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BEHAVIORAL VARIABILITY AND RULE GENERATION: GENERAL, RESTRICTED, AND SUPERSTITIOUS CONTINGENCY STATEMENTS

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This study examined the contingency statements produced by uninstructed human subjects exposed to a task that assessed nonverbal response variability. College students earned points for sequences of eight presses distributed across two keys (four presses on each key). In Experiment 1, when all 70 possible sequences consistently produced points, subjects showed variable nonverbal behavior and wrote rule statements that did not confuse necessary and sufficient requirements. When only 15 of 70 sequences produced points, most subjects showed stereotyped key-pressing behavior and some confusion of necessary and sufficient requirements, reporting that between 1 and 4 sequences earned points. In Experiment 2, subjects were exposed to two conditions in which some sequences consistently earned points and the remaining sequences produced points on a random ratio 2 schedule. Most subjects showed stereotyped key pressing, but two subjects produced atypical patterns of nonverbal responding. With few exceptions, rule statements written at the end of the experiment either greatly underestimated the number of sequences that consistently produced points or made reference to contingencies that had not been programmed (e.g., trial-to-trial alternation of responses). Subjects who wrote superstitious rules showed schedule insensitivity indicative of verbal control.

When verbally competent humans are exposed to operant contingencies without benefit of instruction, they frequently generate verbal descriptions of the task at hand. These self-instructions or self-rules often show close correspondence to nonverbal responding (Catania & Cutts, 1963; Duvinsky & Poppen, 1982; Harzem, Lowe, & Bagshaw, 1978; Leander, Lippman, & Meyer, 1968; Lippman & Meyer, 1967), but in some cases, both verbal and nonverbal behavior are poorly controlled by environmental events. For example, Leander et al. (1968)

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found that 24% of subjects exposed to fixed-interval (FI) schedules responded at high rates and reported that reinforcement was dependent on a certain number of responses.

The relationship of self-instructions to nonverbal behavior has been interpreted in three ways. The cognitive view asserts that rules, hypotheses, and expectancies are the necessary determinants of nonverbal responding (Levine, 1975; Spielberger & DeNike, 1966). In contrast, some investigators have suggested that the self-generated rules recorded in studies of human operant behavior are mere "epiphenomena" and have no causal status (Baron & Galizio, 1983; Pouthas, Droit, Jacquet, & Wearden, 1990; Wearden, 1988). A third position, which could be labeled "interactionist," suggests that most subjects enter the human operant laboratory with extensive verbal and nonverbal repertoires and that behavior in one domain can occasion behavior in the other (Hineline & Wanchisen, 1989; Lowe, 1979). For example, Lowe (1979) argued that many unusual nonverbal performances observed in human operant experiments are difficult to explain without knowledge of the subject's self-instructions. Although a number of authors have concluded that verbal behavior generated by the subject can affect nonverbal responding (Lowe, 1979; Poppen, 1982; Zettle & Hayes, 1982), this controversy is far from resolved.

For a number of reasons, self-instructions have significant potential for the control of nonverbal behavior. First, in both its overt and covert forms, vocal behavior is of lower effort, and frequently shorter time course, than other forms. These characteristics facilitate the emergence of verbal behavior and make it likely to precede or occur concurrently with nonverbal responding. Second, most human subjects have extensive histories of reinforcement for rule following, under the control of both social consequences (pliance) and environmental events (tracking; Hayes, Zettle, & Rosenfarb, 1989). Investigations of externally provided instructions have demonstrated effects on the acquisition (Kaufman, Baron, & Kopp, 1966) and maintenance of behavior (Hayes, Brownstein, Haas, & Greenway, 1986; Kaufman et al., 1966; Shimoff, Catania, & Matthews, 1981). Finally, a number of social environments provide reinforcement for the generation and communication of contingency-specifying statements (Skinner, 1969, pp. 142-143).

The present research was aimed at identifying some of the environmental conditions and behavioral correlates associated with accurate and inaccurate rule-generation. A matrix task similar to that used in a number of other studies (Barrett, Deitz, Gaydos, & Quinn, 1987; Hayes et al., 1986; Schwartz, 1982b, 1988) was chosen because it allowed the presentation of a variety of experimental conditions. In an attempt to obtain rule statements that were both unconstrained (e.g., by forced choice questionnaires) and minimally affected by the social context of the experiment, verbal descriptions of the contingencies were recorded as written answers to the open-ended question, "What do you have to do to earn points?"

Experiment 1

Using a similar task, Schwartz (1982b) found that most subjects adopted a stereotyped pattern of responding and confused the necessary and sufficient requirements for reinforcement (i.e., subjects reported that a single response sequence produced points, when, in fact, several did). Experiment 1 was an attempt to replicate this finding and examine the circumstances associated with subject's confusion.

Method

Subjects

Six experimentally naive Connecticut College undergraduates were recruited from an Introductory Psychology course for a study in "problem solving." In exchange for participating, students received partial credit toward their course grades. Three subjects were women (S2, S3, and S5), and three men (S1, S4, and S6). The mean age was 19.4 years, $SD = 1.4$.

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 presented on the computer screen, and a 1-cm diameter circle appeared in one of the boxes.

