the participants were instructed to find the rule and not to maximize points; thus, errors in rule discovery cannot be attributed to motivational conditions that favored nonverbal over verbal behavior. Because the experimental conditions did not provide motivation for earning points, it is not clear whether these superstitious rules would control nonverbal behavior. The present study represents an examination of rule generation rather than rule governance. However, previous research provides evidence that similarly generated superstitious rules can control nonverbal responding (e.g., Vyse, 1991).

Although behavioral variability may lead to more accurate rule generation in some operant contexts (e.g, Schwartz, 1982 and the present FR 1 contingency), it is poorly suited to others. The two participants in the RR condition who produced the highest frequencies of dominant sequences (greater behavioral stereotypy) also produced the only nonsuperstitious rule statements. In this condition, there were two sources of variability: the matrix of possible patterns (sequences) and the random schedule of point delivery. To be successful under these circumstances, the participants had to approach the task scientifically and hold one of these variables constant. The only way to do this was to adopt a stereotyped sequence of responses. Such a strategy eliminates the adventitious reinforcement of particular sequences and appears to make it more likely that random point delivery will be described as such.

SK's verbal response demonstrates a different relationship of behavioral stereotypy to problem solving. Under the FR 2 contingency, nonverbal behavior produced points that were intermittent but not random. Thus the only source of variability was produced by the matrix of possible response sequences. SK's written solution said:

> By round 2, I was moving the circle the same way every time. I gave up trying to find a pattern because I realized I was getting a point every other time, no matter how I moved the circle.

The plot of SK's key-pressing behavior is consistent with this report, showing higher levels of variability in the first two sessions and almost complete stereotypy after this point. Thus, in contrast to the RR condition, behavioral variability was associated with rule discovery, and (according to the participant's statement) behavioral stereotypy emerged after the solution had been found.

When a shaman's rain-making ritual is not followed by the end of a drought, sometimes the power of the shaman is questioned (as well it should be), but on other occasions, the failure is attributed to some error in the execution of the ritual (Falk, 1986). In our own, everyday lives we sometimes execute sequences of responses that are only inconsistently rewarded. Starting a car in cold weather, taking a college exam, rolling dice in a craps game, and buying a candy bar from a vending machine are all activities that involve a sequence of responses that may only be intermittently reinforced. If pulling the vending machine plunger does not result in the presentation of a candy bar, the disappointed consumer may attribute this failure to having inserted the coins too forcefully or not forcefully enough. The present study suggests that these inaccurate tacts—or, in cognitive terms, misattributions—are more likely when the consequences of nonverbal behavior are inconsistent and not merely intermittent.

Future research should proceed in two directions. First, investigations of other schedule parameters would establish whether, for example, richer and leaner schedules of random consequences control similarly inaccurate rule statements. In addition, the matrix task used in the current study is designed to allow response variability; however, it is unclear whether this is a necessary condition for the development of superstitious rules. Experimentation with different response requirements and discriminative stimuli would thus help to further specify the conditions for accurate and inaccurate rule discovery.

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Appendix

Verbatim Written Responses of Participants in Each Condition

[The participant's initials and the classification of the rule statement (superstitious/nonsuperstitious) are given at the beginning of each response. Where the contingency description is classified as superstitious, the superstitious statements are italicized and the criterion or criteria met are labeled a, b, or c. See text for further explanation.]

Fixed Ratio 1

DS—nonsuperstitious. To earn points I had to move the circle to the diagonally opposite square on the grid, in my sequence, as long as it got there. To do this I had to use the Z and slash (/) moved it down, these were the only directions I was able to move the circle.

KK—nonsuperstitious. You don't have to earn points. Because in order for the program to go on you can still clear the screen w/out gaining pts. It seems as though it is fixed just under a certain number of trials.

In order to earn a pt. you have to get to the lower right corner box without going off the screen.

KC—nonsuperstitious. To earn points you have to get the ball to the square that is in the right hand corner. You can do that by using the Z or the / in any combination, making sure that you don't go too far to the right or too far down or you don't receive a point. Every pattern I tested gave me a point when I reached the bottom right hand corner.

IJ—nonsuperstitious. You must progress from the upper left-hand corner of the grid to the lower right-hand corner by moving down and across—you may not go backwards horizontally or upwards vertically as this will mean a failure to earn points. In other words, once you reach the bottom of the grid and press the vertical key you lose. The same happens if you reach the far side and press the horizontal key.

