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EFFECTS OF SELF-GENERATED RULES ON THE DEVELOPMENT OF SCHEDULE-CONTROLLED BEHAVIOR

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College students responded under a multiple differential-reinforcement-of-low-rate 5-s fixed-ratio 8 schedule, with components alternating every 2 min. After 40 programmed minutes of acquisition and 12 min of maintenance, without notice, both schedules changed to extinction for 28 min. During acquisition, between alternations of the multiple schedule, some subjects were asked to develop rules describing the schedule contingencies. Other subjects were given these same rules between alternations, and a third group neither received nor were asked to develop rules. By the end of the acquisition phase, self-generated-rule subjects were more likely to show schedule-typical behavior than were subjects not asked to generate rules. The behavior of those given rules was similar to those asked to generate rules at the end of acquisition, but yoked-rule subjects acquired schedule-typical behavior at a quicker rate. By the end of extinction, during the period corresponding to the previous fixed-ratio interval, all no-rule subjects who had earned points during acquisition and maintenance were responding at a rate of less than 30 responses per minute. Only 3 of the 9 self-generated-rule subjects and 2 of the 5 yoked-rule subjects were similarly responding at this low rate. Results suggest that asking subjects to develop self-rules facilitates acquisition, but can retard extinction. Results also suggest that self-generated rules function similarly to external rules.

Key words: self-rules, verbal behavior, rule-governed behavior, sensitivity to contingencies, multiple schedule, button press, adult humans

The role of self-instructions in the development and maintenance of human operant behavior has been difficult to characterize. On the one hand, some have argued that human and nonhuman behavioral differences are due primarily to the effects of verbal behavior on learning and performance (e.g., Lowe, 1979, 1983). On the other hand, others have stated that self-instructions are often a reflection of environmental relationships and thus may simply be a by-product of other controlling variables (e.g., Perone, Galizio, & Baron, 1988; Rachlin, 1977). Private verbal behavior is especially problematic in this regard. It is unrecorded, it is the product of an unknown history, and it is controlled by unspecified contingencies (Catania, Matthews, & Shimoff, 1982).

Anecdotal evidence suggests that self-instructions may serve to facilitate the solution of complex problems. Teachers frequently tell their students to solve problems by "thinking about the problem." Parents admonish their children to "think about what I have just said" when they want their children's behavior to come under their verbal control. Clinicians will tell their clients to "think about what has happened" to help their clients' behavior come under the control of complex social contingencies. And researchers will often "brainstorm" a problem in order to generate new hypotheses or ideas. Yet, in spite of the anecdotal evidence suggesting that the development of self-rules about complex problems helps to solve those problems, there are little empirical data on the issue.

It seems clear that external instructions or rules can rapidly establish new performance. This new performance may be established more rapidly than behavior that is gradually shaped through nonverbal contingencies of reinforcement (e.g., Ayllon & Azrin, 1964; Galizio,

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1979; Hayes, Brownstein, Haas, & Greenway, 1986; Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; Kaufman, Baron, & Kopp, 1966). Yet external rules often lead to an insensitivity to changing contingencies. Behavior under the control of instructions may not change when contingencies change, even when the behavior has made contact with those contingencies (e.g., Baron, Kaufman, & Stauber, 1969; Buskist & Miller, 1986; Harzem, Lowe, & Bagshaw, 1978; Hayes, Brownstein, Haas, & Greenway, 1986; Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; LeFrancois, Chase, & Joyce, 1988; Matthews, Shimoff, Catania, & Sagvolden, 1977; Shimoff, Catania, & Matthews, 1981). Thus, although rule-governed behavior may initially be more sensitive to control by complex contingencies, such behavior may also become insensitive to changing contingencies.

It may be that the effects of self-instructions are much the same as the effects of external instructions. Skinner (1945) has noted that self-rules are developed and maintained in a manner similar to the way external rules gain control over behavior. The verbal community reinforces behavior under the control of internal stimuli just as it reinforces behavior under the control of external stimuli. Thus, it may be that as with external rules, self-rules facilitate the acquisition of complex behavior, especially when the reinforcement contingencies are complex. But, it may also be that as with external instructions, behavior under the control of self-instructions may become insensitive to changing contingencies.

The present study was designed to investigate the effects of self-developed rules on task performance during both acquisition and extinction, and to compare self-instructed performance with externally instructed performance, and with performance that was not instructed. Subjects in one condition generated self-rules, and were yoked with other subjects who were given these self-rules as external instructions. In this way, the role of self-instructions could be compared to the function of these same rules as external instructions. Subjects in a third condition were not asked to generate rules, nor did they receive any external instructions. They were yoked, however, in the amount of time it took self-rules subjects to develop self-rules.

METHOD

Subjects

Twenty-nine undergraduates at Auburn University served as subjects, as either an option to satisfy psychology course requirements or to earn extra credit in psychology classes. Subjects were assigned to one of three conditions: self-generated rules, yoked rules/yoked time, or no rules/yoked time. Assignments were random except that additional subjects were added to groups based upon the number of previous subjects in the group who displayed schedule-sensitive behavior. Two subjects failed to complete the extinction phase (see below) due to mechanical difficulties (1 in the yoked-rules/yoked-time condition and 1 in the no-rules/yoked-time condition). For these subjects, only data from acquisition trials are presented.

Setting and Apparatus

Each subject participated individually, and was seated at a table before a computer console. Subjects in the self-rules condition had access to a computer keyboard; the others did not. In front of each subject was a three-button console connected to the computer. The computer screen presented a 5 × 5 3-in. square grid with a circle in the upper left corner of the grid. At the bottom of the screen, a light alternated every 2 min from the bottom right corner to the bottom left corner, as schedule components changed. The setting, apparatus, and schedule contingencies were similar to those developed by Schwartz (1980) and used by Hayes, Brownstein, Haas, and Greenway (1986) and Hayes, Brownstein, Zettle, Rosenfarb, and Korn (1986).

Procedure

Upon arriving for the experimental session, all subjects were given the following instructions:

> Thank you for participating in this experiment in learning processes. We are interested in studying certain aspects of the learning process which are common to all people. During this study you will be alone in this room. Your task is to try to earn points on this five-by-five grid on the monitor. You can earn points by moving the circle on the grid from the upper left-hand corner to the bottom right-hand corner. Moving

the circle to the lower right-hand corner involves these two buttons and these two lights. Try to see how many points you can get.