Procedure

Six to eight 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 subject 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. You should try to earn as many points as possible. 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 subject 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 intertrial interval, the current point total was shown with the message "ADD ONE POINT." Points could be earned only for sequences of key presses that moved the circle from the upper left-hand 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 experiment consisted of two phases of three or four sessions each. In the first phase, any eight-press sequence that included equal numbers of left and right presses would produce a point (the "Any" condition). In the second phase, points were earned as in the earlier phase, with the added restriction that key-pressing sequences had to begin with two left presses (Z key) to obtain a point (the "LL" condition). Under these circumstances, 70 different sequences produced a point in the first phase, and 15 sequences produced a point in the second. Subjects were moved from Phase 1 to Phase 2 after obtaining 80% of the available reinforcements for three (S1) or four consecutive sessions.

Rule statements. Following each phase of the experiment, the experimenter entered the room and handed the subject a pen and a 21.6 cm x 14.0 cm piece of paper with the question "What do you have to do to earn points?" written on it. Subjects were given as much time as necessary to complete their answers. (Verbatim transcripts of the written statements from both experiments are presented in the Appendix.)

Results

The key-pressing behavior of each subject is summarized in Figure 1. The frequency of the dominant sequence for each phase is indicated, as well as the number of unique sequences used in each session. During the first phase of the experiment, all six subjects earned over 80% of the points possible in each session and showed relatively high levels of behavioral variability, averaging between 12.3 (S1) and 24.5 (S4) different sequences per session.

In the second phase, subjects showed greater levels of behavioral stereotypy, indicated by higher mean frequencies of their dominant sequences, $t(5) = 3.97$, $p < .05$, and fewer unique sequences per

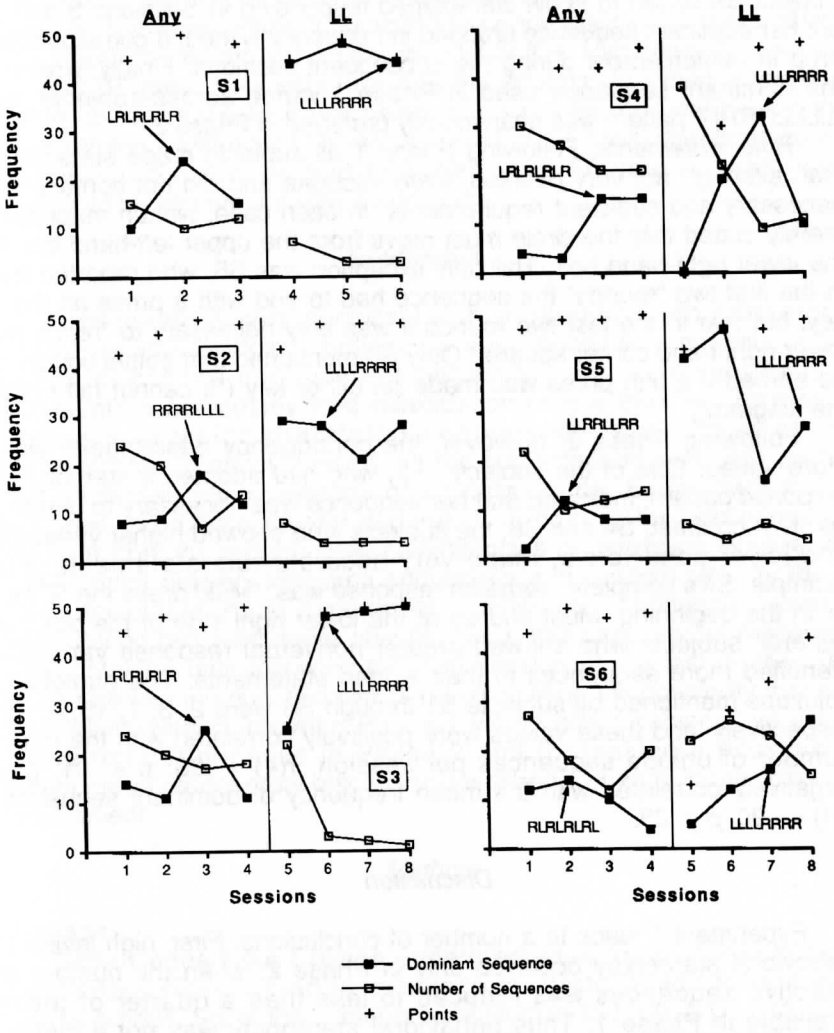

Figure 1. Individual plots of the key-pressing behavior of the six subjects in Experiment 1. Subjects' dominant sequences for each phase are identified.

session, $t(5) = 3.18$, $p < .05$, but there were wide individual differences, with subjects falling into three distinct categories. Subjects S1 and S3 adopted a highly stereotyped pattern of responding, using the "LLLLRRRR" sequence almost exclusively, and, in other than Session 5 for S3, both obtained over 80% of the points possible in the phase. In contrast, S4 and S6 earned few points in the early sessions of the second phase and showed relatively high levels of response variability. Finally, S2 and S5 achieved over 80% point levels in Phase 2 without (a) high behavioral variation or (b) exclusive use of a single sequence.

Subject S5 began to show stereotyped responding in Sessions 5 and 6, but her dominant sequence dropped in frequency without a corresponding drop in reinforcement during the subsequent sessions. Finally, whereas the dominant sequence used in Phase 1 varied across subjects, the "LLLLRRRR" pattern was unanimously preferred in Phase 2.

