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AN EXPLORATION OF REMOTE HISTORY EFFECTS IN HUMANS: II. THE EFFECTS UNDER FIXED-INTERVAL, VARIABLE-INTERVAL, AND FIXED-RATIO SCHEDULES

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Five undergraduates responded under a fixed-ratio (FR) 145 schedule, and 5 others responded under a differential-reinforcement-of-low-rate (DRL) 20-s schedule. Both groups were then exposed to a differential-reinforcement-of-rates-with-pacing 1 s < interresponse time (IRT) ≤ 2 s schedule. Following this, probe sessions under fixed-interval (FI) 20-s, variable-interval (VI) 20-s, and FR 145 schedules were interspersed among baseline sessions of the 1 s < IRT ≤ 2 s schedule. Response rates under the FI and VI schedules were higher for participants with a history of the FR schedule than for those with a DRL history. Under the FR schedule, such a systematic difference by remote histories was observed only during the first of the 3 probe sessions.

Key words: behavioral history, remote history effects, interreinforcer intervals, interresponse times, differential-reinforcement-of-rates-with-pacing schedules, screen touch, humans

Weiner (1964) found that humans with histories of fixed-ratio (FR) schedules responded at high rates under fixed-interval (FI) schedules, whereas those with differential-reinforcement-of-low-rate (DRL) schedule histories responded at low rates under the same FI schedules. Since this seminal work appeared, many investigators have shown with different species 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).

Weiner (1969) also reported a result suggesting that organisms' behavior was affected by schedules that had been in effect in the *remote* past. He exposed humans to DRL, FR, and FI schedules, in that order. Response rates during ten 1-hr sessions under the FI schedule were low and not similar to those shown under the FR schedule, which had been in effect immediately before the current FI schedule. Rather, the rates more closely resembled those shown under the DRL schedule, which had been in effect long before the FI.

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Contrasted with the effects of immediate histories, which have been found ubiquitously (e.g., Nader & Thompson, 1987; Urbain et al., 1978; Wanchisen et al., 1989), the reliability and generality of the effects of remote histories are restricted. The general method for the study of remote history effects consists of three conditions: A particular history of responding is established (remote history condition), a history of responding different from the remote history is established (immediate history condition), and the influence of these histories on current performance is examined (testing condition). Some experiments have shown that the remote history effects were different across experiments, as if they had depended on the sequence of the schedules presented. Such remote history effects were found in humans when the sequence was (a) DRL, FR, and FI or (b) FR, differential-reinforcement-of-other-behavior (DRO), and FR, whereas no such effect was found when the sequence was (c) FR, DRL, and FI; (d) FR, DRO, and FI; (e) FR, fixed-time (FT), and FI; or (f) FR, extinction, and FI (Weiner, 1969, 1982). In other experiments, by contrast, the effects appeared to differ depending on schedules in the testing condition, the final part of the sequence. Response rates for human participants who had been exposed first to an FR schedule and then to a DRO were higher than those of participants exposed first to a DRL schedule and then to a DRO when the rates were assessed under the FR schedule, but not when they were assessed under FI, VI, or DRL schedules (Okouchi, 2007). Cole (2001) and LeFrancois and Metzger (1993), moreover, reported that the responding of rats under FI schedules was affected by immediate FR schedule histories rather than by remote DRL schedule histories. The present experiment provides some evidence that human responding under FI, VI, and FR schedules was affected by FR and DRL schedules that had been in effect in the remote past.

The present experiment is unique in terms of three procedures. First, values of the schedules were set such that interreinforcer intervals (IRIs) became longer during the testing condition than during the immediate history condition. This practice was employed because previous post-hoc molecular analyses suggested that the remote history effects tended to occur when the obtained IRIs of the testing condition were longer than those of the immediate history condition (Okouchi, 2007). Under a testing condition during which IRIs are long, responding that was reinforced in the immediate history condition becomes nonreinforced. Under such a condition, responses that had previously been reinforced, for example, those in the remote history condition, may recur, as is described also in the literature on resurgence (e.g., Epstein, 1985).

Second, the present experiment selected a schedule of differential-reinforcement-of-rates-with-pacing (Ferster & Skinner, 1957, pp. 498-502) 1 s $<$ interresponse time (IRT) $\leq$ 2 s as an immediate history. Previous experiments of remote history effects have used FR (Cole, 2001; Weiner, 1969, 1982), DRL (Cole, 2001; Weiner, 1982), or DRO (Okouchi, 2007; Weiner, 1982) schedules as immediate history schedules, each of which usually produces high-rate or low-rate responding. The 1 s $<$ IRT $\leq$ 2 s pacing schedule, by contrast, can produce intermediate rates of responding. Such intermediate rates of responding may be more suitable as a baseline to detect the net effects of remote histories than the high or low rates, because the intermediate rates can increase or decrease, free from both ceiling and floor effects.