The circle on the grid moved according to a multiple differential-reinforcement-of-low-rate (DRL) 5-s fixed-ratio (FR) 8 schedule. When the DRL schedule was in effect, the light in the bottom right corner of the screen was lit, and the first button press after 5 s moved the circle on the grid. Responses made prior to 5 s reset the timer. When subjects earned points, the interval was timed from the last DRL response. The left button on the panel moved the circle one square to the right, and the right button moved the circle one square down. When the FR schedule was in effect, the light in the left corner of the screen was lit, and eight button presses were required to move the circle. If the eighth response was on the left button, the circle moved across one square to the right. If the eighth press was on the right button, the circle moved down one square. When subjects moved the circle through the grid to the bottom right corner, a message flashed on the screen telling subjects to "push the middle button to receive your point." Pushing the middle button on the console had no programmed effect while the schedule contingencies were operating. The DRL and FR schedules alternated every 2 min with pauses between alternations during the acquisition phase only, as indicated below. To avoid alerting subjects to the time-based nature of the DRL contingency, no subject was asked to remove his or her watch.

There were three phases in the experiment: acquisition, maintenance, and extinction. During acquisition, the DRL FR multiple schedule was in effect for 40 programmed minutes, during which subjects in each condition received different instructions as indicated below, and during which subjects could earn points. During maintenance, the DRL FR schedule continued for an additional 12 min, without pause between alternations and without differential instructions. Subjects could continue to earn points during this 12-min interval. This interval provided a bridge into the third phase (extinction) without introducing the extinction phase abruptly. The extinction phase was in effect for the next 28 min, during which no points could be earned, and nothing that the subjects did would move the circle on the grid. However, the lights on the bottom of the computer screen continued to alternate every 2 min, exactly as they did during the first two phases. After extinction, a message on the computer screen announced that the experiment was over.

In addition to the initial minimal instructions described above, subjects in each condition were given the following instructions:

Self-generated-rules condition. Subjects (n = 9) in this condition were told:

At certain times during the experiment, you will be asked to type in the way to move the circle when the light is either in the lower right hand corner or the lower left hand corner. During these times, you need to type in your answers on this keyboard. If you don't know the way to move the circle, guess.

For these subjects only, a keyboard connected to the computer was placed next to the button console. At the end of each 2-min interval in the initial 40-min acquisition phase, the following messages appeared on the screen: (After DRL) "The way to move the circle when the light is in the lower right hand corner is. . . ." (after FR) "The way to move the circle when the light is in the lower left hand corner is. . . ." The program would not advance until subjects had typed a response to the message and pushed the return on the keyboard. No points were given for typing in messages, and no differential consequences were applied based upon the message typed.

Yoked-rule/yoked-time condition. Each subject in this group (n = 10) was yoked to 1 self-rules subject. In addition to the initial minimal instructions, yoked-rules subjects received the following message on the computer screen after each 2-min interval during the acquisition phase: (after DRL) "The way to earn points when the light is in the lower right hand corner is . . . (rule given by matched self-rules subject for that interval)." (after FR) "The way to earn points when the light is in the lower left hand corner is . . . (rule given by matched self-rules subject for that interval)." Each yoked-rule subject was given the identical message typed in by a matched self-rules subject for that specific interval regardless of the accuracy of the rule. After the message appeared, there was a short pause that corresponded to the length of time the matched self-rules subject used to write his or her response. After the pause, the 5 × 5 grid returned to the screen and the program continued.

No-rule/yoked-time condition. Each subject in this group ($n = 10$) was given only the initial minimal instructions. There was a short pause after each 2-min interval in the acquisition phase. The length of the pause was yoked to the length of time 1 self-rules subject used to type his or her response for that interval, but no message appeared on the screen and no further instructions were given to these subjects. After the short pause, the program continued.

RESULTS

Figure 1 shows the performance of individual subjects in all three groups. To describe schedule control, an index was calculated for each subject by dividing the number of responses in the FR component by the total number of responses in both the FR and DRL components during each consecutive 4-min period (cf. Hayes, Brownstein, Haas, & Greenway, 1986; see Appendices 1 and 2 for the response rates in each component). Because the best way to earn points on these schedules was to respond quickly during the FR and slowly during the DRL, the greater the number (ranging from 0 to 1.00), the more likely the subject was to show a combination of both high-rate FR behavior and low-rate DRL behavior.

All curves in Figure 1 were smoothed using the Hanning algorithm (Bendat & Piersol, 1986). This algorithm was applied only to the graphical display of the time-series data in order to emphasize overall trends in the data and to deemphasize trial-by-trial variation. The algorithm computes data point Y on trial i (designated as a block in the figure) using the weighted mean of three points, as follows:

$$Y_i = .25Y_{i-1} + .5Y_i + .25Y_{i+1}.$$

The first and last data points of each phase (acquisition, maintenance, and extinction) are the simple means of the first two and last two data points of the phase, respectively.

Terminal Performance in Acquisition

By the end of the acquisition phase, more rules than no-rules subjects were displaying schedule-typical behavior. During all of the last three blocks of acquisition, 7 of the 9 self-rules subjects and 6 of the 10 yoked-rules/yoked-time subjects obtained indices of at least .90. Only 1 of the 10 subjects in the no-rules/yoked-time group, however, obtained an index of least .90 for all of the last three blocks of acquisition.

To show rate differences in terminal performance for each component, Figure 2 displays FR and DRL performance plotted against each other for the last 4 min of the acquisition phase (the last 2-min FR interval and the last 2-min DRL interval). The solid lines reflect perfect DRL performance (24 responses in the 2-min interval). Seven of the 9 self-rules subjects and all 10 yoked-rules subjects displayed DRL behavior that was within 10 responses of perfect performance. Only 3 of the 10 no-rules subjects, however, performed at within 10 responses of perfect DRL behavior.

A test of central tendency comparing these three groups on this measure was inappropriate, because the groups differed significantly in their variances. An Ansari–Bradley test of dispersions (Hollander & Wolfe, 1973) was applied to the data. This nonparametric analysis assesses the probability that two groups have comparable variances and are thus drawn from the same population. This test confirmed that by the end of the acquisition phase, there was significantly more variability in DRL performance for the no-rules/yoked-time group than for the other two groups ($Z = 2.38$, $p < .02$, self-rules vs. no rules; $Z = 3.82$, $p < .0001$, yoked rules vs. no rules).