Rule statements. Following Phase 1 all subjects made statements that, although not very detailed, were accurate and did not confuse the necessary and sufficient requirements. In each case, written responses merely stated that the circle must move from the upper left-hand box to the lower right-hand box. The only exception was S5, who reported that in the first two "rounds" the sequence had to end with a press on the Z key, but that in the last two rounds it was only necessary to "reach the lower right hand corner square." Only S6 mentioned that points could not be earned if a fifth press was made on either key ("It cannot fall out of the diagram").

Following Phase 2, however, the contingency descriptions were more varied. One of the subjects, S3, who had adopted a stereotyped response pattern, indicated that her sequence was necessary to obtain a point. In contrast, S4 and S6, the subjects who showed higher variability and lower point totals, made very accurate rule statements. For example, S4's complete, verbatim response was: "Must press the 'Z' key 2x in the beginning. Must end up at the lower right side of the box." In general, subjects who showed greater nonverbal response variability identified more sequences in their written statements. The number of solutions mentioned by subjects S1 through S6 were 2, 3, 1, 15, 3, 15, respectively, and these values were positively correlated with the mean number of unique sequences per session, $r(4) = .98$, $p < .01$, and negatively correlated with the mean frequency of dominant sequence, $r(4) = -.90$, $p < .05$.

Discussion

Experiment 1 leads to a number of conclusions. First, high levels of behavioral stereotypy occurred only in Phase 2, when the number of effective sequences was reduced to less than a quarter of those available in Phase 1. Thus behavioral stereotypy was not a simple function of point delivery; rather, it was controlled by points earned in the context of a large number of sequences that did not produce points. All subjects lost some points at the beginning of the first phase when they made more than four left or right presses, but under this modest limitation subjects maintained high levels of variability. Only when the probability of point loss was increased in the initial-LL condition did a dominant response topography emerge.

Second, the present results are consistent with Schwartz's (1982b) finding that behavioral stereotypy was associated with contingency descriptions that confuse the sufficient and necessary requirements for reinforcement. In Phase 2, Subjects S1, S2, S3, and S5 were successful

in following the experimenter's instruction to earn as many points as possible, but when asked to describe the contingencies of the problem, they could do little more than describe what they had done. Conversely, S4 and S6 gave very accurate rule statements, but their nonverbal behavior appears to have been not strongly controlled by the experimenter's instruction. When reminded of the initial directions during debriefing, S4 said he had forgotten, and S6 said he was more interested in "figuring out how it worked."

Experiment 2

Experiment 1 was successful in producing both behavioral stereotypy and restricted contingency descriptions in a majority of the subjects, but the confusion of necessary and sufficient causes represents a particularly mild dissociation of rule from environmental demands in which the stated contingency is a subset of the contingencies in effect. Indeed, all the subjects achieved high scores and described valid methods of earning points. Experiment 2 was designed to produce greater separation of both verbal and nonverbal behavior from the programmed contingencies by arranging fixed-ratio 1 (FR 1) point delivery for some sequences and random-ratio 2 (RR 2) points for others. As in Experiment 1, different contingencies were in effect during two successive phases, but in this case, verbal responses were obtained only following the final session of the last phase. This procedure had the dual purpose of (a) eliminating the possibility that rule statements written following Phase 1 would affect subjects' verbal or nonverbal performance in Phase 2 and (b) making it possible to determine whether verbal responses described a change in the schedule requirement.

Method

Subjects

Eight Connecticut College undergraduates from an Introductory Psychology class served in exchange for partial credit toward their course grades. Six of the subjects were women (S8, S9, S11, S12, S13, and S15), and two men (S10 and S14). The mean age was 19.2 years, $SD = 0.8$.

Setting Apparatus

The apparatus and experimental space were the same as in Experiment 1.

Procedure

Each subject completed a total of eight to ten sessions on a single day. Instructions were the same as those used in Experiment 1, and they were presented in identical fashion. The basic operation of the computer

(i.e., trial sequence, point delivery, and intertrial interval) was unchanged. Each session lasted 50 trials.

Experimental conditions. The experiment consisted of two phases of three to six sessions each. Subjects were moved from Phase 1 to Phase 2 when they had completed at least four sessions and had received over 80% of the total possible points in at least two sessions.

In Phase 1, the "LL50" condition was in effect. This produced a point for any eight-press sequence that contained equal numbers of left (Z) and right (/) presses and began with two left presses. Any sequence that did not begin with two left presses but met the requirements of the "Any" condition was awarded a point on a random 50% of all trials (RR 2). This condition provided a FR 1 schedule for 15 sequences and a RR 2 schedule for 55 sequences.

In Phase 2, the contingencies were the same as in the previous phase except that to receive consistent point delivery, the first two presses in a sequence had to be a left followed by a right. This "LR50" condition arranged FR 1 points for 20 sequences and RR 2 points for 50 sequences.

Rule statements. The procedure for obtaining subjects' rule statements was exactly the same as in Experiment 1, but in this case, verbal responses were collected only following the final session of Phase 2.

Results

The nonverbal responding of each subject is summarized in Figure 2. All eight subjects met the requirements for moving to Phase 2 within six sessions, and all but S9 attained point levels of over 80% by the final session of Phase 2.

