*EFFECTS OF REINFORCEMENT HISTORY ON
RESPONDING UNDER PROGRESSIVE-RATIO
SCHEDULES OF REINFORCEMENT*

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The effects of experimental history on responding under a progressive-ratio schedule of reinforcement were examined. Sixteen pigeons were divided into four equal groups. Groups 1 to 3 were trained to peck a key for food under a fixed-ratio, variable-ratio, or differential-reinforcement-of-low-rate schedule of reinforcement. After training, these pigeons were shifted to a progressive-ratio schedule, later were shifted back to their original schedule (with decreased rates of reinforcement), and finally were returned to the progressive-ratio schedule. Pigeons in Group 4 (control) were maintained on the progressive-ratio schedule for the entire experiment. To test for potential "latent history" effects, pigeons responding under the progressive-ratio schedule were injected with *d*-amphetamine and given behavioral-momentum tests of prefeeding and extinction. Experimental histories affected responding in the immediate transition to the progressive-ratio schedule; response rates of pigeons with variable-ratio and fixed-ratio histories were higher than rates of pigeons with differential-reinforcement-of-low-rate and progressive-ratio-only histories. Pigeons with differential-reinforcement-of-low-rate histories, and to a lesser degree pigeons with variable-ratio and fixed-ratio histories, also had shorter postreinforcement pauses than pigeons with only a progressive-ratio history. No consistent long-term effects of prior contingencies on responding under the progressive-ratio schedule were evident. *d*-Amphetamine and resistance-to-change tests failed to reveal consistent latent history effects. The data suggest that history effects are sometimes transitory and not susceptible to latent influences.

Key words: behavioral history, progressive-ratio schedules, behavioral momentum, *d*-amphetamine, schedule transitions, key peck, pigeons

Although it is generally assumed that previous exposure to contingencies of reinforcement and punishment may affect present behavior, the emphasis within the field of operant conditioning has been on the experimental analysis of current, not past, contingencies. The common practice of using the same animals in multiple experiments has reflected the prevailing belief that current contingencies overshadow the effects of past contingencies. Consequently, there have been relatively few empirical studies on the topic often referred to as *behavioral history* (Wanchisen, 1990; Wanchisen & Tatham, 1991).

However, an increasing number of studies have shown that past contingencies can significantly influence performance under the

control of current contingencies (e.g., Wanchisen, 1990; Wanchisen & Tatham, 1991). For example, Urbain, Poling, Millam, and Thompson (1978) trained rats under either a fixed-ratio (FR) 40 or a differential-reinforcement-of-low-rate (DRL) 11-s schedule of reinforcement, and then shifted them to a fixed-interval (FI) 15-s schedule of reinforcement. Subjects with an FR history responded at higher rates under the FI schedule than did the subjects with a DRL history. A similar effect in rats was reported by Bickel, Higgins, Kirby, and Johnson (1988), Johnson, Bickel, Higgins, and Morris (1991), and LeFrancois and Metzger (1993). Wanchisen, Tatham, and Mooney (1989) demonstrated that a history of responding under a variable-ratio (VR) schedule of reinforcement affected rats' rates and patterns of responding under a subsequent FI schedule.

Experimental history often influences the ways that drugs affect behavior (e.g., Barrett, 1977; Egli & Thompson, 1989; Nader & Thompson, 1987; Urbain et al., 1978). Barrett (1977), for example, showed that *d*-amphetamine increased punished responding in monkeys with a history of responding under a

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shock-avoidance contingency, but produced no increase in response rates in animals without this history. Interestingly, before *d*-amphetamine was administered, there were no differences in baseline rates of punished responding among animals with different histories; differences were "revealed" only after responding was challenged with drug administration. Thus, the effects of history may remain "latent" until another variable (e.g., a drug) is imposed upon the performance maintained by the prevailing contingency (see Egli & Thompson, 1989; Wanchisen & Tatham, 1991).

