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AN EXPLORATION OF REMOTE HISTORY EFFECTS IN HUMANS

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One group of undergraduates responded under a fixed-ratio (FR) 25 schedule and a second group responded under a differential-reinforcement-of-low-rate (DRL) 5-s schedule (first history phase). Both groups of subjects were then exposed to a differential-reinforcement-of-other-behavior (DRO) 5-s schedule (second history phase), and finally to fixed-interval (FI) 5-s (Experiment 1), variable-interval (VI) 5-s (Experiment 2), extinction, FR, and DRL (Experiment 3) schedules (history testing phase). Response rates under the extinction and the FR schedule in the history-testing phase were higher for subjects with a history of the FR schedule than for subjects with a DRL history. Such a systematic difference by remote histories was not observed when the FI, VI, and DRL schedules were in effect during testing.

Investigators have recently paid attention to the effects of historical contingencies on current behavior (cf. Tatham & Wanchisen, 1998). History effects are observed when past experiences exert control over present behavior thereby reducing the control exerted by current contingencies (Freeman & Lattal, 1992). For example, Weiner (1964) found that humans responded differently under identical fixed-interval (FI) schedules of reinforcement depending on the schedules to which they had been exposed. Subjects with histories of fixed-ratio (FR) schedules responded at high rates under the FI schedules, whereas those with differential-reinforcement-of-low-rate (DRL) schedule histories responded at low rates under the same FI schedules. Similarly, many investigators have shown with nonhuman animals under different schedules that current behaviors were affected by schedules immediately before the current ones (e.g., Nader & Thompson, 1987; Urbain, Poling, Millam, & Thompson, 1978; Wanchisen, Tatham, & Mooney, 1989).

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Organisms' behavior may also be affected by schedules that were in effect in the remote past. Weiner (1969) exposed humans to DRL, FR, and FI schedules in that order and found that response rates under the FI schedule were low. The FI performance was not similar to that shown under the FR schedule which had been in effect immediately before the current FI schedule but rather to that shown under the DRL schedule which had been in effect long before the FI. Based on this finding, Weiner speculated that the FI responding might have been affected by a DRL schedule history remote from the current FI contingency.

The generality of Weiner's (1969) results, however, may be restricted because of the lack of replications across schedules and species. First, Weiner did not find the effects of remote FR histories when the sequence of schedules were (a) FR, DRL, and FI, (b) FR, differential-reinforcement-of-other-behavior (DRO), and FI, (c) FR, fixed-time (FT), and FI, or (d) FR, extinction, and FI. Second, Cole (2001) and LeFrancois and Metzger (1993) reported that the responding of rats under FI schedules was affected by immediate FR histories rather than DRL schedules that had been in effect before the FR.

The following procedural feature may also restrict the generality of Weiner's (1969) results. Weiner compared performances under a current schedule with those under previous ones, and concluded that remote history effects occurred because the current performances were similar to those observed under the remote schedule. This design has a limitation that possible history effects can not be isolated from control of the current schedules. This limitation may complicate the assessment especially when FI schedules are used as a test for human subjects. The human FI performances has large individual differences, and one of the typical patterns is indistinguishable from that shown under DRL schedules (Lowe, 1979). Scrutiny of Weiner's results of Experiments 2 and 5, furthermore, suggests that 6 of 8 cases that demonstrated the remote history effects were tested under the FI schedule when every response was punished by a point-loss. Because response rates in humans under the FI schedules decrease considerably when such a punishment contingency is added (e.g., Weiner, 1962) as they also do in nonhumans (e.g., Azrin & Holz, 1961), it is difficult to attribute the low-rate responses shown under these FI and punishment contingencies to the previous schedule histories. Under the standard FI schedule without punishment, 2 of 3 subjects showed the remote effects of the DRL history, but the remaining 1 did not (Weiner, 1969).

Using a different research design from that of Weiner (1969), the present experiments examined whether human schedule performances were affected by schedule histories remote from the current schedule. To build a remote history, half the subjects were initially exposed to one schedule (Schedule 1), and the other half were exposed to a different one (Schedule 2). Then, an identical schedule (Schedule 3) was in effect for all subjects to build an immediate history until the responding between the subjects with different histories became indistinguishable. Finally, the

responding under a current schedule (Schedule 4) was compared between the different historical subjects. This design permits us to demonstrate that either one or both remote histories (Schedules 1 and/or 2) affected the current responding if performances under the immediate historical schedule (Schedule 3) did not differ and if those under the current schedule (Schedule 4) differed depending on the remote historical schedules.

As a remote history, undergraduates were exposed first to an FR or DRL schedule, both of which have been used exclusively to establish remote histories (Cole, 2001; LeFrancois & Metzger, 1993; Weiner, 1969) and most frequently to establish immediate histories (e.g., Nader & Thompson, 1987; Urbain et al., 1978; Weiner, 1964). The subjects were then exposed to a DRO schedule as an immediate history. The DRO schedule, which delivered a reinforcer after a specified period of no responding (Catania, 1991), usually eliminates the response almost completely (Lattal, 1991). Thus, it would be expected that the effects of FR and DRL histories disappeared during this second condition. Finally, in Experiment 1, the effects of the remote histories were examined by comparing the responding under an identical FI schedule between the subjects with different histories. The FI schedule has been used exclusively to test remote history effects (Cole, 2001; LeFrancois & Metzger, 1993; Weiner, 1969), and is one of the schedules most frequently used for testing immediate history effects (e.g., Baron & Leinenweber, 1995; Urbain et al., 1978; Wanchisen et al., 1989; Weiner, 1964).

Experiment 1

Method

Subjects

Subjects were 2 male and 4 female undergraduates recruited from an educational psychology class at Osaka Kyoiku University. They were 22 to 24 years old, and none had experience with operant conditioning experiments.

Apparatus

The experimental room was 1.70 m wide, 2.20 m deep, and 2.17 m high. A Nihon Electric Company PC-9821AP microcomputer, located in an adjacent room, was used to control the experiment. The subject sat at a desk facing a color display monitor (250 mm wide by 180 mm high) equipped with a Micro Touch Systems touch screen. A filled white circle (55 mm diameter) was presented in the center of the black screen and each touch on the circle (operandum) was defined as a response. All inter-event times were recorded in real time, with 50-ms resolution. A second white circle (30 mm diameter) was presented at the bottom left of the monitor. Each touch to the circles was accompanied by a brief sound through a speaker beneath the desk. A point counter was located at the top right of the monitor.

Procedure

Subjects were required to sign an informed consent agreement that specified the frequency and duration of their participation and the average earnings for such participation. They were asked and agreed to remain in the experiment for a maximum of eight 120-min experimental periods, and actually participate in three to five experimental periods. A 120-min experimental period was conducted once per day, two times per week. During this period, a maximum of 15 variable-duration sessions occurred. Sessions were separated by 1- to 2-min breaks. After every experimental period, subjects were paid for their performance (2 yen per 100 points, approximately .015 U.S. dollars). Upon completion of the entire experiment, subjects were paid for their participation (100 yen per 120 min) and were debriefed. The overall earnings for each subject ranged from 3,500 to 3,700 yen.