The addition of the RR 2 contingency for sequences that did not meet the LL contingency in Experiment 2 did not affect the level of behavioral stereotypy observed in subjects' key-pressing responses. Comparisons of Experiment 1 Phase 2 and Experiment 2 Phase 1 failed to reveal significant differences in the mean number of points, $t(12) = 0.45$, $p > .05$; unique sequences, $t(12) = 0.27$, $p > .05$; or dominant sequences, $t(12) = 0.12$, $p > .05$. Again, however, there were wide individual differences. Stereotyped behavior emerged in six of the eight subjects (S8 through S13) by the end of Phase 1. Subject S14 had more moderate levels of stereotypy, and S15 produced an unusual pattern of responding that will be discussed later. The LLLLRRRR sequence was dominant for most subjects, but S11 and S15 adopted the LLRLRLRR and LLLRRRLR sequences, respectively.

Most subjects maintained high point levels after the change to LR50, but three of the subjects (S9, S14, and S15) dropped below 40 points in the early sessions of Phase 2. Of these, S14 and S15 returned to high point levels over the following sessions, but S9 showed a stable pattern of earning approximately half the total points available.

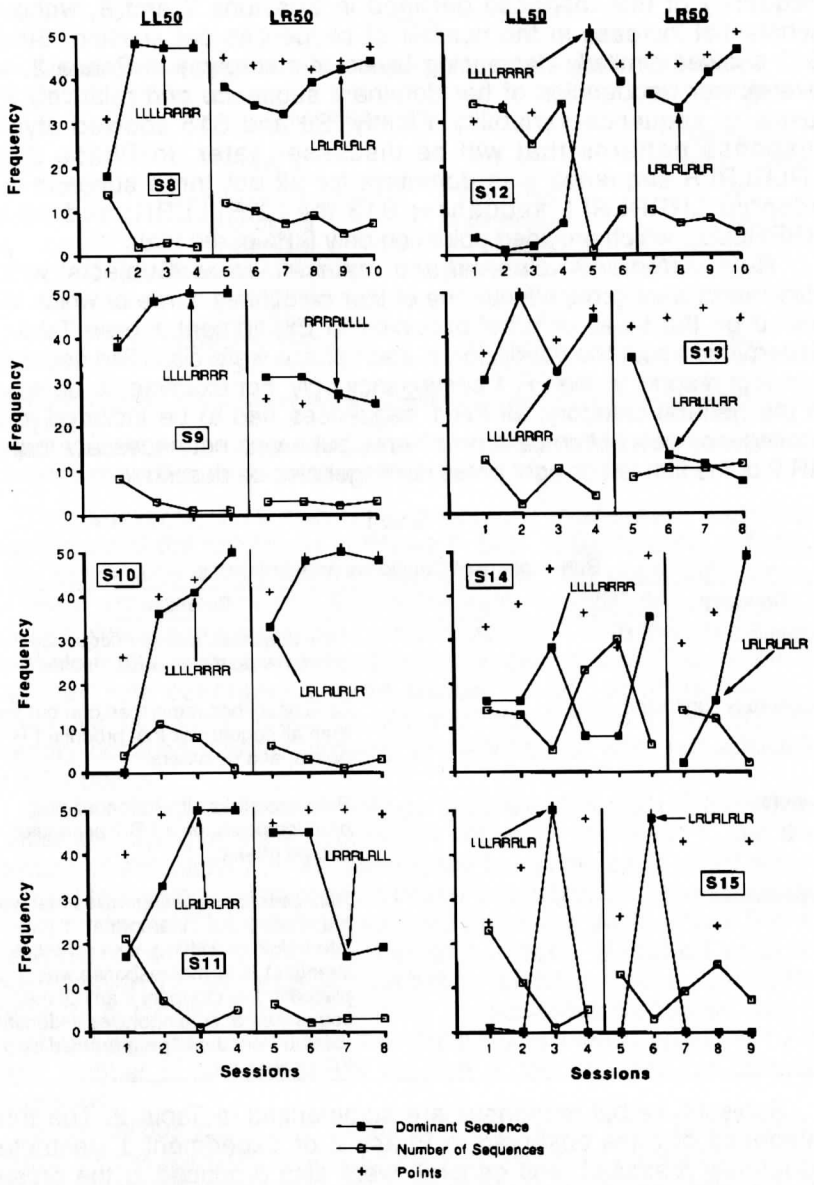

Figure 2. Individual plots of the key-pressing behavior of the eight subjects in Experiment 2. Subjects' dominant sequences for each phase are identified.

Behavioral stereotypy was evident in the key-pressing behavior of three subjects (S8, S10, and S14) during Phase 2. Subject S11 adopted a single dominant sequence in the early sessions of the phase, but the

frequency of this response declined in Sessions 7 and 8, without a substantial increase in the number of sequences per session. Subject S13 showed similarly decreasing levels of stereotypy in Phase 2, with even lower frequencies of her dominant sequence and relatively high levels of sequence variability. Finally, S9 and S15 showed atypical response patterns that will be discussed later. In Phase 2, the LRLRLRLR sequence was dominant for all but three subjects: S11 adopted LRRRLRLL sequence; S13 the LRRLLLRR; and S9 the RRRRLLLL, which provided points on only 50% of the trials.

Rule statements: General and restricted rules. Subjects' written statements were grouped into one of four categories, three of which were based on the types of rules observed in Experiment 1 (see Table 1). Statements about the conditions in each phase were classified separately and with respect to the FR 1 contingency only. For example, to be scored in the general category, all FR 1 sequences had to be included in the contingency description (and no others), but it was not necessary that the RR 2 or the fifth-left-or-right-press contingencies be described.