Whereas the effects of experimental history in nonhumans are currently receiving increased attention, there has traditionally been greater acceptance that history profoundly influences human behavior (e.g., Skinner, 1953). Indeed, early work by Weiner (1964, 1969) clearly demonstrated the effects of FR and DRL histories on humans trained to press a key for point reinforcers. The issue of experimental history has been a focal point in a recent debate on the suitability of using humans as subjects in basic research on operant conditioning (Baron, Perone, & Galizio, 1991a, 1991b; Branch, 1991; Buskist, Newland, & Sherburne, 1991; Dinsmoor, 1991; Palmer & Donahoe, 1991; Perone, Galizio, & Baron, 1988; Pierce & Epling, 1991; Shull & Lawrence, 1991; Wanchisen & Tatham, 1991). Some authors (e.g., Baron *et al.*, 1991a; Perone *et al.*, 1988; Pierce & Epling, 1991) favor and encourage the use of humans as subjects in basic research, but others (e.g., Branch, 1991; Palmer & Donahoe, 1991) are skeptical that human subjects can provide useful data in revealing basic mechanisms of behavioral control. A main reason for questioning the utility of human subjects in basic research is the fear that the extensive and complex histories humans bring to any experiment will mask the true effects of the current experimental contingencies.

This concern is based partly on experimental studies with humans and nonhumans that have demonstrated the influence of history (e.g., Wanchisen *et al.*, 1989; Weiner, 1964) and have given some researchers (e.g., Branch, 1991) the impression that history effects are ubiquitous. Although consideration of historical variables is clearly important in predicting behavior, the conditions under which history

does or does not affect behavior have not been clearly specified, and it is premature to argue that history effects are omnipresent in human or nonhuman subjects. The relative lack of data in this field gave purpose to the present study; it is an attempt to begin mapping out the conditions that foster, or minimize, historical effects. Most history-related studies have trained subjects to respond under schedules that generated high (i.e., FR or VR) or low (i.e., DRL) response rates, followed by a shift to a common time-based schedule of reinforcement such as FI (Bickel *et al.*, 1988; Freeman & Lattal, 1992; Johnson *et al.*, 1991; Le-Francois & Metzger, 1993; Urbain *et al.*, 1978; Wanchisen *et al.*, 1989; Weiner, 1964), fixed-time (FT) (Alleman & Zeiler, 1974), or variable-interval (VI) (Freeman & Lattal, 1992; Nader & Thompson, 1987) schedules. Little is known about the effects of history on performance that is maintained by ratio schedules of reinforcement. In one exception, Egli and Thompson (1989) showed that the suppressive effects of methadone on pigeons' key-pecking rates under an FR schedule were attenuated by a history of responding under an FI schedule of reinforcement.

Therefore, the present study examined the effects of history on behavior controlled by a ratio-based schedule of reinforcement. Animals were trained under an FR, VR, or DRL schedule of reinforcement and then were shifted to a progressive-ratio (PR) schedule of reinforcement (Hodos, 1961). Under a PR schedule, the first reinforcer is delivered after a fixed number of responses, and this number is incremented after each food delivery (e.g., 8, 16, 24, 32, etc.) until some "break point" is reached, at which time responding stops. PR schedules have previously served as sensitive baselines to study the effects of several variables, including magnitude of reinforcement and drugs (Hodos, 1961; Thomas, 1976; Thompson, 1972), and we hypothesized that it might also serve as a sensitive baseline to study the effects of prior contingencies.

In the present study, pigeons with different experimental histories (i.e., FR, VR, and DRL) were trained under a common PR schedule of reinforcement, and their data were compared to control pigeons that responded under the PR schedule for the entire experiment. Two values of FR (40 and 160), VR (40 and 160), and DRL (5 and 10 s) were

examined to provide a wide range of reinforcement rates during the history phase of the experiment and to mimic the parameters used in previous experiments (e.g., Freeman & Lattal, 1992; Urbain et al., 1978). In addition to comparing response rates, highest ratio reached in a session (break point), and postreinforcement pause (PRP), other tests were conducted to determine whether groups differed in ways not revealed by simply comparing performance on the common PR schedule. First, *d*-amphetamine was injected as animals responded under the PR schedule, and dose-response curves were compared across groups. Second, response strength was measured under the PR schedule by using Nevin's (1974, 1979) behavioral momentum model. According to this model, response strength may be measured by the extent to which operant behavior resists change from disruptive sources. In the present experiment, responses were disrupted by feeding subjects immediately before the PR session and by extinction. It was hoped that these manipulations (i.e., drugs and resistance-to-change tests) would reveal differences among groups that might have remained latent when examining baseline responding (cf. Barrett, 1977; Egli & Thompson, 1989; Files, Branch, & Clody, 1989).