The groups also displayed dissimilar FR behavior at the end of the acquisition phase. Eight of the 9 self-rules subjects, 8 of the 10 yoked-rules subjects, and 5 of the 10 no-rules subjects emitted at least 300 responses in the 2-min FR interval. An Ansari–Bradley test of dispersions confirmed that the self-rules and no-rules groups also differed significantly from each other in their variance on this measure ($Z = 2.21$, $p < .03$). The no-rules group displayed significantly more variability in data than did the self-rules group. No other between-group differences were significant.

Acquisition Pattern

To show differences across groups in acquisition pattern, each individual acquisition curve was fitted according to a cubic polynomial, using an orthogonal least squares re-

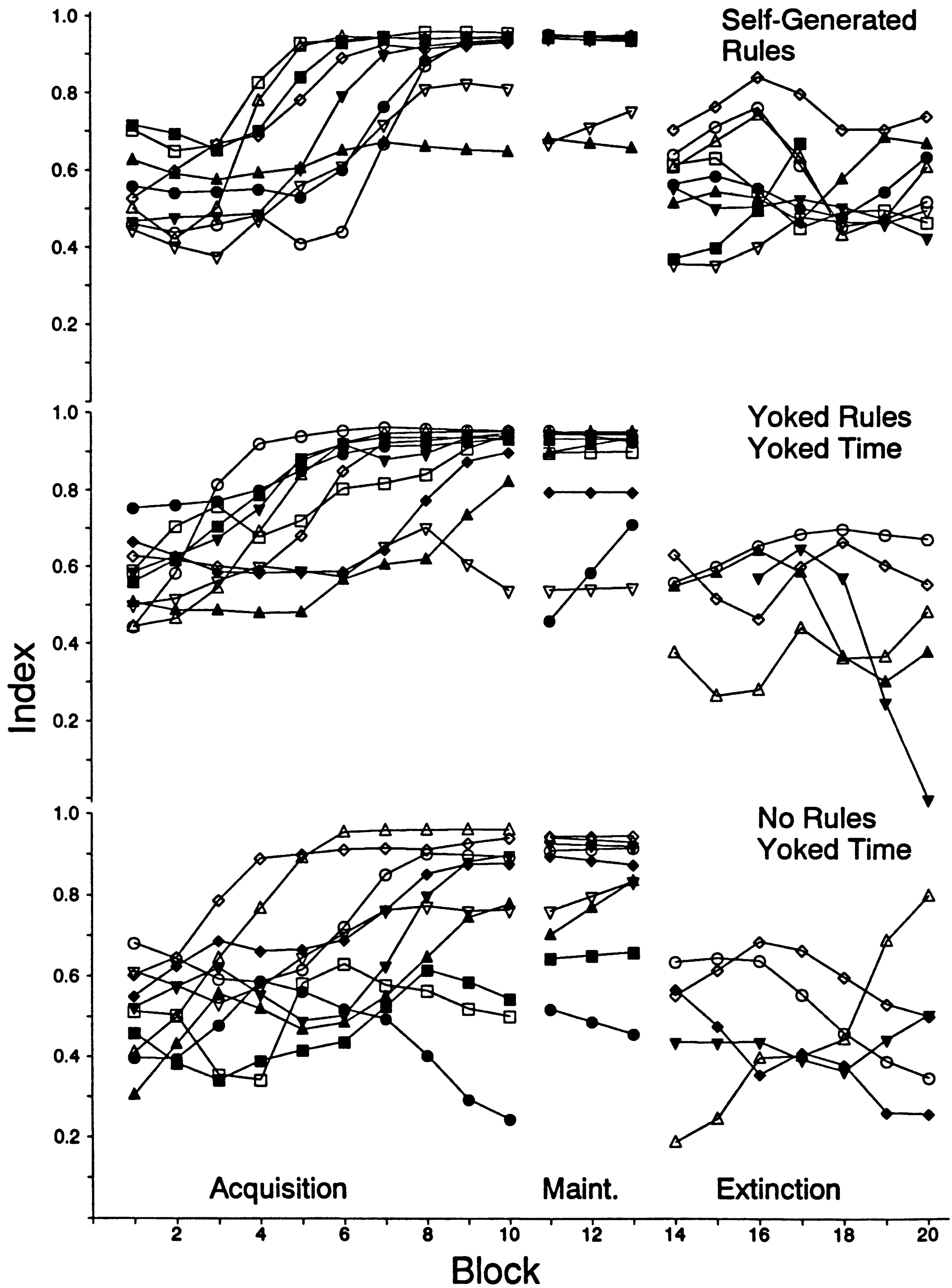

Fig. 1. Discrimination index for each subject across the three phases of the study. The index was calculated by dividing the number of responses in the FR component by the total number of responses in both the FR and DRL components during each consecutive 4-min period. For the extinction phase, only data from those subjects who earned points on both sets of schedule contingencies during at least the last block of acquisition and all three blocks of maintenance are presented. All curves were smoothed by the Hanning algorithm (see text).