Table 1

Rule Statement Categories and Definitions

Category	Definition
Restricted	Rule describes a single sequence that produces points on a FR 1 schedule.
Moderately Restricted	Rule describes more than one but fewer than all sequences that produce FR 1 points, and no others.
General	Rule describes all sequences that produce points on a FR 1 schedule, and no others.
Superstitious	Rule describes contingencies that were not in effect (i.e., trial-to-trial alternation or within-phase schedule changes). A verbal response was placed in this category if any of the sequences or contingencies it identified differed from those programmed by the FR 1 schedule.

Subjects' verbal responses are summarized in Table 2. The three categories of rules observed in Phase 2 of Experiment 1 (restricted, moderately restricted, and general) were also produced in the present experiment. Although a greater proportion of subjects produced restricted rule statements than in Phase 2 of Experiment 1, this comparison was not statistically significant (Fisher's Exact $p = .30$). In each case subjects who produced restricted rules identified the LLLLRRRR sequence in Phase 1 and the LRLRLRLR sequence in Phase 2.

Table 2

Classification of Subject's Verbal Responses for Each Phase of Experiment 2

Subject	Rule Statements		Mention of Condition Change
	Phase 1	Phase 2	
S8	Superstitious/Restricted[a]	Restricted	Yes
S9	Restricted	Superstitious[b]	Yes
S10	Restricted	Superstitious	Yes
S11	Moderately Restricted	Superstitious	Yes
S12	Restricted	Restricted	Yes
S13	Restricted	General	Yes
S14	Moderately Restricted	Restricted	Yes
S15	Superstitious	Superstitious	No

[a]Described a pattern of alternating sequences early in Phase 1 and a single sequence later in the phase.
[b]Subject S9 wrote that she "couldn't figure out what the correct sequence was." and then described a contingency involving trial-to-trial alternation.

Two subjects, S11 and S14, produced moderately restricted descriptions of the conditions in Phase 1. Both subjects drew a diagram of the matrix with a diagonal line extending from the upper left corner to the lower right and indicated that in the early "rounds" the circle had to remain below the diagonal line. Furthermore, S11 wrote that, in Phase 2, the circle had to stay above the diagonal to earn points. The "below the diagonal" rule describes a large subset (11 of 15) of the initial-LL sequences, but S11's "above the diagonal" rule fell into the superstitious category because it included many sequences that were not scheduled for FR 1 points.

Subject S13 produced the only general rule statement in Experiment 2. After identifying only the LLLLRRRR sequence for Phase 1, she drew a picture of the matrix with Xs marking the boxes the circle could enter in the "next few rounds." The marked boxes incorporated all the sequences programmed for FR 1 point delivery and no others. As in Phase 2 of the previous experiment, the number of correctly identified solutions encompassed the full range of possibilities (cf. S8 in Phase 1 and S13 in Phase 2), but in this case, the number of sequences mentioned was not correlated with the variability of key-pressing as measured either by the mean number of sequences per session or the frequency of dominant sequences.

Superstitious rules. In contrast with the results from Experiment 1, several of the subjects in this experiment reported superstitious rules describing contingencies that were not in effect. Three subjects, S8, S9, and S10, indicated that points were earned through a pattern of alternating sequences. Subject S8 began with a superstitious performance description for Phase 1, followed by a restricted one:

> For a few rounds, I had to go straight across and then straight down and then the next time, straight down and then straight

> across. After a while, to earn a point it was only necessary to move the circle straight down and then straight across.

In Sessions 2 through 4, S8 used the LLLLRRRR response almost exclusively, but she produced this description of Session 1 despite (a) having received points for sequences other than LLLLRRRR and RRRRLLLL and (b) not receiving points for some RRRRLLLL sequences.

Subject S10's statement described a changing response requirement:

> In some rounds when a pattern is discovered it will work continuously for 50 times (i.e., [drawing of matrix with the LLLLRRRR sequence indicated]), but in other rounds I believe some key boxes must be hit and they alternate from time to time, making it almost unpredictable.

Subject S9 identified the LLLLRRRR sequence for Phase 1, then after indicating that she could not find the "correct sequence" in the other sessions, she wrote: "I either went down & then across or across and then down. The times in which I didn't score any points, I counted it as that I was supposed to have gone the other way." This statement suggests that a point could have been earned on every trial using either the LLLLRRRR sequence or the RRRRLLLL sequence, but that the correct sequence changed from trial to trial. In reality, under the LR50 condition, both these sequences were scheduled for RR 2 point delivery.

Subject S9's case is particularly noteworthy because her point totals dropped from a perfect 50 at the end of Phase 1 to 26 for the first session of Phase 2 and remained at approximately this level through the four sessions of Phase 2. A trial-by-trial analysis of S9's performance indicated that, in the 200 trials of Phase 2, only three responses were not either the LLLLRRRR or the RRRRLLLL sequence. At the start of the first session of the phase, she produced an RLLLLRRR sequence followed by an LLLLRRRR and did not receive a point for either one. Beginning on the third trial, she adopted a pattern of irregular alternation between the LLLLRRRR and RRRRLLLL responses that continued (with two exceptions) through the end of the experiment, despite continued low earnings.

The most unusual results were obtained for S15. Her complete written response was:

> Figure out the pattern. For example, down 2 over 3 down 1 over 1 down 1 would be a pattern. I wasn't sure if the numbers necessarily added up to equal each other but there was a set pattern of how to get from the top corner to the bottom corner. The pattern changed for each round. Down 1 over 4 down 3. For each round 1 pattern worked consistently.