Third, the present experiment used testing schedules as probes. Probe sessions under FR, VI, and FR schedules were interspersed among baseline sessions of the 1 s < IRT ≤ 2 s pacing schedule. Though not common, some studies of history effects have used drugs (Barrett, 1977; Cohen, Pedersen, Kinney, & Myers, 1994; Egli & Thompson, 1989; Nader & Thompson, 1987, 1989; Poling, Krafft, & Chapman, 1980; Urbain et al., 1978), drinking water (Johnson, Bickel, Higgins, & Morris, 1991), prefeeding (Cohen et al., 1994; Doughty, Cirino, Mayfield, Da Silva, Okouchi, & Lattal, 2005), and schedules (Okouchi, 2003, 2007) as probes, and have found some effects that were not observed during the baseline (Barrett, 1977; Egli & Thompson, 1989; Johnson et al., 1991; Okouchi, 2007). The probe technique, of course, cannot identify longevity of the effects but permits a replication of multiple conditions economically (Sidman, 1960, pp. 120–127). Because we do not know which schedules can contribute to remote history effects, at present this technique is reasonable to explore the effects under different schedules.

Of the schedules we used in the remote history condition, the FR schedule was presented again as a probe in the testing condition, but the DRL was not. The FR testing schedule was selected because of its reliability. Previous experiments have found remote history effects under FR schedules (Okouchi, 2007; Weiner, 1982). Thus, the FR schedule was expected to allow an examination of whether the remote history effects obtained in the previous experiments could be replicated in the present experiment. The remote history effects, by contrast, have not been found under the DRL schedule (Okouchi, 2007). Under this schedule, even the immediate history effects have been found only transiently (Wanchisen, Sutphin, Balogh, & Tatham, 1998). These facts indicate that the DRL does not have precedence over other schedules to be used in the testing condition.

Method

Participants

Four male and six female undergraduates recruited from an educational psychology class at Osaka Kyoiku University served as participants. They were 18 to 20 years old, and none had experience with operant-conditioning experiments.

Apparatus

The room in which the experiment was conducted was 1.70 m wide, 2.20 m long, and 2.17 m high. A Nihon Electric Company PC-9821AP microcomputer, located in an adjacent room, was used to control the experiment. The participant sat at a desk facing a color display monitor (250 mm wide by 180 mm high) equipped with a MicroTouch Systems touch screen. A filled white circle (55 mm in diameter) was presented in the center of the black screen, and each touch on the circle (operandum) was defined as a response. All interevent times were recorded in real time with 50-ms resolution. A second white circle (30 mm in diameter) was presented at the bottom left of the monitor screen. 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 screen.

Procedure

Participants signed an informed consent agreement that specified the frequency and duration of their participation and the average earnings for such participation. They agreed to remain in the experiment for a maximum of eight 90-min experimental periods and actually participated in seven to eight experimental periods. After every experimental period, participants were paid for their performance (2 yen per 100 points, approximately .018 US dollars). Upon completion of the entire experiment, participants were paid (100 yen per 90 min) and debriefed. The overall earnings and the earnings per hour for each participant ranged from 4,502 to 4,800 yen (approximately 40.809 to 43.510 US dollars), and from 375 to 447 yen (approximately 3.399 to 4.052 US dollars), respectively. Although it may seem low, this amount of earnings is comparable to that in previous history experiments using Japanese students (Okouchi, 2007). A clear difference in response rates between FR and DRL schedules (shown in the Results section) indicates that the rates were under the control of the schedule contingencies and suggests that points exchanged for money functioned as a reinforcer.

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

> Your task is to earn points. A hundred points are worth 2 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 screen of the display monitor. If you touch the circle, the center circle may disappear, and then a small circle will appear in the bottom of the monitor screen. By touching the small circle, you can earn points. Accumulated points will be shown in the top right of the screen.
>
> The words "READY" and "GO" will appear in sequence on the monitor screen. When the word "GO" disappears, the task will begin and last until the words "GAME OVER" appear on the screen.

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

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 screen. A touch during a 3-s consummatory response period darkened the circle and accumulated 100 points on the top right counter. If the participant did not touch the circle during this period, no points were delivered. This occurred only 9 times during the experiment, out of 19,634 opportunities for the consummatory response.

Each session lasted until 40 reinforcers occurred, except for each of the probe sessions, which lasted until 40 reinforcers occurred or 20 min (excluding the consummatory response periods) elapsed, whichever came first. Thereafter, the words "GAME OVER" appeared at the top left of the monitor. During a 90-min experimental period, a maximum of 10 variable-duration sessions occurred. Sessions were separated by 1- to 2-min breaks. This experimental period was conducted once per day, two times per week.