JM—nonsuperstitious. You must move the circle that is in the top left hand corner of a 5 square x 5 square box into the bottom right corner. If you leave the 5 x 5 box at any time, you get no points. It does not matter in which direction or pattern that you use. You can only move down or right though. As soon as you maneuver the ball into the bottom right box, you get a point.

KD—nonsuperstitious. To earn points I had to move the circle from the top left hand corner of the 16-square grid to the bottom right hand corner. To do this, I used the 'Z' and the "/' keys—the 'Z' moved the circle down one space, and the '/' moved it to the right one space. I could not earn a point if I accidentally moved the circle off the grid.

MP—superstitious (b). Using the Z & / keys on the key board, I had to get the [circle] from the upper left hand corner of the 25 square grid to the lower right hand corner. The Z key moved the [circle] down & the / moved it to the right. *The upper right hand corner, and once the lower left hand corner were "out of bounds" and once the top 2 squares of the left hand column were "out" & I assumed the entire column was.* There were 2 patterns that consistently produced a point (Z/Z/Z/Z/ and /Z/Z/Z/Z). The patterns ZZ//ZZ// and //ZZ//ZZ worked as well, but I only used them in the last 2 sections. *There were sessions when the circle could not go in the "out of bounds" corners and any pattern that didn't involve them would result in a point.*

JH—nonsuperstitious. To earn points, you must move the circle from the upper left-hand corner of the grid to the lower right-hand corner of the grid, using the "Z" (down) and "/" keys. It does not matter what route you take to get to the lower-right square.

Fixed Ratio 2

RD—nonsuperstitious. The object which starts in the upper left hand corner has to be moved to the lower right-hand corner. You receive a point every other time the object reaches this corner.

CS—superstitious (a and c). You have to press the Z tab twice and then the / tab until you reach the last square on the bottom right hand corner of the grid.

When the next grid comes on you don't receive any pts. no matter what

pattern you type in (I tried all kinds of patterns but none of them worked). *Using a step pattern ([drawing of a staircase shape]) you start off by going down 2 boxes (by pressing the Z tab twice) then you go across one box (by pressing the / tab. Continue this pattern until you reach the bottom right hand square..*

On the 3rd grid you press the / tab twice and then the Z tab until you get to the bottom right hand corner. On the 4th grid you don't receive any pts. no matter what you do. *Using the step pattern ([drawing of a staircase shape]) you first go across 2 boxes (pressing the / tab twice) and then moving down one box (by pressing the Z tab once). You continue this pattern (2 across, 1 down) until you reach the bottom-right had corner box.*

Therefore, every other grid gets a point if you follow the above instructions.

SK—nonsuperstitious. I moved the circle from the starting square to the bottom right-hand square. Every other time I did this, I earned a point. At first I thought there was a set pattern, but by round 2, I was moving the circle the same way every time. I gave up trying to find a pattern because I realized I was getting a point every other time, no matter how I moved the circle.

BH—nonsuperstitious. To earn points, you have to move the cursor from the top left square down to the bottom right square two times. In other words, the first time you move the cursor there, there will be no apparent result, but the next time you will receive a point. It does not matter what pattern of movement you use to get there. If you move the cursor out of the box, never reaching the bottom right square, it will not count to get you points. But it will also not interfere in having to reach the bottom right two times. In other words, if you have reached the destination once already, you can go out of bounds as many times as you want, but the second time you reach the destination, you will receive the point.

You can move any way to get to the destination. It is merely getting there that will give you points. You need not repeat the same pattern both times to receive points.

At no time did I receive a point on the first try.

CD—superstitious (b and c). Every other screen there is the possibility of earning a point by going out in the bottom right corner either from the top or left side. *If you go from the left you have to land one the one above the left first then go down and right.* From the top you simply have to go down. *The two possibilities can be switched by going out on any of the right or bottom boxes.*

The computer is set up to do only one of the two possibilities at one time. To switch to the other choice you *can go out any of the boxes on the right side or bottom, excluding the bottom right corner.*

If I began using one pattern which worked in the beginning, it would work consistently. *However, I had no choice as to which pattern I began with. To switch patterns I had to go out either right side or the bottom.*

CJ—nonsuperstitious. To earn points you had to go from one corner to the other. This could be accomplished by pushing a series of keys down and over or over and down. It seemed that you could only earn pts. every other try. Also, if you went off the grid by pushing the wrong keys, you wouldn't score the next time. Any pattern really seemed to work scoring every other time. No matter what the pattern was you couldn't score every time.