On the first day of the experiment, each subject was asked to silently read the following instructions (translated from Japanese to English).

> Your task is to earn as many points as you can. A hundred points are worth two yen. In addition, you will be paid 100 yen for every day you spend in the experiment. Payment for points will be made at the end of each visit and payment for participation will be made at the end of the last visit.
>
> A circle will be shown in the center of the display monitor. If you touch the circle, the center circle may disappear, then a small circle will appear in the bottom of the display monitor. By touching the small circle, you can earn points. Accumulated points will be shown in the top right of the display monitor.
>
> The words "READY" and "GO" will appear in sequence on the display monitor. When the word "GO" disappears, the task will begin and last until the words "GAME OVER" appear on the display monitor.

The typed set of instructions remained on the desk throughout the experiment. Questions regarding the experimental procedure were answered by telling the subject to reread the appropriate sections of the instructions. Then the words "READY" and “GO” were presented in sequence in the top left of the display monitor. After the word “GO” disappeared, a circle, which served as the operandum, was presented in the center of the display monitor.

When the schedule requirement was met, the center circle was darkened and the circle for the “consummatory response” was presented at the bottom left of the monitor. A touch during a 3-s consummatory response period darkened the circle and accumulated 100 points on this counter. If the subject did not touch the circle during this period, no points were delivered. This occurred only 7 times during the experiment out of 9,600 opportunities for the consummatory response.

Each session lasted until 40 reinforcers occurred. Thereafter, the words "GAME OVER" appeared at the top left of the monitor.

Three subjects each were randomly assigned to one of two conditions: (a) FR history or (b) DRL history. FR history subjects were exposed first to a FR schedule, and DRL history subjects were exposed to a DRL schedule. The DRL schedule reinforced a response if a specified time period had elapsed since the last response. The DRL also reinforced the first response following a reinforcer if the postreinforcement pause (PRP) was longer than the specified time period. Following this first history phase, all subjects were exposed to a DRO schedule in the second history phase, then finally to an FI schedule in the testing phase. For all subjects, each phase of the first and second histories lasted 10 sessions, whereas the testing phase lasted 20 sessions. The values of the FR, DRL, and DRO schedules increased progressively over the first several sessions of each phase, whereas the FI value was set at 5 s throughout the phase. That is, the values of the FR schedule in the first, second, and third sessions were 5, 15, and 25 responses, respectively. The values for the DRL and DRO schedules in the first, second, third, and fourth sessions were 1, 2, 3, and 5 s, respectively. In the reminder of the sessions, the values for the FR, DRL, and DRO schedules were set at 25 responses, 5 s, and 5 s, respectively.

Results and Discussion

Because of experimenter error, 1 subject in the DRL history condition was exposed to unplanned schedule contingencies during the first history phase. The data from this subject will not be described further.

Figure 1 shows the response rates of each subject for each session. During the first session of the first history phase, there was no systematic difference in response rates between subjects exposed to the FR and DRL schedules. With continued exposure, response rates for all subjects exposed to the FR schedule were higher than those for all exposed to the DRL schedule. Thus, the responding for each subject was well controlled by the contingencies in effect. During the first session in which the DRO schedule was introduced, response rates for 2 (Subjects 4 and 6) of 3 subjects who had been exposed to the FR schedule were higher than those for subjects who had been exposed to the DRL schedule, suggesting the carry-over effects of prior FR and DRL schedules. However, final response rates under the DRO were extremely low for all subjects, irrespective of their different schedule history (FR or DRL). When the schedule in effect was changed to the FI, response rates for all subjects remained low. During the last 7 sessions, response rates for subjects with the FR history were higher than those with the DRL history, though the magnitude of difference was very small.

Weiner (1969) found that a remote DRL history affected the subsequent FI responding, whereas others did not observe such an effect (Cole, 2001; LeFrancois & Metzger, 1993). Because the former finding is from humans and the latter from rats, we may be tempted to attribute this inconsistency to species differences. However, the present results from

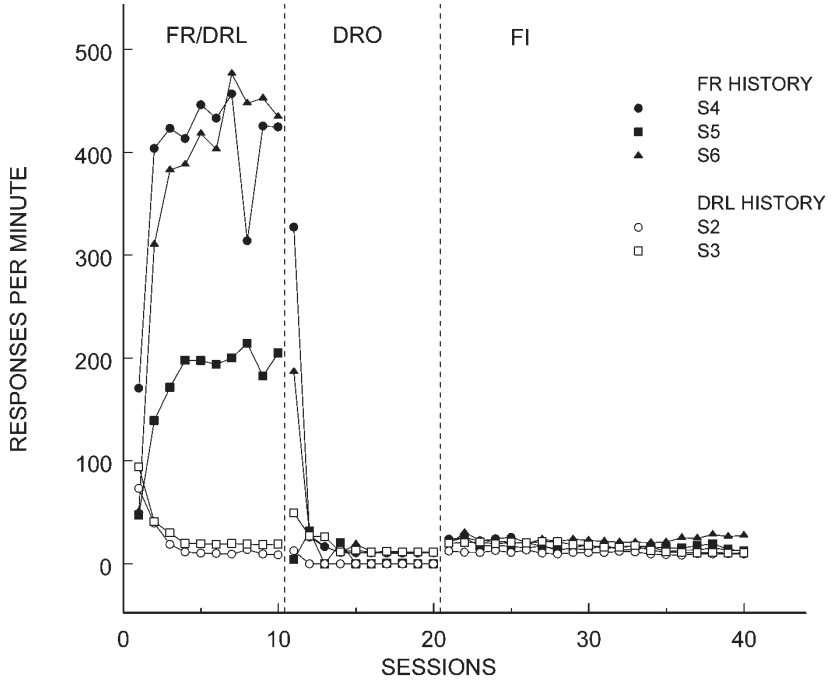

Figure 1. Response rates in each session for each subject of Experiment 1. *FR/DRL* identifies the first history phase in which an FR schedule was in effect for Subjects 4, 5, and 6, and a DRL schedule for Subjects 2 and 3. *DRO* identifies the second history phase in which a DRO schedule was in effect. *FI* identifies the testing phase in which an FI schedule was in effect. Filled circles, squares, and triangles represent responding for Subjects 4, 5, and 6, respectively, whereas open circles and squares respectively represent responding for Subjects 2 and 3.

humans are consistent with those from rats. Moreover, Weiner's results are difficult to interpret because his testing procedure punished every response. Thus, the inconsistent results across the studies may be due to procedural variables rather than phylogenetic ones.