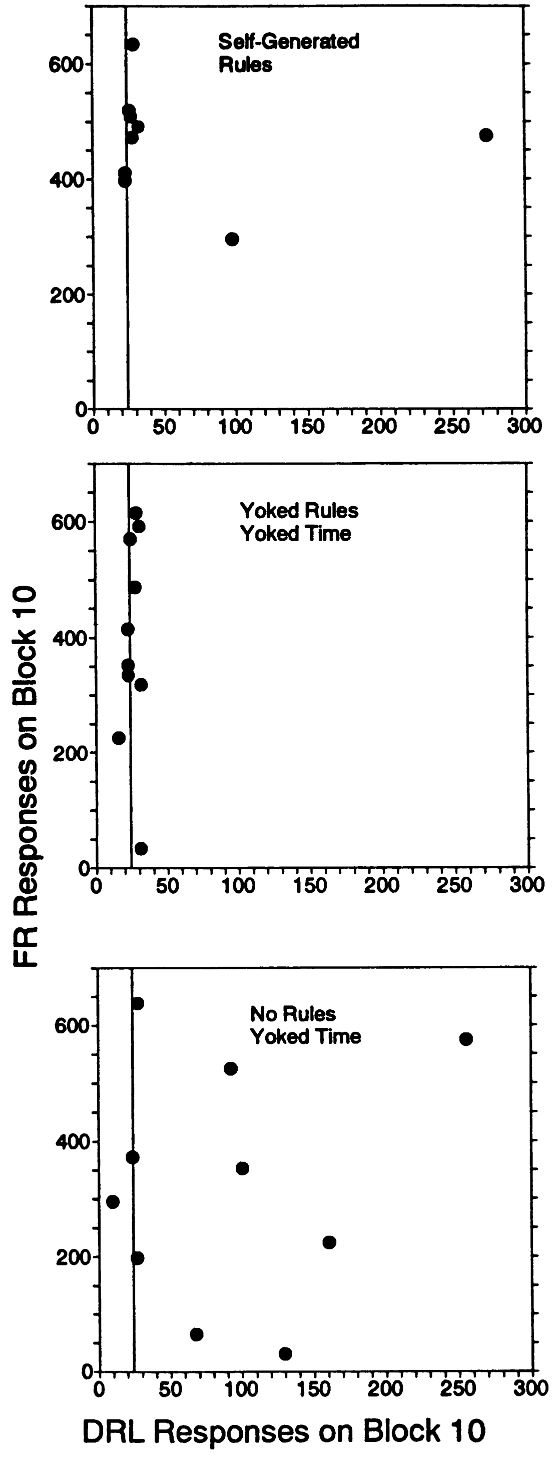

Fig. 2. Number of responses in the last 2-min FR period of the acquisition phase plotted against number of responses in the last 2-min DRL period of the acquisition phase. The upper panel represents subjects in the self-rules group, the middle panel subjects in the yoked-rules/ yoked-time group, and the lower panel subjects in the no-rules/yoked-time group. The solid lines reflect "perfect" DRL responding.

gression function (Cohen & Cohen, 1983). In all cases, at least 95% of the variance in the individual time-series curve was accounted for by the polynomial regression. A third-order polynomial produced four descriptors of acquisition: a midpoint, a linear coefficient, a quadratic coefficient, and a cubic coefficient. These independent regression coefficients were then compared across groups using a one-way analysis of variance derived from a nonparametric rerandomization of the data (see Cox & Cory-Slechta, 1987, for a further discussion of this analysis).

Results revealed that groups differed significantly from each other on the cubic component ($p = .04$). This measure assesses whether there are two curvatures or deviations from the linear in the data. Post hoc tests showed that the self-rules group differed from the yoked-rules/yoked-time group on this measure ($p < .01$), whereas the difference between the self-rules and the no-rules/yoked-time groups approached conventional levels of significance ($p = .08$). The yoked-rules and no-rules groups did not differ significantly from each other.

To illustrate group differences in the cubic component, Figure 3 displays median group acquisition curves. Each curve was formed using a cubic polynomial equation. Such a curve differs from one formed from the simple index values because each curve has been fitted using a least squares regression function. To create the median curves, the median midpoint, linear, quadratic, and cubic coefficients, respectively, were inserted into the polynomial equation (see Cohen & Cohen, 1983, for a further discussion of these curve-fitting techniques).

All three curves suggest that the groups began acquisition at about the same level of performance (Figure 3; see indices at Block 1). Moreover, both the self-rules and yoked-rules/yoked-time groups ended acquisition at equally high rates (see indices at Block 10). The self-rules median curve, however, is S-shaped. It shows a rapid acquisition of learning between Blocks 3 and 8, with an asymptote apparent by the end of the acquisition phase. Neither

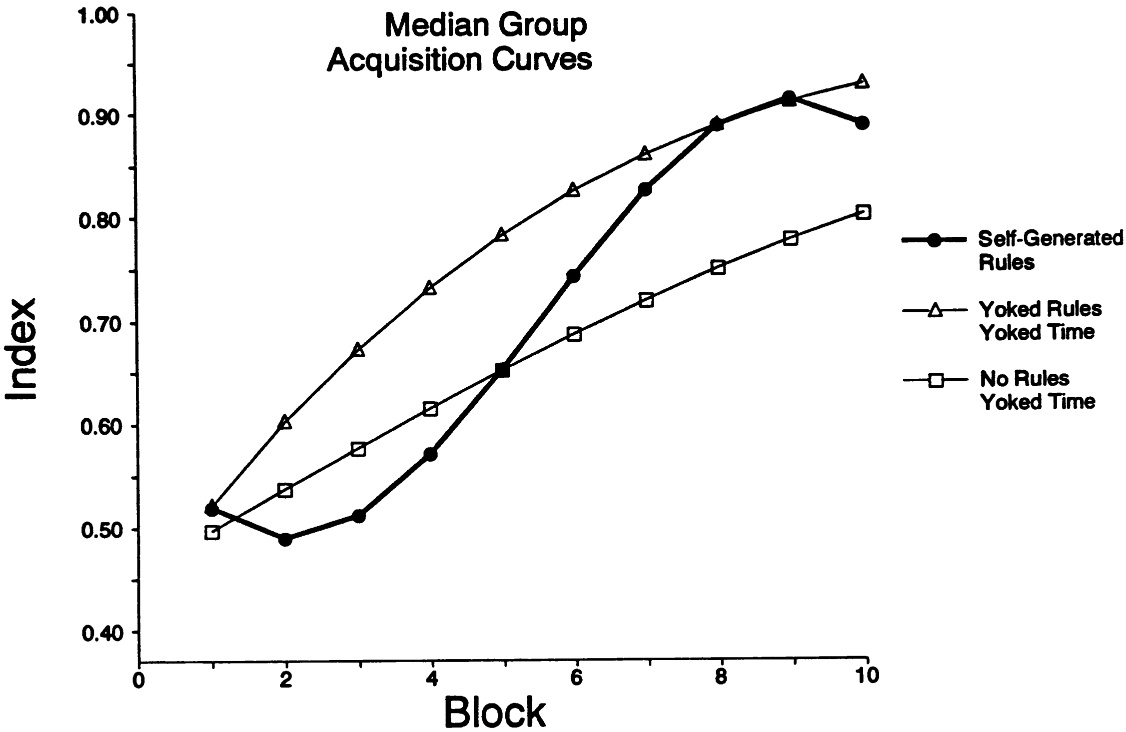

Fig. 3. A reconstruction of the median group acquisition curve formed from the median coefficient of each polynomial term for each group.

of the other two curves shows this S-shaped pattern. The yoked-rules/yoked-time curve reflects a rapid rate of learning, with an asymptotic trend toward the end of acquisition. The no-rules/yoked-time curve, by contrast, shows a linear trend continuing to the end of the acquisition phase, with no asymptote apparent in the data.

Correspondence Between Rules and Behavior

Table 1 shows the rules developed by subjects in the self-rules group after the final FR and DRL intervals of the acquisition phase. All self-rules subjects developed a rate-based rule for the FR contingency, and 8 of the 9 subjects developed a time-based rule for the DRL contingency. A rate-based rule was defined as any rule that stated that the buttons needed to be pressed rapidly or for a particular number of times to move the circle. A time-based rule was defined as any rule that stated that one needed to wait between button presses to move the circle. The 1 subject (subject 26) who failed to develop a time-based rule for the DRL contingency developed a superstitious rule involving the middle button (which had no effect on moving the circle). Despite this superstitious rule, this subject earned points consistently during the DRL phase.