METHOD

Subjects

Sixteen experimentally naive male White Carneau pigeons were maintained at 80% of their free-feeding body weights (100% weights ranged from 444 to 631 g), with the exception of 2 birds in the FR condition (closed economy, see below) that were not intentionally deprived (100% weights ranged from 446 to 470 g). Water was freely available in their home cages, where a 12:12-hr light/dark cycle was maintained (lights on at 6:00 a.m.).

Apparatus

Four modular (Coulbourn Instruments) pigeon chambers were housed in sound-attenuating cubicles. The key (2.5 cm diameter) was located in the center of the work panel, 6.0 cm from the ceiling, and was transilluminated red. A minimum force of 0.10 N operated the key. Mixed grain was presented through an aperture below the key; the aperture was illuminated red during each food cycle. White

noise was continuously present in the experimental room to mask extraneous sounds. Contingencies were controlled by an IBM-PC® computer, Coulbourn Instruments Lab-Linc® interface, and Pascal programming.

Procedure

Pecking on a red key was established by autoshaping and was maintained on a continuous reinforcement (CRF) schedule for one session. Experimental sessions (except for PR and two FR [closed economy] subjects) lasted 45 min. Sessions were conducted Monday through Friday, except for 2 pigeons (open economy) in the FR group that also were studied on Saturday and 2 other pigeons (closed economy) in the FR group that were studied daily. Each session was preceded by a 10-min blackout. Following CRF training, subjects were divided into four equal groups: VR 40, FR 40, DRL 5 s, and PR 8. The feeder cycle was 4 s under VR, FR, and DRL conditions and 3 s under the PR condition. The red key-light was turned off during each food presentation. No houselight was used.

Variable ratio. Pigeons 3143, 3103, 1638, and 2133 were trained under a VR schedule of reinforcement, in which food was presented after an average number of responses. Pigeons spent one session each under VR 8, 16, 24, and 32, before being placed on a VR 40 schedule. There were 15 ratios in the VR 40, arranged according to an arithmetic distribution (e.g., 5, 10, 15, 20, etc.). Following each reinforcement, one of the ratios was randomly selected from the set of 15. This condition was in effect for 40 to 46 sessions.

Fixed ratio. Following CRF training, 4 pigeons had one session each under FR 5, 10, 20, and 30, before reaching FR 40. Under the FR 40 schedule, food was delivered after 40 key pecks. Pigeons 1693 and 1894 responded in an open economy (see Hursh, 1980) in which each session was 45 min long, and supplemental food was given in the home cage immediately after each session, when necessary, to maintain 80% free-feeding body weights. Pigeons 1896 and 3109 responded in a closed economy in which the experimental sessions lasted 14 hr, and they received no postsession feeding. On Saturday and Sunday, these pigeons responded for 40 consecutive hours with a cup of water in the chamber and were removed on Monday morning. The FR subjects

were the last animals of the day to be placed in the chambers; the open-economy pigeons were removed immediately after the session, and the closed-economy pigeons responded into the night and were removed at 7:30 a.m. The FR condition was in effect for 41 to 46 sessions.

Differential reinforcement of low rate. Pigeons 1689, 15640, 1672, and 4350 were trained on a DRL 5-s schedule, in which food was scheduled for the first response after 5 s, and a response before 5 s reset the interval. This condition was in effect for 40 to 45 sessions.

Progressive ratio (control). Pigeons 1654, 7901, 4765, and 3523 responded under a PR 8 schedule of reinforcement. The first reinforcement of the session was delivered after eight responses, and the number of responses for subsequent reinforcers was increased by increments of eight (e.g., 8, 16, 24, 32, etc.). The experimental session ended when no reinforcer was obtained within 20 min of the last food delivery. These pigeons remained on PR 8 for 75 to 77 sessions before receiving drugs (see below).

Switch to progressive-ratio schedule. Once response rates showed no increasing or decreasing trends for at least five consecutive sessions, pigeons in the VR, FR, and DRL groups were switched to the PR 8 schedule for 30 sessions (with the exception of DRL Bird 4350 that had 25 sessions). The 2 pigeons in the FR closed-economy group were reduced to 80% of their free-feeding (preexperimental) body weights for this condition.

d-Amphetamine administration. After 30 sessions of PR training (25 for DRL Bird 4350; 75 to 77 for PR-only control pigeons), *d*-amphetamine was administered in the breast muscle in a volume of 1 mL/kg body weight before Tuesday and Friday sessions according to the following sequence: 0 (saline), 0.3, 1, 3, 10 mg/kg. After an injection, the pigeon was immediately placed in the chamber, and the PR session was conducted as usual.