The results of Experiment 1 and those of the previous studies (Cole, 2001; LeFrancois & Metzger, 1993) consistently suggest that there was no effect of the remote histories on current behavior. Nevertheless, to conclude that any histories remote from the current contingency do not affect current behavior would be premature because those results were obtained under limited conditions. In the case of Experiment 1, values of the DRO and FI schedules, which were equated according to a generally accepted practice to equate the interreinforcer intervals (IRIs) under the past and current schedules (e.g., Freeman & Lattal, 1992; LeFrancois & Metzger, 1993), may have been relevant to the results. As generally described (Lattal, 1991), the DRO eliminated the response almost completely (Figure 1). Following the transition from the DRO to the FI, the subjects would have continued to pause as they did under the DRO

schedule. Because the value of the FI was equal to that of the DRO, the FI probably timed out before the subjects started to respond. A response after the pause, therefore, can produce a reinforcer under the FI. Such a pause-respond pattern may have reinforced and been repeated throughout the FI sessions.

To further examine the above speculation, the transition from the DRO to the FI schedule was analyzed in detail. Table 1 shows PRPs, number of responses, reinforced interresponse times (IRTs), obtained interreinforcer intervals (IRIs), and number of responses per minute in the last 3 reinforcers under the DRO schedule and in the first 6 under

Table 1

Molecular Data in Last Three Reinforcers during Last DRO Session and in First Six Reinforcers during the First FI Session of Experiment 1

Reinforcer	PRP	Number of responses	Reinforced IRT	Obtained IRI	Rate of responses
FR history					
Subject 4					
DRO schedule					
38	.8	1	-	5.8	10.4
39	.6	1	-	5.6	10.8
40	.6	1	-	5.6	10.7
FI schedule					
1	1.1	2	13.2	14.3	8.4
2	.6	3	4.2	5.3	33.8
3	.6	3	2.2	5.8	31.3
4	.6	5	2.2	6.8	44.1
5	.6	2	4.5	5.1	23.7
6	.6	3	2.6	6.0	29.9
Subject 5					
DRO schedule					
38	-	0	-	5.0	0.0
39	-	0	-	5.0	0.0
40	-	0	-	5.0	0.0
FI schedule					
1	11.5	1	11.5	11.5	5.2
2	.9	3	8.1	11.5	15.6
3	1.3	3	2.4	6.1	29.8
4	1.0	5	3.1	6.9	43.5
5	3.5	2	2.8	6.3	19.1
6	4.6	2	1.6	6.1	19.6
Subject 6					
DRO schedule					
38	.3	1	-	5.3	11.4
39	.2	1	-	5.2	11.5
40	.5	1	-	5.5	10.8
FI schedule					
1	.7	2	10.3	10.9	11.0
2	.5	2	12.8	13.3	9.0
3	.5	4	7.2	12.1	19.8
4	.6	3	7.4	11.3	16.0
5	3.2	2	3.6	6.8	17.7
6	.5	3	3.9	7.7	23.4

DRL history					
Subject 2					
DRO schedule					
38	-	0	-	5.0	0.0
39	-	0	-	5.0	0.0
40	-	0	-	5.0	0.0
FI schedule					
1	24.2	1	24.2	24.2	2.5
2	.9	2	9.9	10.8	11.1
3	5.1	1	5.1	5.1	11.8
4	4.2	2	9.8	14.0	8.6
5	2.7	2	7.9	10.6	11.3
6	5.7	1	5.7	5.7	10.6
Subject 3					
DRO schedule					
38	.3	1	-	5.4	11.2
39	.3	1	-	5.3	11.3
40	.4	1	-	5.4	11.1
FI schedule					
1	.5	2	12.0	12.5	9.6
2	.4	3	7.5	9.7	18.7
3	.3	2	4.7	5.1	23.7
4	.3	3	4.8	9.3	19.4
5	.3	2	4.8	5.1	23.6
6	.3	2	4.8	5.1	23.6

the FI schedule. These molecular data support our speculation. First, there was almost no response under the DRO schedule. Subjects 4, 6, and 3 responded once immediately after every reinforcer, then paused until the next reinforcement, whereas Subjects 5 and 2 did not respond at all between the reinforcers. Second, the responding before the first FI reinforcement was identical to that during the previous DRO schedule. Subjects who had responded immediately after reinforcement under the DRO showed short PRPs under the FI, whereas those who had no response under the DRO showed PRPs longer than 5 s. Third, subjects with short PRPs and those with long PRPs emitted two and one responses, respectively, for the first reinforcement, suggesting that the first response after the pause was reinforced for each subject. The reinforced IRTs were longer than 5 s for all subjects. Finally, following the first reinforcement, one to five responses occurred for each reinforcer with reinforced IRTs ranging from 1.6 s to 12.8 s, suggesting that a chain of pause-respond was repeated under the FI schedule.

These molecular analyses of the transition from the immediate historical condition (DRO) to the current test condition (FI) shed light on interactions between the two conditions as a variable possibly relevant to the remote history effects if the effects exist. Studies of the immediate history effects have suggested that when the environmental stimuli experienced during the history building and testing conditions are similar, history has stronger effects (Freeman & Lattal, 1992; Nader & Thompson, 1987; Okouchi, 2003a, 2003b). Thus, it is plausible to conclude that the strong effects of the second history maintained by the functional similarities between the last two conditions (the second history

and testing phases) obscured the effects of the first history. At present, this explanation is not contradicted by the results obtained. Because schedules differed only between the second historical and testing conditions in experiments by Cole (2001) and LeFrancois and Metzger (1993), IRIs, often accompanying the schedule change, merit careful consideration as an environmental variable (Okouchi, 2003b). For 2 rats in Cole's experiment exposed to DRL, FR, and FI in that order, mean IRIs of the FI schedule were within 27% of those of the immediately previous FR schedule. Although exact IRIs were undetermined in LeFrancois and Metzger's experiment, the practice of basing the FI value on the average IRIs of DRL and FR schedules does not suggest that there were large differences in IRIs between FR and FI.

Experiment 2

Experiment 2 examined the effects of remote histories of FR and DRL schedules on performance under a VI schedule, which has frequently been used for testing immediate history effects as well as FI schedules (e.g., Freeman & Lattal, 1992; Nader & Thompson, 1987; Poling, Krafft, & Chapman, 1980), but never used for testing remote history effects. The VI schedule, first of all, varies the IRI from one reinforcer to the next. Thus, transition from the DRO to the VI can provide a greater change in environmental stimuli than that from the DRO to the FI did. Thus, if environmental similarities or differences between the immediate historical condition and the history testing condition affect the occurrence of remote history effects, responding under the VI schedule may be different between subjects who were exposed to the FR schedule and those exposed to the DRL.

Method

Subjects and Apparatus

Sujects were 2 male and 4 female undergraduates, 20 to 35 years old. Details of subject screening, informed consent, subject payment, and apparatus were identical to those employed in Experiment 1.