To examine further the relationship of S15's verbal and nonverbal behavior, the frequency of her dominant sequence within sessions was calculated and plotted in the Figure 3. Congruent with her verbal report, S15 produced a different dominant sequence in each session. This was the only subject whose written statement did not mention a change in conditions that corresponded with the transition to Phase 2, but in six of nine sessions the initial key presses of her most frequent response sequence matched the contingencies in effect. When the dominant sequence came under the RR 2 schedule, her point total dropped accordingly (cf. Session 5 in Figures 2 and 3).

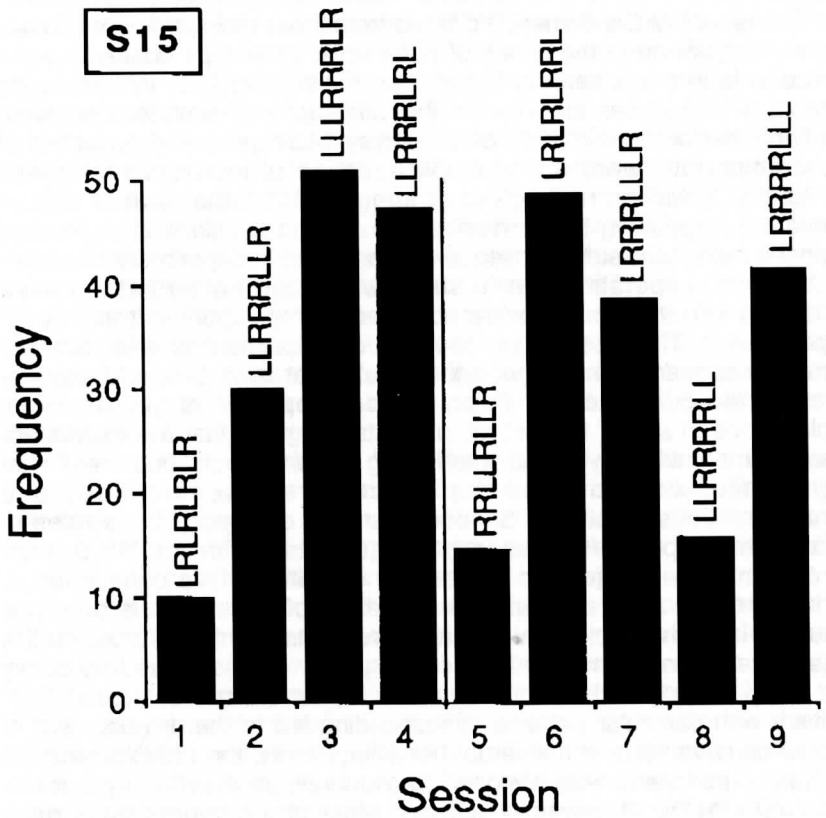

Figure 3. The frequency of S15's dominant sequence for each session of Experiment 2. The dominant sequence for each session appears above the session bar.

A trial-by-trial analysis of S15's first two sessions revealed that her nonverbal behavior was in accordance with her stated rule by the beginning of the second session. In Session 1, S15 received 25 points, nine of which were for sequences that met the initial-LL requirement. Of these nine, the majority (six) were LLRRLLRR responses; however,

points were awarded for three other sequences that met the FR 1 requirement. She ended the session with four initial-LL sequences: a LLRRLRLR, followed by three LLRRLLRRs. Despite this history of contact with the FR 1 contingency, in Session 2, S15 did not emit any of the four types of LL sequences observed in the previous session. In fact, the LLRRLLRR response did not emerge again until Session 8, at which point it fell under the RR 2 contingency. Such a pattern of nonverbal behavior is difficult to explain without reference to rule governance.

Discussion

The results of Experiment 2 differed from those of Experiment 1 in two ways. First, although the levels of behavioral stereotypy observed were comparable to those seen in Phase 2 of Experiment 1, in this case, the number of sequences identified in the subjects' written statements were not correlated with their levels of stereotypy. More general descriptions of the contingency were not a simple function of increased response variability. This contrasting result suggests that the relationship of nonverbal responding to the number of reported solutions is dependent upon the more consistent consequences provided in Experiment 1.

Second, superstitious rule statements (and nonverbal behavior consistent with those rules) were observed in this experiment and not in Experiment 1. This dissociation of verbal descriptions and environmental demands appears to have been the result of at least two, and possibly three, interacting factors. First, the development of superstitious explanations in some, but not all, subjects suggests that the individual's preexperimental history was a determining influence, but it is unclear what experiences contribute to the generation of superstitious and nonsuperstitious solutions. Second, the lack of superstitious rules in Phase 2 of Experiment 1 suggests that contact with the RR 2 point contingency was a second necessary condition. This conclusion is consistent with the traditional interpretation of superstitious behavior resulting from the accidental pairing of response and reinforcer. In the present case, under the RR 2 schedule, points were delivered randomly and independently of the sequences emitted, but the coincidence of point delivery with particular patterns of responding led to the development of superstitious verbal and nonverbal behavior. Finally, the matrix task used in these experiments was designed to allow response variability, but it is not clear whether this was necessary. Most of the superstitious rules observed in Experiment 2 made reference to changing sequence patterns, yet subjects responding on a simple telegraph key for RR 2 points under similar stimulus, instructional, and rule-reporting conditions might develop superstitions of different shapes (e.g., making reference to the timing or force of key presses). Additional research is needed to isolate the variables that control the development of these forms of verbal and nonverbal behavior.