Return to original schedules. After the last injection, pigeons in the VR, FR, and DRL groups were returned to their original schedules of reinforcement, except that the schedule values were increased to VR 160, FR 160, and DRL 10 s. Pigeons in the FR and VR groups had two intermediate sessions of FR 80 and VR 80, respectively, before the final schedule value was reached. Once again, no attempt was made to maintain a fixed body weight for sub-

jects in the closed-economy FR 160 condition. After 20 sessions under these schedule values, pigeons in the VR, FR, and DRL groups were switched to the PR 8 schedule for 20 sessions.

Resistance-to-change tests. After the final 20 sessions under PR 8, pigeons were prefed 5% and then 10% of their ad libitum body weights 1.5 hr before selected PR 8 sessions. Both the 5% and 10% prefeeding tests were conducted twice (with the exception of Pigeons 4765 [PR] and 3109 [FR], who were tested only once), and responding was allowed to recover to baseline levels between successive tests. PR-only control pigeons were not placed in the chambers for approximately 4 weeks after the *d*-amphetamine condition. These subjects then received seven to nine sessions of additional PR 8 training and were then given resistance-to-change tests. Pigeon 4765 died for unknown reasons 2 days after the second resistance-to-change test (10% prefeed). When responding stabilized after the last prefeeding session, subjects received three consecutive 90-min extinction sessions in which pecking the red key had no scheduled consequences.

RESULTS

The most meaningful analysis of a history effect involves a comparison of performance under the common PR schedule of reinforcement for subjects with different experimental histories and control subjects with only a PR history. The major dependent variables under the PR schedule were overall response rate, highest ratio reached in a session (break point), and PRP. Table 1 presents the average rates of reinforcement for the last five baseline sessions before the schedules were changed to PR; these data are presented simply to show that a wide range of reinforcement rates were scheduled during the history phases of the experiment. Cumulative records (not presented) showed that under the PR 8 schedule, pigeons completed a series of increasingly larger ratio requirements, with the PRP gradually lengthening until 20 min passed without a food delivery. In most cases, sessions terminated during a PRP and not during a ratio response run.

Figure 1 presents overall response rates averaged over the last five baseline sessions under VR 40, FR 40, and DRL 5-s schedules (left panels) and VR 160, FR 160, and DRL 10-s

schedules (right panels). Also shown are response rates for the first 10 sessions of the first and second PR 8 conditions. Only the first 10 sessions of each PR condition are shown in order to facilitate examination of the transition to the PR schedule; also, performance stabilized quickly under the PR schedule, and no additional information is gained by presenting all PR sessions. Response rates were determined by dividing total responses by total session time (excluding feeder cycles). Data for Sessions 1 to 10 of the PR-only (control) group are superimposed in each left panel on the data of subjects with different experimental histories, and the PR-only data for Sessions 31 to 40 are superimposed in each right panel. Sessions 31 to 40 for control pigeons were used as a comparison because experimental pigeons received 30 PR sessions in the first phase of the experiment (with the exception of DRL Pigeon 4350, who had only 25 PR sessions). A comparison of the control data with the data from subjects with different experimental histories is facilitated by a global view within each panel of the half-filled square symbols and dashed lines (PR-only group) with the open symbols and solid lines (experimental groups). Baseline response rates were generally highest under the VR schedules and lowest under the DRL schedules, although exceptions can be noted. Baseline response rates under the closed-economy FR conditions (Pigeons 1896 and 3109) were low because session time was relatively long and subjects in a closed economy do not usually spend the entire session responding. Baseline response rates increased when the FR was increased from FR 40 to FR 160, but no systematic changes in response rates were observed when VR and DRL schedule values were increased. When conditions were shifted to the PR 8 schedule, response rates adjusted quickly and were relatively stable for most subjects across the first 30 PR sessions and again across the second 20 PR sessions.

Differential effects of experimental history were seen in the immediate transition to the PR schedule. Pigeons with a VR 40 history had higher response rates than all 4 PR-only pigeons in the first PR 8 session and higher rates than 3 of the 4 PR-only subjects in Sessions 2, 3, and 4; pigeons with a VR 160 history had higher response rates than 3 of the 4 PR-only pigeons during Session 1 of the

Table 1

Mean rate of reinforcement (food deliveries per hour) for the last five baseline sessions before the transition to the progressive-ratio schedule.