Procedure. Three subjects each were randomly assigned to one of two conditions: (a) FR history, or (b) DRL history. Details of the procedure were as described in Experiment 1, except that a VI 5-s schedule was in effect during the testing phase. A constant-probability progression (Fleshler & Hoffman, 1962) consisting of 20 intervals was used to generate the VI schedule. Each of the intervals was presented once in a 20-interval block in a randomized order.

Results

Figure 2 shows that, just as in Experiment 1, response rates for the 3 subjects under the FR schedule were higher than those for the other 3 under the DRL schedule, and that response rates under the DRO were

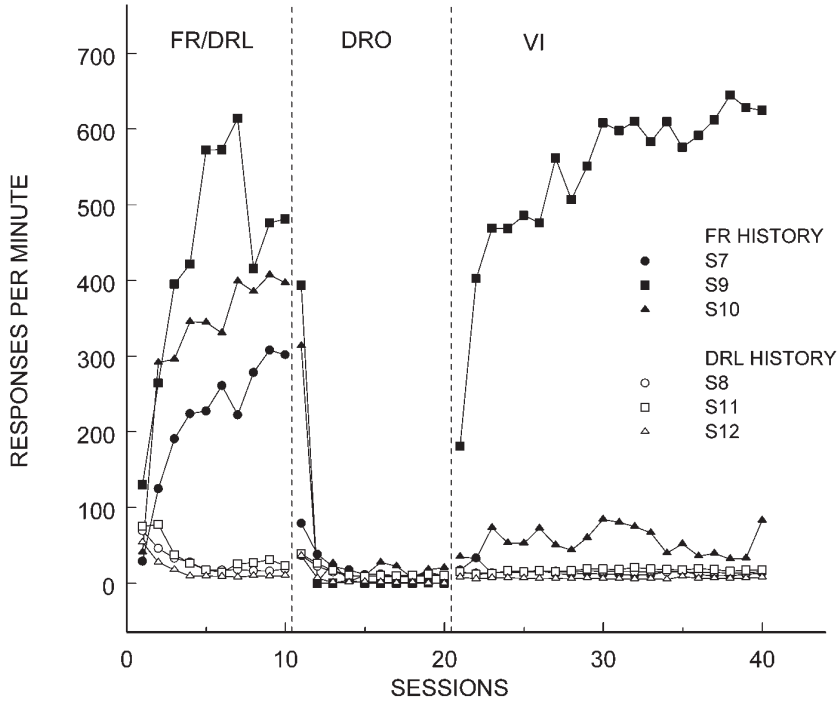

Figure 2. Response rates in each session for each subject of Experiment 2. *FR*/*DRL* identifies the first history phase in which an FR schedule was in effect for Subjects 7, 9, and 10, and a DRL schedule for Subjects 8, 11, and 12. *DRO* identifies the second history phase in which a DRO schedule was in effect. *VI* identifies the testing phase in which a VI schedule was in effect. Filled circles, squares, and triangles represent responding for Subjects 7, 9, and 10, respectively, whereas open circles, squares, and triangles respectively represent responding for Subjects 8, 11, and 12.

extremely low for all 6 subjects irrespective of their history. Results tested under the VI schedule were different from those tested under the FI in Experiment 1. Response rates during all 20 sessions for 2 (Subjects 9 and 10) of 3 with the FR history were higher than those for any of the 3 subjects with the DRL history. For the remaining subject (Subject 7), by contrast, the rates were indistinguishable from those for the DRL history subjects.

Differences in results between Experiments 1 and 2 may shed some light on variables relevant to the emergence of remote history effects. The only procedural difference between these two experiments is the testing schedule (an FI in Experiment 1 and a VI in Experiment 2). Because the value was equal at 5 s, only the variability of IRIs of the testing schedule distinguishes the environmental conditions of the two experiments. That is, the programmed IRIs were fixed at 5 s in Experiment 1 but ranged from .1 s to 20 s in Experiment 2.

As in Experiment 1, the transition from the second history phase to the testing phase was analyzed in detail. Under the DRO schedule,

subjects responded once immediately after a reinforcer, then paused until the next reinforcement, or did not respond at all between the reinforcers, consistent with the results in Experiment 1. For subjects with a history of the DRL schedule reinforced, with a few exceptions described below, IRTs were generally long (ranging from 2.3 to 27.3 s) and response rates were low (ranging from 6.1 to 26.2 responses per minute) during the first 20 VI reinforcers, consistent with the results under the FI in Experiment 1. Short reinforced IRTs (ranging from .5 to 1.2 s) and high response rates (ranging from 49.6 to 113.2 responses per min) were found during the 1st, 3rd, 5th, and 8th reinforcers for Subject 8 and during the 3rd and 18th reinforcers for Subject 11. These exceptional data are probably due to the programmed short IRI (ranging from .1 to 1.0 s) and the obtained short PRPs (ranging from .5 to 1.2 s).

Table 2 shows local data as in Table 1 during the first 20 VI reinforcers for each subject with the FR history. Programmed IRIs also are shown.

Table 2

Molecular Data in First 20 Reinforcers under VI Schedule of Experiment 2

Reinforcer	PRP	Number of responses	Reinforced IRT	Programmed IRI	Obtained IRI	Rate of responses
Subject 7						
1	1.0	2	12.6	1.3	13.5	8.9
2	.8	1	.8	.4	.8	77.9
3	.5	4	4.8	7.5	8.6	28.1
4	.8	4	3.0	8.7	10.7	22.4
5	.8	2	4.7	4.9	5.5	21.9
6	.9	2	3.9	2.4	4.8	24.9
7	3.9	1	3.9	1.0	3.9	15.5
8	3.0	1	3.0	.1	3.0	20.1
9	2.1	2	2.6	4.3	4.7	25.4
10	2.6	2	2.7	3.2	5.3	22.6
11	3.8	1	3.8	1.6	3.8	15.8
12	3.7	1	3.7	2.0	3.7	16.1
13	3.5	5	5.8	20.0	20.4	14.7
14	6.9	1	6.9	2.8	6.9	8.7
15	5.0	2	5.7	10.4	10.7	11.2
16	8.7	1	8.7	3.7	8.7	6.9
17	4.6	3	4.0	13.0	13.1	13.8
18	10.6	1	10.6	5.6	10.6	5.6
19	7.0	1	7.0	6.5	7.0	8.6
20	4.2	1	4.2	.7	4.2	14.5
Subject 9						
1	11.1	1	11.1	1.3	11.1	5.4
2	1.8	1	1.8	.4	1.8	33.5
3	1.0	16	.2	7.5	7.6	127.0
4	1.4	32	4.4	8.7	9.7	197.1
5	2.1	10	.5	4.9	5.1	116.7
6	5.9	1	5.9	2.4	5.9	10.1
7	.9	2	1.2	1.0	2.1	57.1
8	.8	1	.8	.1	.8	80.0
9	1.7	5	.9	4.3	5.2	57.8