Two male and three female participants each were randomly assigned to one of two conditions: (a) FR history (Participants 1, 3, 5, 8, and 10) or (b) DRL history (Participants 2, 4, 6, 7, and 9), where Participants 1, 8, 2, and 7 were male. There was no systematic gender difference in the results. FR and DRL history participants were exposed first to FR and DRL schedules, respectively, in the remote history condition. Then, all participants were exposed to a $T_1 < IRT \leq T_2$ pacing schedule in the immediate history condition, followed by the testing condition.

The remote history condition lasted 15 sessions. The values of the FR and DRL schedules increased progressively over the first six sessions. In the first, second, third, fourth, and fifth sessions, the values of the FR schedule were 5, 10, 20, 40, and 80 responses, respectively, whereas those for the DRL schedule were 1, 2, 4, 8, and 16 s, respectively. In the remainder of the sessions in this condition, the values for the FR and DRL schedules were set at 145 responses and 20 s, respectively. The final values of the FR and DRL schedules were determined such that relatively long IRIs were produced.

The immediate history condition lasted 10 sessions. The lower limit of the required IRT for reinforcement (T_1) was 1 s throughout the condition, whereas the upper limit of that (T_2) in the first, second, third, fourth, and fifth sessions of this condition was 21, 17, 9, 5, and 3 s, respectively. In the remainder of the sessions in this condition, the upper limit was 2 s. Any IRT or postreinforcement pause (when the first response following a reinforcer occurred) that was longer than the lower limit (T_1) and equal to or shorter than the upper limit (T_2) was followed by the consummatory response period.

The testing condition lasted 25 sessions. In each session of this condition, one of the following schedules was in effect: FI 20 s, VI 20 s, FR 145, or $1 \text{ s} < IRT \leq 2$ s. The first three schedules were used as probes (cf. Okouchi, 2007). As described previously, all of these schedules were used as testing schedules in previous experiments and provided different results (Cole, 2001; LeFrancois & Metzger, 1993; Okouchi, 2007; Weiner, 1969, 1982). Unlike previous experiments, values of the present testing schedules were set to produce IRIs longer than those in the immediate history condition and approximately equal to those in the remote history condition. A constant-probability progression (Fleshler & Hoffman, 1962) consisting of 20 intervals was used to generate the VI schedule. After the probe session and before the next one, the participants were returned to two sessions of the $1 \text{ s} IRT \leq 2$ s baseline. The order of the probe schedules was as follows: FI, VI, FR, FR, VI, FI, FI, VI, and FR. Intervals between the date of the last session of the remote history condition and that of the first testing session were 8, 5, 7, and 14 days for Participants 1, 5, 4, and 7, respectively, whereas the intervals were less than 3 days for the remainder.

Results

Differences in response rates and IRIs between the two groups of different schedule histories (FR and DRL) were evaluated not only visually but also statistically by using the Mann-Whitney *U* test for nonparametric comparisons of independent groups. The alpha value was set at the 0.05 level in all analyses.

Remote History Condition

Table 1 shows the median response rate for the last three sessions of the remote history condition for each participant. Response rates for all participants exposed to the FR schedule were higher than those for any exposed to the DRL schedule. The difference between the two groups was significant ($p < .01$). Thus, the responding for each participant was controlled well by the contingencies in effect. Table 2 shows the median IRI for the last three sessions of this condition for each participant. The IRIs for the FR participants were between 14.4 s and 28.1 s, and those for the DRL participants were between 22.6 s and 32.5 s, indicating that the ranges of the IRIs for the FR and DRL participants overlapped. There was no significant difference in the IRIs between the groups.

Table 1
Median Responses per Minute for the Last Three Sessions of the Remote and Immediate History Conditions and for Baseline Sessions Immediately Before the Probe. Between-Group Differences Were Evaluated Using the Mann-Whitney U Test for Nonparametric Comparisons of Independent Groups (Bottom Row).

Participant			
FR history	Remote	Immediate	Baseline
1	538.1	51.1	45.5
3	584.8	83.5	79.3
5	539.8	57.1	46.5
8	521.4	45.3	42.9
10	309.5	69.2	64.4
DRL history			
2	2.8	47.9	53.2
4	2.5	46.1	51.5
6	2.0	40.4	41.8
7	7.4	36.2	46.8
9	2.8	52.7	55.3
Mann-Whitney			
U test	$p < .01$	ns	ns

Table 2
Median Interreinforcer Intervals (in Seconds) for the Last Three Sessions of the Remote and Immediate History Conditions, for Baseline Sessions Immediately Before the Probe, and for Three Sessions of FI, VI, and FR Probes. Between-Group Differences Were Evaluated Using the Mann-Whitney U Test for Nonparametric Comparisons of Independent Groups (Bottom Row).