Schedule	Subject			
	3143	3103	1638	2133
VR40	122	158	279	122
VR160	71	10	65	47
	1693	1896	1984	3109
FR 40	71	5	57	5
FR 160	42	8	93	8
	1689	15640	1672	4350
DRL 5 s	109	423	97	213
DRL 10 s	16	40	103	66

Note. Subjects 1896 and 3109 responded under a closed economy.

second PR condition. Similarly, pigeons with an FR history had higher response rates than 3 of the 4 PR-only pigeons during Sessions 1, 2, and 3 of the first PR condition and during Session 1 of the second PR condition. Finally, pigeons with a DRL 5-s history had lower response rates than pigeons with a VR 40 history in the first session of the PR condition. After these early sessions during the immediate transition to the PR schedule, response rates stabilized, and no consistent differences were observed among the groups.

The highest FRs completed in a session (break point) under the PR 8 schedule are presented in Figure 2. Pigeons completed ratios ranging from 16 to 1,281 responses. The break-point data in Figure 2 resemble the response-rate data in Figure 1. In the immediate transition to the PR schedule, pigeons with VR 40 and FR 40 histories had higher break points than 3 of the 4 PR-only pigeons during Sessions 1 and 2 of the first PR condition; 3 of the 4 subjects with a VR 160 history had a higher break point than PR-only subjects during Session 1; and subjects with an FR 160 history had higher break points than 3 of the 4 PR-only subjects during Sessions 1 and 2. After these early sessions, break points stabilized, and no consistent differences were observed among the groups.

Figure 3 shows the average PRPs for the last five baseline sessions and the PRPs for the first 10 sessions of the first and second PR 8 conditions. The PRP for each session was obtained by averaging the time between each food delivery and the first response in a ratio re-

Fig. 1. Average response rates of the last five baseline sessions (B) under VR 40, FR 40, and DRL 5-s schedules (left panels) and VR 160, FR 160, and DRL 10-s schedules (right panels). Open points connected by solid lines show response rates for the first 10 sessions of the first PR 8 condition (left panels) and the second PR 8 condition (right panels), respectively, for VR, FR, and DRL groups. The data for the first 10 sessions of the PR-only group (half-filled squares, dashed lines) are superimposed on the data for the VR, FR, and DRL groups in each left panel, and the data of Sessions 31 to 40 for these subjects are superimposed in each right panel. The numbers adjacent to symbols in each panel represent different pigeons. The vertical axis is logarithmic.

Fig. 2. The highest FR achieved in a session (break point) for the first 10 sessions of the first PR 8 condition (left panels) and the second PR 8 condition (right panels), respectively, for VR, FR, and DRL groups, and break points of PR-only subjects during Sessions 1 to 10 (left panels) and Sessions 31 to 40 (right panels). Other features are identical to Figure 1.

Fig. 3. Average PRP of the last five baseline sessions (B) under VR 40, FR 40, and DRL 5-s schedules (left panels) and VR 160, FR 160, and DRL 10-s schedules (right panels). Also shown are the PRPs for the first 10 sessions of the first PR 8 condition (left panels) and the second PR 8 condition (right panels), respectively, for VR, FR, and DRL groups, and PRPs of PR-only subjects during Sessions 31 to 40 (right panels). The PRP was inadvertently not recorded for the first 30 sessions of the PR-only group. Other features are identical to Figure 1.

Fig. 4. Ratio of response rate during a drug session to rate on the immediately preceding session as a function of dose of *d*-amphetamine for pigeons with VR, FR, and DRL histories and for pigeons with only a PR history (PROG RATIO). Pigeons responded under a PR 8 schedule during the drug regime.

quirement. The PRP in the last ratio requirement of the session (no food delivered) was not included in these calculations. The PRP was inadvertently not recorded for the first 30 sessions of the PR-only group. In the first PR condition, subjects with a DRL 5-s history had shorter pauses after reinforcement than those with an FR 40 history during Sessions 1 and 2. In the second PR condition, all 4 pigeons with a DRL 10-s history had shorter PRPs than the PR-only pigeons during Sessions 1, 2, 3, and 5, and 3 of the 4 DRL 10-s pigeons had shorter PRPs during Sessions 6, 7, and 9. All 4 pigeons with a VR 160 history had shorter PRPs than the PR-only pigeons during Session 1. Pigeons with a DRL 10-s history also had shorter PRPs than pigeons with an FR 160 history during Sessions 1 and 2. After these early sessions, PRP stabilized, and no consistent differences were observed among the groups.