Figure 4 shows the relationship between earning points and developing rules. The acquisition phase was divided into 10 2-min segments for both the DRL and FR contingencies. After each 2-min component, self-rules subjects were asked to state rules. The top figure shows the block number in which subjects first stated a time-based rule for the DRL contingency plotted against the block number in which subjects first began to earn points consistently during the DRL contingency. The bottom figure shows the block number in which subjects first stated a rate-based rule for the FR contingency plotted against the block number in which subjects first began to earn points consistently on the FR schedule. Consistent responding was defined as starting with the 2-min block in which subjects first began to earn points on that schedule. Subjects also continued to earn points in all subsequent 2-min blocks on that schedule during the acquisition phase.

Some subjects began to earn points on the

Table 1

Rules developed by each self-rules subject after the final FR and DRL intervals of the acquisition phase.

Subject		
1	DRL:	Press one button, then press the other button, release both and wait several seconds, then repeat.
	FR:	Press the button eight times.
2	DRL:	Wait about 5 or 6 seconds before you push the button each time.
	FR:	For every eight times you press the button (right or left), the circle will move.
8	DRL:	To move the circle down, press the right button, wait 5 seconds, and press it again; to move the circle across, press the left button once, wait 5 seconds, and press it again.
	FR:	To move the circle across, press the left button eight times in a row; to move the circle down, press the right button eight times in a row.
9	DRL:	Give it 5-second intervals.
	FR:	Pushing fast now.
14	DRL:	Push the buttons with a time space between pushes.
	FR:	Push the buttons in rapid succession.
17	DRL:	Press either button to move the dot, but wait about 5 seconds before pressing the next one.
	FR:	Press the right button eight times and the square goes down. Press the left button eight times and the square goes to the right.
18	DRL:	Wait at least 5 seconds between pushing each button.
	FR:	Push the buttons in a series of eight as fast as possible to receive many points.
26	DRL:	The left button 16 times and the middle button 16 times move the circle one time to the right. The right button and the middle button move the circle down.
	FR:	Press the left button eight times to go to the right. Press the right button eight times to go down.
28	DRL:	Wait approximately 12 seconds between pressing buttons.
	FR:	Press button eight times to get circle to move.

schedule before developing accurate rules, and others developed accurate rules before earning points (Figure 4). Most subjects, however, began earning points and developing accurate rules within the same or adjacent 2-min block for that schedule. Three self-rules subjects

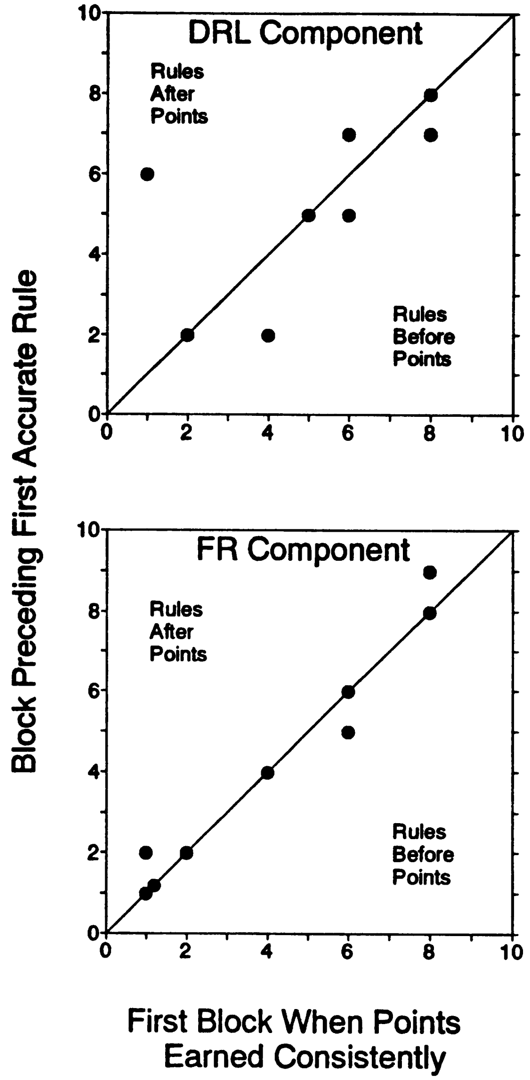

Fig. 4. The top figure shows the component number in which each self-rules subject first developed a time-based rule for the DRL contingency plotted against the component number in which that subject first began to earn points consistently during the schedule. The bottom figure shows the component number in which each self-rules subject first developed a rate-based rule for the FR contingency plotted against the component number in which that subject first began to earn points consistently on the FR schedule. Points above the diagonal reflect subjects who developed accurate rules after beginning to earn points consistently. Points below the diagonal reflect subjects who developed accurate rules before earning points consistently on the schedule. Those points falling on the diagonal represent subjects who developed accurate rules immediately following the component in which they began to earn points consistently on the schedule.

stated a time-based rule for the DRL contingency before earning points consistently on the schedule, 3 subjects stated a time-based rule immediately following the 2-min block in which they began to earn points consistently, and 2 subjects stated time-based rules in subsequent 2-min blocks after beginning to earn points consistently. Six of the 9 subjects, however, developed a time-based rule and began earning points consistently on the schedule within the same or adjacent 2-min DRL block. Yet, 1 subject never developed a time-based rule for the DRL contingency.

A similar pattern was observed for the FR contingency. Six of the 9 self-rules subjects first stated a rate-based rule for the FR schedule immediately following the 2-min block in which they began to earn points consistently, 1 subject developed a rate-based rule in the 2-min FR block immediately before beginning to earn points consistently on the schedule, and 2 subjects began to earn points consistently on the schedule in the 2-min FR block prior to developing a rate-based rule. Thus, as with the DRL contingency, although some subjects began earning points on the schedule before stating accurate rules and others stated accurate rules before earning points, there was a close correspondence in time between earning points and writing an accurate rule.