WM—nonsuperstitious. You earn points by moving the "[circle]" to the lower (farthest) right hand corner of the grid. You must move the circle to this grid square twice to get a point. On the first time in a series the screen will disappear for a moment and it will appear that you will have to start over again. The sequence that I used to move the circle to the lower right grid square was not significant to getting the point.

BF—nonsuperstitious. No points are earned if you move off the board.

If piece is moved to lower right hand box, points are earned every other time piece is moved to that box. Pattern of moving piece to get to box is irrelevant; alternating keys, moving all the way across and then down (or vice versa) or any other pattern used in moving piece. No matter what path is taken to lower right hand box, points are earned on every other time box is reached.

Random Ratio 2

AV—superstitious (a and c). Go by a certain pattern. The patterns run in 4's. First one [drawing], then [drawing], then I don't know, then [drawing]. But it could be a certain key that needed to be hit every time. If you missed one then the pattern went on anyway. The pattern seemed to be running in 3's then in 4;s. I don't know if there was a real 3rd pattern solution. If I could have figured out the 3rd pattern I would get a pt. every time.

SL—superstitious (a). Get to the lower right hand corner, but there are many ways to get there and *you have to take the correct way to earn a point. Either [drawing] or [drawing] or [drawing] or [drawing] usually worked at some point. The most frequent was [drawing*]. Some times other patterns worked, but the 4 patterns above were easy to use consistently (easy path to remember) and one always worked.

ES—superstitious (c). I earned points by moving the [circle] from the top left hand corner to the bottom right hand corner. I tried many different lateral and horizontal combinations, some of which worked and some which didn't. *I am sure there was some specific method for when the cursor gave points and when it didn't,* but all I could tell was that it was a random process. *As long as I got it to the rt. hand corner and did something else it gave points.* I do not know what the something else was. *Sometimes I did a certain combination twice or did the opposite combinations and I got points for both.*

SY—superstitious (c). You have to move the circle from the starting corner to the opposite corner of the box using different patterns of movement to get there. *You have to move the circle on one half of the square to the opposite corner and the next time was to go on the other side of the square.* I received points for a certain pattern sometimes and other times I would not get points for the same pattern. Later the pattern could be used to get points. I never figured out exactly how to earn points.

FG—superstitious (c). Reach the lower right hand corner based on some sort of pattern, sometimes certain patterns worked sometimes they didn't. Whenever a point was scored I would repeat the pattern again until it stopped giving me points. I never fully figured out when it would give me points or not. *One of the patterns that I did find worked was to go through the following four steps [drawings of a sequence of four patterns].* However this was not always successful. Usually pattern 4 stopped before the other 3.

DC—superstitious (b). You must use the "/" key to move right, and the "Z" key to move down and maneuver the circle to the lower right corner, from the upper left one. Points are scored by moving into the square from the top or side, *and only one of those ways will score a point each round. There is only one way to get a point and it changes from each round. It could be gotten, for instance, by moving into the square from the side, in which case moving into it from the top that turn would have been incorrect. The next turn, the correct way could be to move in from the top, and not from the side. It was possible to have the correct way repeat itself in succession (i.e. correct way to get a point would be to go in from the side once, and the next round as well).* The sequencing of the

point scoring seemed to be random at most times and each time that a sequence seemed logical it would change back to being random again. For example, going in from the side twice, then from the side twice would all elicit a point, but then the sequence would change, and it was no longer possible to score points through that sequence.

KD—nonsuperstitious. To earn a point I moved the sphere from the upper left-hand corner to the lower right-hand corner. Every path that I made the sphere follow worked (earned a point) but not every time. The sum of all the failed attempts (going off the board by accident or just not earning a point at the lower right hand square) and all the points earned was 50 or 51.

I didn't earn a point every time. The relationship between points and failures wasn't constant. I counted the earned points and failures in an attempt to find a relationship. I didn't find one. The points earned and failures didn't seem to be related at all.

KJ—nonsuperstitious. I have absolutely no clue. Completely random—what I did to get points.