Figure 4 presents dose-response curves following *d*-amphetamine injections under the first PR 8 condition. Data are ratios of response rates during a drug session to rates in the session immediately preceding an injection. Values below 1.0 indicate response reductions, and values above 1.0 indicate facilitation. For most animals, low to moderate (0.3 and 1 mg/kg) doses of *d*-amphetamine increased response rates above baseline, whereas higher doses decreased rates. Most importantly, no consistent differences in dose-response curves were observed among the four groups.

Figure 5 presents data from the resistance-to-change tests that were given after the second PR 8 condition. Data are presented as a proportion of response rate under the PR 8 baseline (response rate during a test session divided by response rate of the immediately preceding session). Values below 1.0 represent response reductions. Ratios of the two determinations

Fig. 5. Data from the resistance-to-change prefeeding (left panels) and extinction (right panels) tests. Data are proportion of PR 8 baseline rate. Response rate during a prefeeding test session was divided by response rate of the immediately preceding session. For the extinction tests, response rates during each of three extinction sessions were divided by response rate of the session immediately preceding the first extinction session. Other features are identical to Figure 1.

of the 5% prefeeding conditions were averaged, and the two determinations of the 10% prefeeding conditions were averaged. For the extinction tests, response rates during each of three extinction sessions were divided by response rates of the session immediately preceding the first extinction session. In general, response rates declined during prefeeding and extinction sessions. The only consistent difference among the groups during resistance-to-change tests was observed under the 10% prefeeding test, in which pigeons with an FR history showed lower relative response-rate reductions after prefeeding than did pigeons in the PR-only group, and 3 of the 4 pigeons with a VR history showed lower relative response-rate reductions than did PR-only pigeons.

DISCUSSION

Experimental histories affected responding during the immediate transition to the PR 8 schedule. For example, response rates in Session 1 of the first PR condition were higher for all 4 pigeons with a VR 40 history (range, 66 to 88 responses per minute) compared to pigeons with DRL 5-s (2 to 42 responses per minute) and PR-only (9 to 51 responses per minute) histories. In addition, in Session 1 of the second PR condition, pigeons with VR 160 and FR 160 histories had higher response rates (range, 46 to 128 and 46 to 109 responses per minute, respectively) than pigeons with a PR-only history (14 to 45 responses per minute). Response rates of 3 of the 4 pigeons with VR and FR histories were also higher than rates of pigeons with a PR-only history during Sessions 2 and 3 of the PR 8 schedules. Breakpoint data revealed similar differences among groups in the early sessions of the PR 8 schedules. In general, during the immediate transition to the PR 8 schedule, pigeons with a DRL history had the shortest PRPs, and pigeons with a PR-only history had the longest PRPs. Specifically, pigeons with a DRL 10-s history had shorter PRPs than pigeons with a PR-only history, and this difference persisted for approximately nine sessions of the PR schedule. Pigeons with a DRL history also had shorter PRPs than subjects with FR 40 and FR 160 histories during the first two sessions under PR 8, and pigeons with a VR 160 history had shorter PRPs than PR-only pigeons

during the first PR 8 session. It is not clear why pigeons with a DRL history had the shortest PRPs when the schedule was shifted to PR 8, unless the effect is viewed as a type of contrast that resulted from removing the inhibiting constraints on responding under the DRL schedule. In summary, different behavioral histories affected performance under the PR 8 schedules, but only in the immediate transition to the schedule; no consistent long-term group differences were evident beyond the first several sessions of the PR 8 schedule. The ranges of response rates, break points, and PRPs generally overlapped in all four groups after the first several sessions under the PR 8 schedule (with the exception of the PRP following the DRL 10-s history).

Previous studies have shown that differences in response rates among groups of subjects with different experimental histories might not be revealed until drugs are administered (e.g., Barrett, 1977; Egli & Thompson, 1989; Nader & Thompson, 1987). In the present study, there were no consistent differences in *d*-amphetamine dose-response curves of the four groups under the common PR 8 schedule of reinforcement. When responding was disrupted with extinction, response rates under the PR 8 schedule declined for all subjects, but consistent differences in resistance to extinction were not observed among the four groups. When responding was challenged by prefeeding operations, 4 pigeons with FR histories and 3 pigeons with VR histories were more resistant to satiation (10% prefeeding only) than were pigeons with a PR-only history. It is too premature, however, to state that greater behavioral momentum (Nevin, 1974, 1979) under the PR 8 schedule was derived from FR and VR histories, because resistance-to-change tests of prefeeding and extinction tend to be highly correlated (e.g., Cohen, Riley, & Weigle, 1993) in measurements of behavioral momentum, and in the present study greater behavioral momentum was observed only under the 10% prefeeding condition. It should also be pointed out that tests of behavioral momentum are more sensitive in multiple-schedule than in simple-schedule contexts (Cohen et al., 1993), and the simple-schedule context of the PR 8 schedule might not have revealed potential history effects. In summary, latent history effects were not clearly evident in the present study, at least those that would be re-