Extinction

Figure 1 shows extinction curves for subjects in each of the three groups. Extinction was examined only for subjects who earned points on both sets of schedule contingencies during at least the last block of acquisition and during all three blocks of the maintenance phase. During extinction, the lights associated with each multiple schedule continued to alternate as they had during acquisition and maintenance, but subjects could no longer move the circle or earn points. All subjects in each of the groups showed an immediate change in performance during extinction, suggesting that all subjects were sensitive to the change in contingencies. Each individual extinction curve was fitted according to a linear equation using a least squares regression function. Unlike in acquisition, however, no significant group differences emerged using the index of percentage FR responses as the dependent measure.

Figure 5 shows rate differences in the FR and DRL components separately. The figure shows the number of responses emitted during the last 4 min of the extinction phase (the last 2-min FR interval plotted against the last 2-min DRL interval). During the final FR period, all subjects in the no-rules/yoked-time group emitted less than 60 responses, a rate of less than one response every 2 s. Only 3 of the 9 self-rules subjects and 2 of the 5 yoked-rules/yoked-time subjects emitted as few responses.

A test of central tendency comparing the three groups on this measure was not undertaken because the groups differed significantly in their variances. An Ansari–Bradley test of dispersions confirmed that by the end of the extinction phase, there was significantly less variability in performance in the no-rules/yoked-time group than in the self-rules group ($Z = 2.15$, $p < .03$), whereas the difference between the no-rules/yoked-time group and the yoked-rules/yoked-time group approached conventional levels of significance ($Z = 1.70$, $p = .09$). Even at the end of 28 min of extinction, 4 self-rules subjects and 2 yoked-rules/yoked-time subjects were continuing to respond at a rate of greater than 60 responses per minute.

None of the groups differed significantly from each other in DRL performance at the end of the extinction phase. Whereas all subjects decreased their rate of responding in going from FR to EXT, some subjects in all three groups increased their rate of responding in going from DRL to EXT. During the final 2-min interval corresponding to the previous DRL period, 3 of the 5 no-rules subjects, 3 of the 9 self-rules subjects, and 3 of the 5 yoked-rules subjects increased their rate of responding compared to the final 2-min DRL interval of acquisition.

DISCUSSION

The results suggest that asking people to develop rules facilitates control over behavior by complex contingencies of reinforcement. During acquisition, the behavior of subjects asked to formulate rules came under the control of the schedule contingencies more quickly than did the behavior of those not asked to formulate rules. The data, however, looked different in extinction. During the FR component, when the schedule changed to extinc-

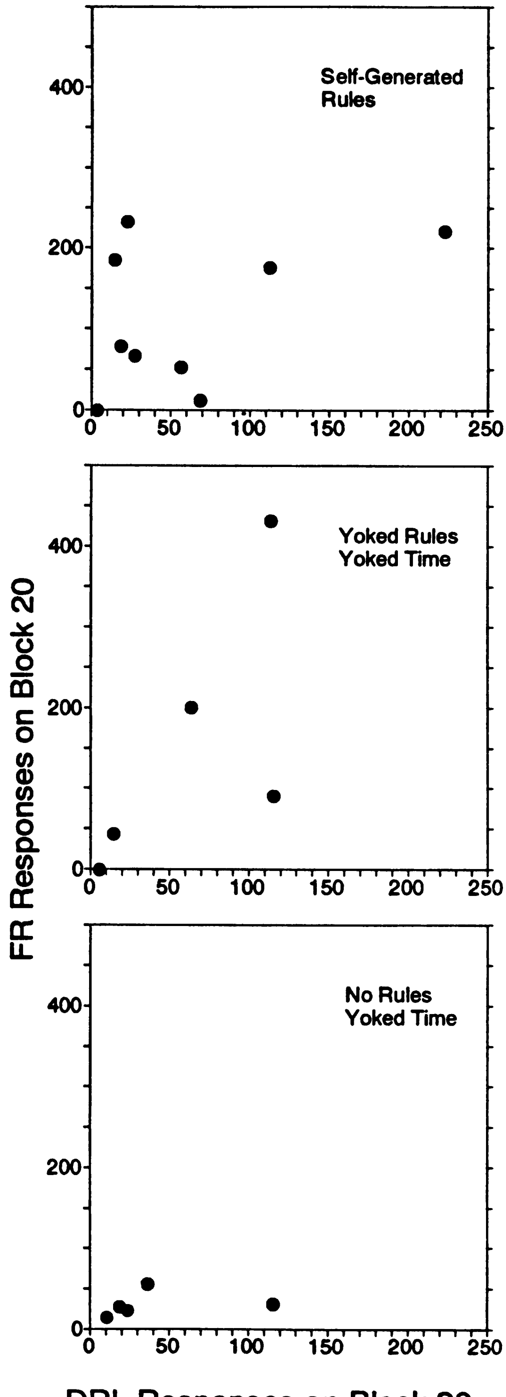

Fig. 5. Number of responses in the last 2-min FR period of the extinction phase plotted against number of responses in the last 2-min DRL period of the extinction phase. Only those subjects who earned points on both sets of schedule contingencies during at least the last block of acquisition and during all three blocks of the maintenance phase are included. Although subjects could no longer move the circle during extinction, the lights associated with each schedule continued to alternate as they had during the other phases. The upper panel represents subjects in the self-rules group, the middle panel represents subjects in the yoked-rules/yoked-time group, and the lower panel represents subjects in the no-rules/yoked-time group.

tion, the behavior of those asked to formulate rules was more variable and was more likely to be of high rate, compared to the behavior of those not asked to formulate rules.

These data replicate with self-rules what has been found with external rules. Previous research has shown that giving subjects accurate rules increases the likelihood that behavior will come under the control of complex contingencies (e.g., Ayllon & Azrin, 1964). The literature also suggests that rules may lead behavior to become insensitive to changing contingencies. When contingencies change, behavior under the control of rules may be less likely to come under the control of new schedule contingencies (e.g., Matthews et al., 1977; see Hayes, 1989, for a review). The present results extend this finding to include control by self-generated rules.

The results of this study also suggest that rule-governed behavior is not always insensitive to changing contingencies (see also LeFrancois et al., 1988; Michael & Bernstein, 1991). In this study, all subjects immediately changed their rate of responding in response to the schedule change. Moreover, by the end of the extinction phase, in the period corresponding to the previous FR interval, half the rules subjects were responding at a rate of less than 20% of their acquisition rate. Thus, at most, these data suggest that both self-generated and externally provided rules may at times decrease the rate at which behavior will adapt to changing contingencies.