10	1.5	4	.8	3.2	3.9	61.5
11	1.0	4	.3	1.6	1.6	146.3
12	1.5	4	.1	2.0	2.1	112.1
13	1.3	40	5.1	20.0	22.3	107.4
14	1.9	2	2.3	2.8	4.1	29.1
15	1.1	8	1.0	10.4	11.1	43.2
16	1.5	8	.3	3.7	3.8	125.7
17	2.8	45	.4	13.0	13.4	201.9
18	2.4	25	.2	5.6	5.6	266.9
19	1.9	55	.1	6.5	6.5	506.1
20	1.2	1	1.2	.7	1.2	49.6
Subject 10						
1	16.6	1	16.6	1.3	16.6	3.6
2	.8	1	.8	.4	.8	72.3
3	.7	3	3.7	7.5	8.2	21.9
4	1.3	2	10.5	8.7	11.8	10.2
5	7.6	1	7.6	4.9	7.6	7.9
6	.9	2	3.1	2.4	4.0	30.2
7	1.0	2	1.8	1.0	2.7	43.8
8	.9	1	.9	.1	.9	70.6
9	.8	4	1.7	4.3	5.6	42.8
10	.8	3	2.3	3.2	4.8	37.7
11	.7	2	2.3	1.6	3.1	39.2
12	.7	2	1.5	2.0	2.3	53.3
13	.7	10	.3	20.0	20.0	30.0
14	.7	2	5.7	2.8	6.4	18.7
15	1.0	9	1.1	10.4	10.8	50.1
16	1.1	4	.9	3.7	4.1	58.5
17	.8	17	2.5	13.0	14.6	69.7
18	1.0	6	2.2	5.6	6.8	53.1
19	.8	2	5.9	6.5	6.7	17.9
20	.9	1	.9	.7	.9	63.8

Note. Data for subjects with an FR history only are shown.

During several early reinforcers immediately after the transition to the VI schedule, performances for Subjects 9 and 10 with the FR history were not different systematically from those for any subjects with a DRL history (results for Subject 7 will be described later). Later in the first VI session, by contrast, performances for Subjects 9 and 10 were different from those of the DRL history subjects. Rates of responding for Subjects 9 and 10 during each reinforcer were higher than those for any subjects with a DRL history since the ninth reinforcer. During intervals programmed longer, responding for these two FR history subjects seems to be different from that for all subjects with a DRL history. For Subjects 9 and 10 (as well as Subject 7), the third reinforcement was their first exposure to an IRI programmed longer than 5 s. During this interval, Subject 9 emitted 16 responses. Thereafter, her response rates were generally high with only an occasional slowdown. Subject 10 did not show any response burst during the first two IRIs programmed longer than 5 s (third and fourth reinforcers), but responded 10 times during 20 s of the 13th reinforcer. For any subjects with a DRL history, by contrast, no more than five responses occurred during any IRIs longer than 5 s.

Although Subject 7 had an FR history, her local responding was not

similar to that of the other FR history subjects. Her number of responses, reinforced IRIs, and response rates in each reinforcer were rather similar to those for the DRL history subjects.

Discussion

Considerable response-rate variability under the VI schedule across the FR history subjects makes it difficult to reach a definitive conclusion on the results of Experiment 2. However, high rates of VI responding for 2 of the 3 FR history subjects were expected by the remote FR history, whereas such an expected result was not found in the FI responding in Experiment 1. Thus, it may not be implausible to suggest that some property of the VI schedule can contribute to the outbreak of remote history effects.

The molecular analyses of the first VI session do not suggest that the remote history effects occur whenever the IRIs of the testing schedule were *different* from those of the immediate historical schedule. Rather, the analyses suggest that the effects occurred during the IRIs of the testing schedule being *long*. Regardless of the remote history, all subjects paused for a certain period during the initial VI exposure, presumably because of carry-over from the immediately previous DRO schedule. When the programmed IRI was long, the response after the pause did not produce a reinforcer. In such an instance, 2 of 3 subjects with an FR history responded frequently (the case of Subject 7 will be discussed later) and reinforced when the last IRT was short. Thereafter, high-rate responding was maintained throughout the VI schedule. Subjects with a DRL history, by contrast, paused again when the response after the pause was not reinforced. Long IRTs produced by these pauses were reinforced, then low-rate responding persisted during the subsequent VI exposure.

In sum, the present molecular analyses suggest that at least two variables may be related to the remote history effects. One is a condition in which behavior, having once been reinforced, becomes nonreinforced, as is referred to also in the literature of resurgence (e.g., Epstein, 1985). Under such a condition, behaviors that had previously been reinforced may re-occur. Another condition probably relevant to the remote history effects is reinforced IRT. As predicted by the IRT reinforcement theory (e.g., Mazur, 2006, pp. 159-160; Skinner, 1938, pp. 270-277) and Skinner's interpretation of superstitious behavior (Skinner, 1948), short reinforced IRTs may have been followed by high response rates and vice versa.

Because the sequence of intervals during the first VI session was adventitiously equal across FR history subjects (Table 2), the response-rate variability across those subjects could not be explained by the procedural differences across them. Rather, this inconsistent result may be caused by the magnitude of nonreinforced periods produced by the VI 5-s schedule. The longest nonreinforced periods (i.e., the longest obtained IRIs) during the first 20 VI reinforcers were 20.4 s, 22.3 s, 20.0 s, 30.9 s, 22.9 s, and 24.8 s for Subjects 7, 9, 10, 8, 11, and 12, respectively.

Thus, it is still an open question what would have happened for Subject 7 if no reinforcer were delivered for a longer time than 20.4 s.

Another variable that may be relevant to the variability across the FR history subjects is an interaction between the current schedule and current behavior. Although programmed contingencies were identical across all subjects, the actual contingencies could differ across them, depending on the responding they emitted. In fact, even under the identical VI schedule, short IRTs were reinforced more frequently for Subjects 9 and 10 who responded frequently than for Subject 7 who seldom responded at all. Thus, such a difference may have enhanced the difference in response rates between the subjects during subsequent VI reinforcers.

Experiment 3

Experiment 3 tested the effects of remote histories of FR and DRL schedules on performance under extinction, FR, and DRL schedules. With the exceptional experiments on immediate history effects (Okouchi, 2003a; Wanchisen, Sutphin, Balogh, & Tatham, 1998), these testing schedules have never been used in studies of history effects. These schedules were selected for the following reasons.