vealed by *d*-amphetamine and resistance-to-change tests.

Responding under the PR schedule was relatively insensitive to prior contingencies beyond the immediate transition to the schedule. These data are consistent with those of Freeman and Lattal (1992), who trained pigeons to respond under a multiple FR DRL schedule and then shifted the subjects to a multiple FI FI schedule (Experiments 1 and 2) or a multiple VI VI schedule (Experiment 3) with equal-valued schedules in both components. Response rates were higher in the FI and VI components whose stimuli previously signaled the FR schedule; however, within approximately 10 to 30 sessions, the effects of history were no longer evident in most subjects as response rates in both FI and VI components converged. Despite these results, other studies have reported that responding under schedules that generate high or low response rates alter long-term rates and patterns of responding under subsequent FI schedules of reinforcement (Bickel *et al.*, 1988; Johnson *et al.*, 1991; LeFrancois & Metzger, 1993; Urbain *et al.*, 1978; Wanchisen *et al.*, 1989; Weiner, 1964). It may be that FI schedules are particularly sensitive to history effects. Response rates under FI schedules may vary over a wide range without affecting rates of reinforcement and may be more influenced by what Zeiler (1977) referred to as indirect variables (*i.e.*, variables such as history that affect behavior but are not directly imposed by the schedule itself). In ratio schedules, rate of reinforcement is directly proportional to rate of response; responding is, therefore, more likely to be influenced by the requirements imposed by the schedule itself (*i.e.*, direct variables, Zeiler, 1977) and less likely to be affected by indirect variables such as history. Responding under ratio schedules may thus be more susceptible to developing "locked rates" (Sidman, 1960), making them relatively insensitive to history variables.

As investigators (see Wanchisen, 1990; Wanchisen & Tatham, 1991) increasingly emphasize the importance of historical factors in accounting for behavioral variability, mechanisms of drug action, and discrepancies in schedule-controlled performance between human and nonhuman subjects, it is important to discover the exact conditions under which history does or does not play a crucial role. Because preexperimental history cannot be

easily controlled in humans, some authors (*e.g.*, Branch, 1991; Palmer & Donahoe, 1991) have argued that adult humans are inappropriate subjects for basic research on operant conditioning. Furthermore, if history effects remain latent, waiting to be "revealed" by some experimental manipulation (Branch, 1991; Wanchisen & Tatham, 1991), then the use of human subjects in basic research may be questionable. Baron *et al.* (1991a, 1991b), however, have argued that the effects of history can be minimized or eliminated in humans by establishing steady-state baselines through long-term exposure to experimental contingencies, by selecting subjects based on common historical characteristics, by providing new histories within the experimental context, and by establishing strong experimental control over behavior. In support of this position, Michael and Bernstein (1991) trained children to respond in a matching-to-sample task using methods of imitation, instruction, or contingency shaping. When exposed to a new discrimination, children with a history of shaping acquired the problem slightly faster than subjects with an imitation or instructional history; however, sufficient exposure to the new contingencies eliminated any long-term differences among the groups.

The present study was an attempt to begin a systematic examination of the conditions that produce carryover effects from one schedule of reinforcement to another. The results support the contention that long-term history effects may be minimized by using contingencies that establish strong experimental control over responding. However, these data do not preclude the possibility of ever finding more sustained history effects under PR schedules. Perhaps other histories (*e.g.*, CRF, FT, FI schedules), other reinforcement parameters (*e.g.*, VR 5), longer exposure to the original schedules (*e.g.*, 100 sessions), other PR schedules (*e.g.*, PR 3 or PR 25), or even other species (*e.g.*, rats) would reveal history effects. Clearly, consideration of history is important in the experimental analysis of behavior. However, long-term history effects do not operate in all experimental contexts.

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