It should also be noted that the decreased rate of responding of the no-rules group at the end of the extinction phase was limited to the FR component. The groups did not differ in their response to the change from DRL to EXT. These results are consistent with other studies of human operant behavior (see Hayes, Brownstein, Haas, & Greenway, 1986, Table 1). Some subjects in each of the three groups increased their rate of responding to the DRL schedule during extinction, whereas others decreased their rate, a finding comparable to what has been found in the literature in changing from DRL to EXT by nonhumans (e.g., Catania, 1970; Holz & Azrin, 1963; Reynolds, 1964). Such a finding, however, complicates the analysis of group differences.

A further finding of this study relates to the correspondence between rules and behavior. Some self-rules subjects described accurate rules before earning points, and others earned points before verbalizing an accurate rule. The data thus suggest that it is not first necessary to develop accurate rules for behavior to come under the control of complex contingencies. The results fail to support mediational accounts of human operant behavior (e.g., Brewer, 1975; Spielberger & DeNike, 1966), which assert that all human performance is mediated by verbal descriptions of schedule contingencies. Instead, the data suggest that, at least for some subjects, accurate verbal descriptions may be a consequence of displaying schedule-appropriate behavior.

Yet, most subjects whose behavior came under the control of the schedule before developing useful rules subsequently developed an appropriate rule within the next 4-min block. Thus, a close correspondence between self-rules and behavior was evident. These results add to the growing body of literature that suggests that there is almost always a high degree of correspondence between one's verbal and nonverbal behavior (Catania, Shimoff, & Matthews, 1989; Hayes, 1986; Lowe, 1979). Regardless of whether self-rules are a product of or an antecedent to nonverbal behavior, rules and behavior are almost always closely intertwined.

Research on self-rules has previously shown that when verbal behavior is shaped, nonverbal behavior will become closely linked to the shaped verbal behavior. Catania et al. (1982), for example, shaped subjects' verbal responses regarding schedule performance and found that such shaping led to schedule-controlled behavior that was consistent with verbal behavior, regardless of the schedule contingencies. Based upon these findings, Catania et al. (1982) concluded that ". . . a particularly effective way to change human behavior is to change the individual's private talk or, in other words, to change what the individual thinks" (p. 246).

The present study takes this analysis a step further by showing that shaping is not required for nonverbal behavior to become linked with verbal behavior. Merely asking subjects to verbalize self-generated rules will lead to greater schedule control. Thus, one particularly effective way to change human behavior is to ask subjects to verbalize self-rules; shaping verbal behavior does not seem to be critical.

The applied literature has already shown that verbally monitoring a socially significant target behavior will frequently lead to desirable changes in that behavior (see Nelson, 1977, for a review). Abrams and Wilson (1979), for example, found that asking subjects to self-monitor verbally the number of cigarettes smoked led to a significant reduction in daily cigarette consumption. But, it is unclear from these data why verbally monitoring a nonverbal behavior should lead to significant changes in that behavior (Nelson & Hayes, 1981).

Critchfield and Perone (1990) offer three possible explanations for changes induced by self-reports. First, prompts for self-reports may function as implied demands, and thus may gain instructional control over behavior. Second, self-reporting may lead to new forms of self-observation, and new behavior may gain control over the target behavior. Third, self-reports may function as a form of feedback on behavior change, and may serve to modify behavior in a manner similar to that produced by other consequences. Future research should help determine the mechanism through which self-rules increase the likelihood that behavior will come under the control of complex contingencies.

A final finding of the study relates to the similarity between the self-rules and the yoked-rules subjects' data. The behavior of both groups tended to be similar at the end of both acquisition and extinction. This similarity may provide some clues to understanding the role of self-rules in the experimental analysis of behavior. Self-rules, as with external rules, are developed and maintained because of reinforcement contingencies controlled by the social, verbal community (Skinner, 1945). Through the process of "induction" (Skinner, 1945, p. 274), external rules may become self-rules and self-rules must eventually become public in order for their use to be differentially reinforced and maintained. Thus, as the data suggest, at times the distinction between self-rules and external rules may not have functional significance (cf. Moore, 1980).

But there are important differences between self-rules and external rules. In this study, self-rules subjects developed rules based upon their own previous rules and observations of their own behavior. Yoked-rules subjects had no such history when receiving external rules. In fact, the data suggest that there were differences between the behavior of the two groups. Yoked-rule subjects' behavior tended to conform to the schedules at a quicker rate (see Figure 3), even though by the end of acquisition both groups were performing similarly. Self-rules subjects showed less variability in FR responding at the end of acquisition than did no-rules subjects, whereas there was no statistically significant difference in FR variability comparing the yoked-rules and no-rules groups. Thus, much still needs to be learned about how the contingencies controlling the correspondence between self-rules and behavior are different from the contingencies controlling the following of external rules.

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APPENDIX 1

Number of responses for each subject during each block of acquisition.

Subject	Yoked to subject	Component	Block number 1	2	3	4	5	6	7	8	9	10
Self-rules group												
1		DRL	124	210	263	38	19	28	26	19	24	29
		FR	393	384	313	420	289	393	452	561	566	635
2		DRL	31	17	18	19	21	24	25	22	22	23
		FR	32	12	13	27	11	14	56	283	380	399
8		DRL	31	138	37	23	25	24	30	30	29	27
		FR	122	36	34	128	440	436	544	448	520	511
9		DRL	73	108	138	82	72	49	31	60	52	98
		FR	63	81	57	80	112	56	105	242	367	297
14		DRL	30	18	6	64	97	22	28	31	37	28
		FR	17	41	11	136	295	430	320	320	431	474
17		DRL	41	118	203	232	67	25	30	32	28	26
		FR	99	312	327	435	529	452	554	460	494	521
18		DRL	29	65	91	80	109	111	82	28	30	23
		FR	48	64	112	112	104	144	320	287	402	412
26		DRL	77	331	319	328	388	235	231	273	281	274
		FR	206	364	448	512	512	496	495	512	553	477
28		DRL	42	32	34	28	25	28	35	41	32	32
		FR	36	29	34	23	31	167	384	448	504	493
Yoked-rules/yoked-time group												
3	1	DRL	29	22	39	151	76	42	38	33	10	16
		FR	15	113	164	212	215	203	184	126	225	227
4	2	DRL	50	25	24	37	48	26	23	24	24	25
		FR	24	32	187	510	686	676	650	584	512	572
10	8	DRL	52	59	57	29	52	36	27	29	28	29
		FR	40	49	61	65	347	527	542	562	574	616
12	9	DRL	215	132	103	89	42	37	39	26	31	31
		FR	255	112	159	123	73	38	73	108	38	35
15	14	DRL	47	103	128	259	185	27	29	28	30	28
		FR	104	134	236	309	313	370	312	384	476	489
19	17	DRL	35	11	86	64	35	18	21	20	25	23
		FR	28	23	180	256	272	256	320	313	356	336
22	18	DRL	61	126	125	82	65	27	26	39	36	23
		FR	142	533	344	364	342	286	296	406	427	416
23	17	DRL	42	98	112	77	107	30	26	42	26	23
		FR	55	80	105	87	64	56	38	60	64	353
27	26	DRL	65	115	236	140	26	26	108	64	31	31
		FR	58	269	414	358	382	548	543	576	590	593
29	28	DRL	98	287	400	394	380	318	135	44	31	32
		FR	253	450	537	565	531	461	192	192	256	320