First, they were preferred for the differential lengths of nonreinforced periods they can produce. Extinction, according to its definitive property, provides a nonreinforced period throughout the session that may permit behaviors that have been reinforced to recover. Because our requirement was 25 responses, the FR schedule may also provide long nonreinforced periods, at least during the first reinforcement immediately after the DRO. The DRL schedule, by contrast, may not provide such long periods. Because the programmed IRI was equated with that of the previous DRO schedule, the DRL schedule can (as the FI schedule did in Experiment 1) reinforce the first response after a pause that had previously produced a reinforcer under the DRO schedule. As discussed in Experiments 1 and 2, whether the first response after the pause is reinforced or not is critical, the remote history effects would occur under the extinction and FR, but not under the DRL.

The second reason these testing schedules were selected is because they can produce differential lengths of reinforced IRTs. In Experiment 2, it was argued whether reinforced IRTs during the VI schedule enhanced the response-rate variability across the FR history subjects and obscured the remote history effects. According to this discussion, more systematic results would be found during the substantially long nonreinforced period produced by the extinction. By contrast, the response-rate variability across subjects may increase under the FR testing schedule since the FR produces different reinforced IRTs, depending considerably on the subject's performance. The DRL schedule, which by definition controls reinforced IRTs, will determine the relative importance of the reinforced IRTs in the emergence and persistence of the remote history effects.

Method

Subjects and Apparatus

Subjects were 3 male and 4 female undergraduates, 18 to 22 years old. Details of subject screening, informed consent, subject payment, and apparatus were identical to those employed in Experiment 1.

Procedure. Two groups of 4 and 3 subjects, respectively, were assigned randomly to the FR history and DRL history conditions. Details of the procedure were as described in Experiment 1, except for the testing phase. In each session of the testing phase, one of the following schedules was in effect: extinction, FR 25, DRL 5-s, or DRO 5-s. The first three schedules were used as probes. After the probe session, and before the next one, the subjects were returned to a DRO 5-s baseline session. The order of the schedules was as follows: extinction, DRO, FR, DRO, DRL, DRO, DRL, DRO, FR, DRO, and extinction, for a testing phase of 11 sessions. Except for the extinction sessions, each session lasted until 40 reinforcers occurred. Each extinction session lasted for 20 min.

Subject 15 required additional DRO schedule training during the second history phase. Her second session of this phase was discontinued after about 1 hr because her persistently high rate of responding had produced no reinforcer to that point. A decreased DRO value (DRO 0.5 s) in the third session produced 40 reinforcers during 316 s with 2,254 responses. The DRO values for Subject 15 increased gradually over Sessions 4 through 8, during which the number of responses declined drastically. The DRO values and number of responses in the fourth, fifth, sixth, seventh, and eighth sessions were, respectively, 1 s and 36 responses, 1.5 s and 1 response, 2 s and no response, 3 s and no response, and 5 s and no response. Thereafter, Subject 15 never responded under the DRO 5-s schedule in Sessions 9 through 14. Thus, Subject 15 participated in a total of 14 sessions in the second history phase.

Results

Figure 3 shows the response rates of each subject for each session of each history phase. For Subject 15, who experienced more sessions in the second history phase than other subjects, only the data during the last 10 sessions of that phase were shown. Results of the history phases replicate those in Experiments 1 and 2. Response rates for subjects under the FR schedule were higher than for those under the DRL schedule, whereas the rates under the DRO schedule were extremely low for all 7 subjects, irrespective of differences in their schedule history.

Figure 3 also shows the response rates of each subject for each testing session. Those rates suggest an interaction between remote histories and current schedules. In both of the FR test sessions, response rates for all 4 subjects with the FR history were higher than those for any of the 3 subjects with the DRL history. During the first extinction session, rates for the FR history subjects also were higher than those for the DRL

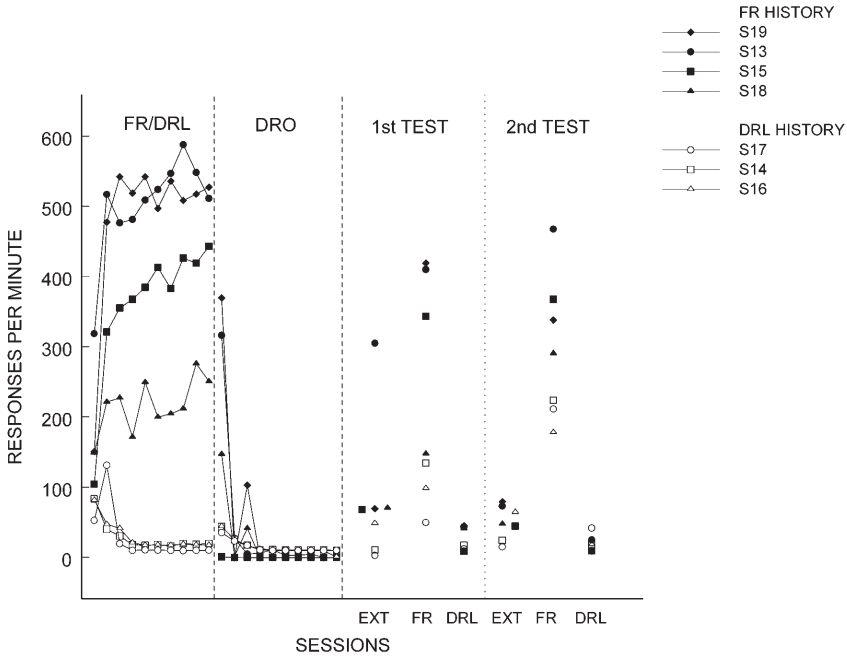

Figure 3. Response rates in each session of the first (FR/DRL) and second (DRO) history phases and in each probe session of the testing phase for each subject of Experiment 3. For Subject 15, data during the first four sessions of the second history phase are not shown (see text for details). *EXT, FR,* and *DRL* below the abscissa identify the probe sessions in which extinction, FR, and DRL schedules, respectively, were in effect. Order of probe schedules shown is the order in which they occurred during the first test (1st TEST); whereas DRL, FR and extinction actually were presented in the second test (2nd TEST). Filled diamonds, circles, squares, and triangles represent responding for Subjects 19, 13, 15, and 18, respectively, who were exposed to an FR schedule in the first history phase, whereas open circles, squares, and triangles, respectively represent responding for Subjects 17, 14, 16, who were exposed to a DRL schedule in that phase.

history subjects. The difference between historical conditions in the second extinction was smaller than that in the first. Except for Subject 16, however, rates for the FR history subjects remained higher than those for the DRL history subjects. Under the DRL schedule, there was no systematic difference in the response rates between the historical conditions.