General Discussion

The Causal Status of Self-Rules

The present experiments have identified some of the conditions under which general, restricted, and superstitious rules can be obtained; however, the causal status of these self-instructions remains unclear. Furthermore, because verbal responses were recorded in a postexperimental questionnaire, there is no direct evidence that these rules existed, in any form, at earlier points in the experiment. The central scientific problem stems from the fact that self-instructions are a dependent variable and, therefore, are not subject to direct manipulation. The environmental context can affect the form of rule produced, but the two will always be confounded. As a result, a philosophy of science that reserves causal attribution for variables that have been independently manipulated presents a substantial obstacle for the study of self-instruction.

Some recent investigations have attempted to establish the functional status of self-rules by showing that verbal behavior emerged prior to corresponding nonverbal behavior (e.g., Wearden, 1988); however, this strategy ignores the relative time course of verbal and nonverbal responses. The low effort and short latency of speech, for example, ensure that it will emerge in advance of many other forms of behavior, but its temporal priority does not make it a controlling variable. For example, if deprived of food for several hours, one may begin to think and talk about going to lunch before actually walking out the door, but the eventual correspondence between verbal and nonverbal behavior is not a function of self-instructional control.

These technical problems notwithstanding, the present investigation provides some evidence for control by self-generated rules. The proof is based on (a) an analysis of differences among individuals and species and (b) the cautious affirmation of the consequent. Although the nature of the subject matter makes these methods necessary, the approach is not without pitfalls. For example, it has recently been demonstrated that the "discrepant" high rate performances of human subjects under fixed-interval schedules of reinforcement can be produced in rats with a history of variable-ratio reinforcement (Wanchisen, Tatham, & Mooney, 1989).

In the present investigation, there was little evidence that the nonverbal behavior of subjects who made restricted and moderately restricted contingency statements was rule-governed. Because these individuals produced nonverbal behavior that was consistent with that of nonhuman species (Schwartz, 1982a), it is impossible to determine whether their key pressing was rule governed or contingency shaped. Even those subjects in Experiment 2 who showed more variable key pressing (e.g., S12 in Phase 1) may have exhibited control by self-instruction or by contingencies that exerted weaker discriminative control than those of Experiment 1.

When subjects produced general rule statements in the second phase of Experiment 1 and in Experiment 2, their behavior appears to

have been motivated by something other than the instruction to maximize points. In some cases, key pressing may have been rule governed, but the rules were probably strategies for testing the contingencies (e.g., systematically trying every path through the matrix) and, as such, went undetected in the questionnaire.

The strongest evidence for rule governance comes from the superstitious performances observed in Experiment 2. Individual subjects pressed the left and right keys in a manner that was both consistent with their verbal statements and inconsistent with what would be expected from nonhuman subjects under similar conditions. Subjects S9 and S15 provide the clearest examples.

Subject S9's nonverbal behavior did not make contact with the FR 1 contingency in Phase 2 of Experiment 2, and, not surprisingly, her verbal response did not describe any aspect of it. What is unusual is the lack of variability in her behavior at the beginning of Phase 2. Following experience with continuous reinforcement, nonhuman species typically show increased variability after a shift to extinction or intermittent reinforcement (Antonitis, 1951; Eckerman & Lanson, 1969). Consistent with this finding, most of the data presented in Figure 2 indicate a negative relationship between total points and the number of unique sequences produced. In contrast, at the beginning of Phase 2, S9 shifted almost immediately from exclusive use of the LLLLRRRR sequence to the alternating LLLLRRRR/RRRRLLLL pattern outlined previously. This rapid movement from one stable topography to another was maintained despite a 50% decrease in point earnings.

Subjects S9's highly stereotyped performance in Phase 1 makes it possible that her Phase 2 key pressing was caused by a form of behavioral momentum; however, this view is weakened by the observation that several subjects who experienced less drastic point losses showed both stereotyped behavior in Phase 1 and increased variability at the beginning of Phase 2 (e.g., S8 and S10). It is more likely that S9's nonverbal behavior was rule governed. In a study of the effects of externally provided instructions, Hayes et al. (1986) suggested that insensitivity to changing contingencies represented evidence of verbal control. Subject S9 demonstrated a similar insensitivity, but in this case, the instructions were self-generated.

Subject S15's behavior contradicted operant psychology's most basic principle: the Law of Effect. A response that produces a reinforcing stimulus should become more probable, but in her case, a sequence that produced points in one session became extremely improbable in the next. At the same time, it is obvious that points were sufficiently reinforcing to maintain a complex pattern of nonverbal responding. Again, it is difficult to explain this behavior without reference to rule governance.

Reinforcement and Rule Learning

It has been suggested that reinforcement impedes the learning of concepts because it produces behavioral stereotypy and restricted rules (Schwartz, 1982b); however, in the present experiments there was no

explicit incentive to learn the general rule. It might be argued that under changing conditions (e.g., if the current dominant sequence stopped producing points) subjects who identified only a single solution would adapt more slowly than subjects who had formulated a more complete rule, but additional research is needed to establish the validity of this view. Furthermore, subjects who produced stereotyped response patterns were relatively efficient: obtaining high point totals while expending little psychological effort (e.g., remembering what previous sequences have been used). This is arguably a superior adaptation to the experimental demands. In contrast, general rule statements were obtained only when (a) the threat of point loss was minimal (Experiment 1, Phase 1) or (b) control by the instruction to maximize points was weak.