APPENDIX 1 (*Continued*)

Subject	Yoked to subject	Component	Block number 1	2	3	4	5	6	7	8	9	10
No-rules/yoked-time group												
5	1	DRL	59	28	29	16	15	112	122	140	121	68
		FR	40	46	17	1	110	118	196	183	127	66
6	1	DRL	51	89	168	155	195	102	30	25	26	27
		FR	128	164	213	235	270	244	270	228	255	199
7	2	DRL	87	62	74	83	33	25	26	28	24	28
		FR	42	61	155	222	512	628	576	682	646	640
11	8	DRL	31	87	135	120	136	141	75	111	128	101
		FR	52	128	128	156	281	289	313	366	387	354
13	9	DRL	32	40	27	27	23	26	23	26	24	24
		FR	80	39	210	208	216	248	326	203	385	374
16	14	DRL	86	341	305	273	290	256	222	63	133	161
		FR	164	121	167	178	207	200	187	191	136	226
20	17	DRL	42	41	43	50	102	122	87	126	100	130
		FR	31	24	31	121	109	128	102	81	41	32
21	18	DRL	283	27	25	24	28	33	22	34	32	256
		FR	31	28	39	24	25	25	34	43	205	576
24	14	DRL	20	21	13	36	12	10	10	14	55	10
		FR	24	21	39	34	12	9	13	128	267	297
25	8	DRL	94	110	40	183	69	134	58	57	45	93
		FR	104	149	192	197	250	184	256	311	428	526

APPENDIX 2

Number of responses for each subject during each block of maintenance and extinction.

		Block number									
		Maintenance			Extinction						
Subject	Component	11	12	13	14	15	16	17	18	19	20
Self-rules group											
1	DRL	28	33	31	97	83	78	81	16	29	57
	FR	608	586	602	107	204	112	36	25	24	53
2	DRL	22	19	25	104	37	10	24	87	38	113
	FR	448	432	330	190	66	136	30	63	29	176
8	DRL	25	31	28	88	76	35	75	88	163	23
	FR	498	457	448	114	144	173	147	55	73	233
9	DRL	82	100	22	102	92	102	64	30	117	28
	FR	296	128	449	96	28	92	50	40	48	67
14	DRL	29	33	27	109	47	27	65	87	32	19
	FR	521	627	674	215	142	253	287	174	67	79
17	DRL	29	30	30	118	214	95	8	5	0	4
	FR	567	636	575	66	136	85	16	38	0	0
18	DRL	26	26	28	128	194	43	214	150	334	15
	FR	473	502	576	118	368	55	174	194	178	185
26	DRL	199	273	283	278	265	131	321	169	55	223
	FR	477	532	551	283	301	212	174	218	291	221
28	DRL	29	32	31	79	129	84	38	94	7	69
	FR	487	536	512	171	98	75	72	47	17	12
Yoked-rules/yoked-time group											
3	DRL	17	21	26	37	25	35	16	32	11	5
	FR	142	205	232	40	28	31	19	0	18	28
4	DRL	21	27	42	33	41	21	22	14	68	15
	FR	512	576	388	42	53	55	36	53	104	44

APPENDIX 2 (*Continued*)

		Block number									
		Maintenance			Extinction						
Subject	Com-ponent	11	12	13	14	15	16	17	18	19	20
10	DRL	29	32	31	120	193	144	24	84	69	114
	FR	576	667	640	207	28	33	41	40	15	432
12	DRL	30	31	30	156	172	168	225	175	206	142
	FR	34	38	36	249	210	329	271	220	135	126
15	DRL	28	29	29	45	111	128	45	75	86	116
	FR	511	508	522	181	98	67	112	134	178	91
19[a]	DRL	22	25	28	71	43					
	FR	322	354	433	85	16					
22	DRL	27	17	20	55	30	50	158	21	26	21
	FR	21	16	330	19	67	63	185	152	31	55
23	DRL	77	46	30	185	228	95	61	60	71	64
	FR	551	561	622	309	209	311	80	50	0	201
27	DRL	29	33	24	0	2	0	88	0	38	6
	FR	576	576	512	0	0	183	38	22	0	0
29	DRL	40	229	40	82	45	69	44	67	85	4
	FR	488	468	489	52	112	60	95	63	26	17
No-rules/yoked-time group[b]											
6	DRL	26	25	24	87	95	93	94	183	106	116
	FR	287	233	319	140	183	174	139	113	98	32
7	DRL	31	48	53	134	108	56	43	49	0	37
	FR	576	675	675	56	10	60	38	9	10	56
11	DRL	133	115	55	64	101	118	37	224	179	49
	FR	363	436	394	105	168	149	99	78	84	14
13	DRL	26	25	26	82	66	11	50	30	30	19
	FR	426	448	448	114	74	53	64	74	21	28
16	DRL	145	141	93	132	84	165	116	131	139	85
	FR	272	250	200	188	178	170	89	112	56	109
20	DRL	88	53	117	76	51	57	20	40	19	82
	FR	56	99	42	28	260	46	22	11	24	38
21	DRL	335	119	70	101	113	115	73	39	71	121
	FR	512	487	468	186	142	120	143	56	46	40
24	DRL	11	38	26	94	27	59	33	35	68	11
	FR	267	316	471	102	15	63	19	17	53	15
25	DRL	26	91	52	153	66	263	53	44	64	24
	FR	477	497	497	181	98	55	49	46	1	24

Note. Data for Subjects 3, 12, 22, 29, 11, 16, 20, and 21 were deleted from the extinction analyses because these subjects failed to earn points on both schedules during at least the last block of acquisition and during all three blocks of the maintenance phase.

[a] Due to mechanical difficulties, Subject 19 failed to complete the extinction phase.

[b] Subject 5 failed to complete both the maintenance and extinction phases due to mechanical difficulties.