Table 3 shows local data during the first six reinforcers of the FR and DRL probe sessions. The local data of the FR probe session for Subject 17 are not shown because they were lost because of mechanical error. Consistent with the results of most subjects in Experiments 1 and 2, subjects under the DRO schedule (not shown in Table 3) either responded immediately after every reinforcement (Subjects 14 and 17) or did not respond at all (Subjects 13, 15, 18, 19, and 16). Consistent with the overall rates in Figure 3, the initial molecular data indicate that response rates under the FR probe schedule were differentiated between

Table 3

Molecular Data in First Six Reinforcers during First FR and DRL Probe Sessions of Experiment 3

Reinforcer	PRP	Number of responses	Reinforced IRT	Obtained IRI	Rate of responses
FR history					
Subject 13					
FR probe					
1	.6	25	.4	41.7	36.0
2	.6	25	.1	3.0	493.4
3	.1	25	.1	2.2	678.7
4	.2	25	.1	2.3	666.7
5	.4	25	.1	2.7	559.7
6	.7	25	.1	3.4	439.9
DRL probe					
1	.4	53	35.2	41.7	76.2
2	.6	118	25.5	37.6	188.4
3	.7	7	6.8	9.1	46.3
4	.4	5	5.7	11.1	27.1
5	.4	2	6.9	7.2	16.6
6	.4	2	5.9	6.3	19.0
Subject 15					
FR probe					
1	23.0	25	.3	31.1	48.2
2	10.2	25	.4	18.0	83.5
3	.5	25	.4	7.4	201.6
4	.4	25	.1	3.0	503.4
5	.2	25	.1	2.7	561.8
6	.3	25	.1	2.6	568.2
DRL probe					
1	14.3	1	14.3	14.3	4.2
2	7.8	1	7.8	7.8	7.7
3	.4	2	6.4	6.8	17.6
4	4.7	2	8.9	13.6	8.8
5	6.4	1	6.4	6.4	9.4
6	4.1	2	8.1	12.2	9.9
Subject 18					
FR probe					
1	161.6	25	.7	199.7	7.5
2	1.6	25	.1	4.9	308.6
3	.3	25	.2	3.4	446.4
4	.1	25	.2	3.7	405.4
5	.4	25	.3	5.0	302.4
6	.4	25	.2	5.0	303.0
DRL probe					
1	11.9	1	11.9	11.9	5.1
2	2.4	2	16.3	18.6	6.4
3	9.0	1	9.0	9.0	6.7
4	8.2	1	8.2	8.2	7.3
5	7.3	1	7.3	7.3	8.2
6	6.8	1	6.8	6.8	8.9
Subject 19					
FR probe					
1	1.4	25	.2	10.2	146.8
2	.5	25	.2	4.1	367.6

3	.5	25	.1	3.8	398.9
4	.4	25	.2	4.5	333.3
5	.7	25	.1	4.1	365.9
6	.9	25	.1	3.8	397.9
DRL probe					
1	.6	106	40.1	52.2	121.9
2	.9	131	17.1	40.8	192.8
3	12.8	1	12.8	12.8	4.7
4	1.1	2	11.7	12.8	9.3
5	9.5	1	9.5	9.5	6.3
6	5.0	3	9.2	17.0	10.6
DRL history					
Subject 14					
FR probe					
1	.9	25	.3	136.0	11.0
2	.9	25	.5	75.8	19.8
3	2.5	25	.3	30.0	50.0
4	.7	25	.3	9.6	155.6
5	.5	25	.4	8.6	175.0
6	.4	25	.5	9.1	165.7
DRL probe					
1	.8	2	8.9	9.7	12.4
2	.6	3	9.1	10.2	17.6
3	.4	3	5.5	10.3	17.5
4	.7	2	6.0	6.7	18.0
5	.1	2	5.9	5.9	20.2
6	.4	2	6.3	6.7	17.8
Subject 16					
FR probe					
1	7.8	25	.3	354.0	4.2
2	1.2	25	.7	16.9	88.7
3	.8	25	.5	10.3	146.3
4	.8	25	.5	10.4	144.8
5	17.9	25	.1	25.1	59.7
6	.7	25	.2	6.3	237.7
DRL probe					
1	.8	68	9.0	21.7	187.8
2	.9	144	14.1	53.7	160.8
3	8.2	1	8.2	8.2	7.3
4	7.4	1	7.4	7.4	8.1
5	6.1	1	6.1	6.1	9.9
6	11.1	1	11.1	11.1	5.4
Subject 17[a]					
DRL probe					
1	1.8	2	22.0	23.8	5.0
2	1.2	3	6.5	8.7	20.6
3	1.0	17	9.5	41.5	24.6
4	5.9	1	5.9	5.9	10.3
5	2.5	2	9.7	12.2	9.8
6	6.5	1	6.5	6.5	9.3

[a] Within-session data of the first FR probe session for Subject 17 were lost because of mechanical error.

subjects with different histories (Table 3). Except for the second reinforcer of Subject 15 and the first reinforcer of Subject 18, response rates in each reinforcer were higher for the FR history subjects than those for the DRL

history subjects. Except for Subject 19, the longest IRI for each subject was longer than that for any subjects in Experiment 2, suggesting satisfactorily long nonreinforced periods being provided. Reinforced IRTs were generally shorter for the FR than for the DRL history subjects, but the magnitude of that difference was quite small. There was no systematic difference in PRPs between them. Thus, the results of reinforced IRTs and PRPs suggest that IRTs between reinforcers in general, including nonreinforced IRTs, were shorter for the FR than for the DRL history subjects. In fact, during the two FR probe sessions, IRTs longer than 1 s occurred only 5, 5, 11, and 7 times for FR history Subjects 13, 15, 18, and 19, respectively, but 32 and 30 times for DRL history Subjects 14 and 16, respectively.

Under the DRL probe schedule, there was no systematic difference in response rates in each reinforcer between the subjects with different histories, consistent with the results of the overall rates in Figure 3. Contrary to our expectations, however, the number of responses emitted in the first reinforcer for some subjects was different from that in Experiment 1. Subjects 13, 19, and 16 emitted 53, 106, and 68 responses until the first reinforcer, respectively, whereas no subjects in Experiment 1 emitted more than two responses. Procedural differences between the two experiments might account for this inconsistency. Contrary to subjects in Experiment 1 exposed to only the FI schedule during the testing phase, subjects in Experiment 3 were exposed to the extinction and FR probe sessions prior to the first DRL probe session. Despite such contaminated conditions, Subjects 15 and 18 with the FR history and Subjects 14 and 17 with the DRL history showed an almost identical performance to that in Experiment 1. That is, the first response after a pause was reinforced during the first DRL reinforcer then the pause-respond pattern was repeated. This coincidence may partially support the hypothesis that reinforcing the first response after a pause hinders the remote history effects.

Because data without a reinforcer do not permit local analyses as shown in Table 3, within-session data obtained from the extinction were analyzed per minute rather than per reinforcer. Figure 4 shows cumulative responses of each subject during the first extinction session as a function of time in minutes. Except for the 18th minute cell, the FR history subjects emitted more responses than the DRL history subjects did. Thus, these local data were generally consistent with the overall rates, indicating systematic differences in responding between the remote histories.