Conclusion

Although the study of rule-governed behavior is a relatively new subfield of behavior analytic research, our current understanding suggests that verbal control of human nonverbal behavior is both powerful and pervasive. To date, most studies have examined the effects of externally provided instructions, but in everyday contexts, both children and adults often approach tasks without benefit of such instruction. The challenge for behavior analysis is to determine (a) what circumstances lead to the generation of rules of various forms and (b) what effect, if any, these verbal responses have on nonverbal behavior.

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Appendix
Verbatim Verbal Reports

Experimental 1 Phase 1

S1 You must move the symbol by using keys on computer to the bottom right square.

S2 There was a 16-box square. "Z" made the circular indicator go down "/" made the circular indicator go right. To get points, the circular indicator had to end up in the lower right hand corner.

S3 When the circle appears in the top left hand corner, I in turn have to get the circle down to the bottom right hand corner of the box.

S4 Go to the bottom right hand corner box.

S5 For the 1st two rounds you have to let the small circle reach the lower right hand corner through the square on the left side of the corner square, not the the above square. [Drawing of the matrix with an arrow pointing into the lower right hand box from the box to the left.] for the last two (3 & 4) rounds, just try to reach the lower right hand corner square. [Drawing of matrix with arrows pointing into the lower right hand box from both the box above and the box to the left.]

S6 Make sure the circle reaches the square in opposite end of the diagram. It cannot fall out of the diagram. If it does, no credit is given.

Experiment 1 Phase 2

S1 Using computer keyboard keys, one must go down far left column and toward the right on the bottom horizontal column to the far right bottom corner. One alternate way—travel through third down, 1 right, 1 down (to bottom) then to far right column.

S2 The "Z" & "/" are used for down & right. To get points, move indicator in an "L" shape. Or move indicator down to the 3rd square on the left side, then carry it across, then down 2 boxes or move the indicator down to the 4th square on the left side, then carry it across, then down one box.

S3 Move the circle down f/ the top left corner to the bottom left corner and across to the bottom right corner of the box.

S4 Must press the 'Z' button 2x in the beginning. Must end up at the lower right side box.

S5 1st & 2nd [picture of matrix with the LLLLRRRR path drawn in] the only way. 3rd & 4th [three drawings of the matrix, one each depicting the LLLLRRRR, the LLLRLRRR, and the LLRRLLRR paths, respectively] three ways.

S6 As before, the circle must reach the opposite end of the diagram, but in its path to the appointed place it must enter any one of the three bottom left squares. [Drawing of the matrix with Xs drawn in the bottom three boxes of the far left column of boxes. Note: This is an accurate description of the LL contingency in effect.]

Experiment 2

S8 Get the circle to the opposite corner (on a diagonal) the way the computer wants you to. For a few rounds, I had to go straight across and then straight down and then the next time, straight down and then straight across. After a while, to earn a point it was only necessary to move the circle straight down and then straight across. For about the last 5 rounds, alternating down, to the right, down, to the right (etc.) would earn a point.

S9 Press the "Z" & "/" buttons the correct sequence. In the 1st 3 trials the "Z" had to be pressed 4 times and then the "/" 4 times. In the other trials, I couldn't figure out what the correct sequence was.

I either went down & then across or across and then down. The times in which I didn't score any points, I counted it as that I was supposed to have gone the other way.

S10 To earn points—or at least one point—I'm not sure if there is a way to earn more than one point in a trial but... You must maneuver the ball on the grid so that it ends up in the opposite corner. In some rounds when a pattern is discovered it will work continuously for 50 times (i.e., [drawing of matrix with the LLLLRRRR sequence indicated]), but in other rounds I believe some key boxes must be hit and they alternate from time to time making it almost unpredictable. I just found a pattern that worked and stuck with it each round.

S11 Well, you have to get from the upper left hand corner to the lower right hand corner. I know that I passed through 8 boxes to do this, but I'm not sure if you could do it in less. For the first half it seemed like you had to move the circle below the "diagonal." For the second half you had to move above it. [Drawing of the matrix with a dotted line extending diagonally from the upper right to the lower left corner.]

S12 Use alternate figures, first Z then /. First 2 I could not figure out a pattern. Then 4 down, 4 across worked for a while. There may have been others that worked.

S13 To go from the starting corner to the lower right corner skipping some boxes that when you pass through them you will not be able to earn any points regardless of whether or not you reach the lower right corner. First few rounds: [Drawing of matrix with the LLLLRRRR and RRRRLLLL sequences filled in with Xs.] The pattern [LLLLRRRR] was always earning pts. The pattern [RRRRLLLL] was not always earning pts. Next few rounds [Drawing of the matrix with Xs in all the boxes that could be entered while still satisfying the initial-LR contingency.]

S14 On the grid, one had to reach the box in the lower right hand corner by following a specific pattern chosen by the computer. With the first five trials, and pattern using the lower left hand square [drawing of the matrix with a shaded area below a diagonal line extending from the upper left-hand corner to the lower right.] would insure a point and patterns using the other squares would sometimes insure a point. For the last trials this did not hold to be true. The only sure pattern was [LRLRLRLR].

S15 Figure out the pattern. For example down 2 over 3 down 1 over 1 down 1 would be a pattern. I wasn't sure if the number necessarily added up to equal each other but there was a set pattern of how to get from the top corner to the bottom corner. The pattern changed for each round. Down 1 over 4 down 3. For each round 1 pattern worked consistently.