Discussion

The results of the extinction and FR probe sessions demonstrate that remote histories of FR and DRL schedules affected responding under the current schedules. These results, together with those under the FI (Experiment 1), VI (Experiment 2), and DRL (Experiment 3), were consistent with our prediction based on the IRIs, that is, when IRIs are thoroughly longer than those under the immediately previous schedule,

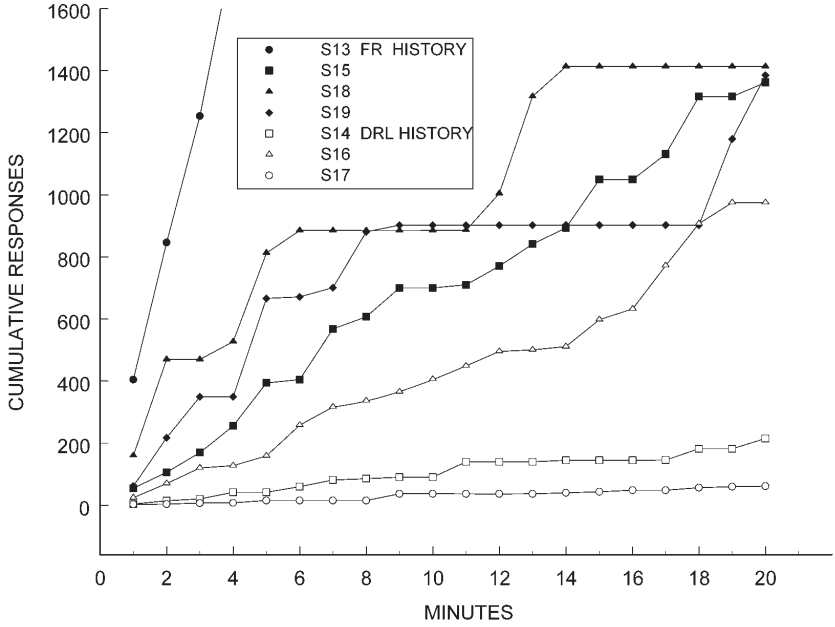

Figure 4. Cumulative frequency of responses of each subject during the first extinction session as a function of time in minutes. Filled circles, squares, triangles, and diamonds represent responding for Subjects 13, 15, 18 and 19, respectively, who were exposed to an FR schedule in the first history phase, whereas open squares, triangles, and circles, respectively represent responding for Subjects 14, 16, and 17 who were exposed to a DRL schedule in that phase. Data during the last 17 min for Subject 13 are not shown because of the large number of his responses (6,104 responses during the session).

an older pattern of responding that produced reinforcers in the past (i.e., high-rate or low-rate responding) may resurge, whereas when the IRIs are not substantially longer than those under the immediately previous schedule, the older pattern may not resurge.

Contrary to the results under the VI schedule in Experiment 2, reinforced IRTs under the FR probe for the DRL history subjects were very short and comparable to those for the FR history subjects. This result suggests that the reinforced IRT under the current schedule is not a necessary condition for the emergence of remote history effects.

General Discussion

In the present experiments, subjects with a history of an FR schedule and those with a history of a DRL schedule responded at high and low rates, respectively, under certain schedules. These results are consistent with those of previous studies (e.g., Nader & Thompson, 1987; Urbain et al., 1978; Weiner, 1964) in that the response rates under the current schedules were different depending on the schedules

that had previously been in effect. The present results, however, were obtained after the rates had become indistinguishable between subjects by eliminating the response under a DRO schedule, thus, demonstrating that behavioral histories remote from current contingencies affected the current responding.

One may, however, criticize the present study for being incomplete. For example, sample sizes of 2 to 4 subjects per condition may be too small to allow for between-subject comparisons, or differential results across the testing schedules may violate the generality of the effects. Though such criticisms may have a certain validity, they do not invalidate the implications of the present study. First, although the sample sizes were indeed small, remote histories of the FR and DRL schedules were found clearly under the first extinction session and two FR probe sessions. These results contrast with those in previous studies that did not find any effects of remote histories (Cole, 2001; LeFrancois & Metzger, 1993) or that obtained the effects using controversial procedures (Weiner, 1969). Secondly, the present experiments found that the remote history effects were a function of the current testing schedules. This finding has not been reported because previous studies have used exclusively FI schedules for testing. Thirdly, the present results suggest one of the variables possibly relevant to the emergence of the remote history effects.

At least two questions have been posed concerning the history effects: Do they occur or not, and, if they do, how long do they persist. In the studies of immediate history effects, findings on the latter question have been inconsistent (e.g., Baron & Leinenweber, 1995; Cole, 2001; Lopez & Menets, 2005; Urbain et al., 1979; Wanchisen et al., 1989), while those on the former question have not. The fact is that the immediate history effects have been found under all of the schedules tested, such as FI (Weiner, 1964), VI (Poling et al., 1980), FR (Wanchisen et al., 1998), DRL (Wanchisen et al., 1998), or extinction (Okouchi, 2003a). This contrasts with remote history effects, which were observed only under limited schedules in the present Experiment 3.

Perhaps the number of conditions required for examining the effects may be related to this inconsistency. The general method for the study of immediate history effects consists of two conditions (Lieving & Lattal, 2003; Tatham & Wanchisen, 1998). In the first, a particular history of responding is established (immediate history condition). In the second, the influence of this history on current performance is examined (testing condition). The examination of remote history effects, by contrast, needs three conditions, remote history, immediate history, and testing conditions.

Depending on the number of conditions, behavioral persistence may affect remote history effects differently from immediate ones. It is very common to find that responding being reinforced in a condition carries over to adjacent conditions. Because of their procedural or definitional properties, immediate history effects inevitably involve such response persistence (Lieving & Lattal, 2003). In this respect, the occurrence of immediate history effects may be said to be largely caused by this

persistence. In contrast, remote history effects are characterized not by the persistence of but rather by the recovery of behavioral effects (Lieving & Lattal, 2003). Because the persistence of behavioral effects produced under remote historical schedules is extinguished prior to the introduction of the testing schedule, it is unlikely to facilitate the emergence of remote history effects. In remote historical experiments, rather, persistence from the immediate historical condition can interfere with remote effects. Variables that inhibit the persistent effects of the immediate history and/or facilitate the recovery of the behavioral effects of the remote history may be critical for the occurrence of remote history effects. The results of the present three experiments suggest nonreinforced period or obtained IRI under the testing condition may be one of those variables.

Immediate history effects are said to depend on at least the following three variables: the history building condition, the history testing condition, and interaction between them (Okouchi, 2003b). According to this discussion, the remote history effects can depend on *seven* variables because any examination of the effects requires three conditions consisting of two history building conditions and one history testing condition. Despite such complexity, the present study has clearly demonstrated the effects of remote FR and DRL histories under the extinction and the FR schedule, and has suggested a variable presumably relevant to their emergence. The present study is exploratory but informative to future experiments examining the determinants of remote history effects.

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