	History conditions			Testing conditions		
Participant	Remote	Immediate	Baseline	FI	VI	FR
FR history						
1	16.2	1.3	1.4	20.5	20.7	22.2
3	14.4	1.5	1.5	21.8	21.2	16.4
5	16.1	1.6	3.2	21.6	21.0	20.0
8	16.7	1.4	1.6	27.7	27.1	16.4
10	28.1	1.8	1.8	21.1	20.8	33.3
DRL history						
2	22.6	1.3	1.2	20.9	21.8	24.1
4	27.2	1.7	1.4	23.5	41.4	27.9
6	32.5	1.5	1.5	32.4	35.3	—[a]
7	26.5	1.7	1.5	27.2	22.3	26.3
9	25.9	1.5	1.5	23.0	25.6	1200.0
Mann-Whitney						
U test	ns	ns	ns	ns	ns	ns

[a]Responses emitted were less than 145 during two of the three FR probe sessions, and no reinforcer occurred.

Immediate History Condition

During the first session in which the $T_1 < IRT \leq T_2$ pacing schedule was introduced, response rates for participants who had been exposed to the FR schedule ranged from 247.0 to 478.9, whereas those for participants who had been exposed to the DRL schedule ranged from 4.3 to 56.7. The difference between the two groups was significant ($p < .01$), suggesting history effects of prior FR and DRL schedules. However, such a difference in response rates was indiscernible on the subsequent sessions. The median responses per min for the last three sessions of the immediate history condition for the FR and DRL history participants were between 45.3 and 83.5 and 36.2 and 52.7, respectively (see Table 1). The median IRIs in this condition for the FR and DRL history participants were between 1.3 s and 1.8 s and 1.3 s and 1.7 s, respectively (see Table 2). The groups did not differ significantly on either measure. These results suggest that (a) the response rates and IRIs were controlled at medium and short values, respectively, in all participants, and (b) effects of FR and DRL histories disappeared with continued exposure to the $T_1 < IRT \leq T_2$ pacing schedule.

Testing Condition

Of the two consecutive baseline sessions of the 1 s < IRT ≤ 2 s pacing schedule before the next probe, data from only the second session were analyzed (see Tables 1 and 2) and were used to calculate percent change in response rates from the baseline to the probe. From the immediate history condition to the baseline of the testing condition, response rates under the 1 s < IRT ≤ 2 s schedule decreased and increased, respectively, for the FR and DRL history partcipants (see Table 1), whereas IRIs did not change systematically (see Table 2). Neither the response rates nor the IRIs during the baseline sessions differed significantly between the FR and DRL history groups.

The median IRI of the three sessions of each probe schedule in each participant is shown in Table 2. The value in the FR probe for Participant 6 was not obtained because no reinforcer occurred during two of the three probe sessions. As shown in Table 2, the median IRIs during the probe sessions were comparable to those during the remote history sessions and longer than those during the immediate history and baseline sessions. There was no significant group difference in the IRIs in any probe schedules.

The left panel of Figure 1 shows the median response rate in each type of probe schedule for each participant. The rates were higher for all

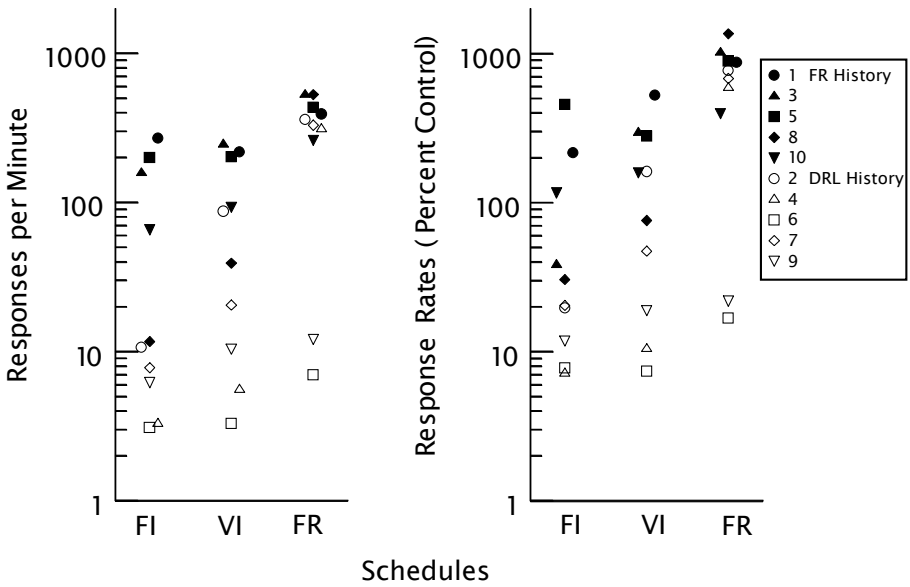

Figure 1. The response rate for each participant under each probe schedule (left panel). On the right panel, the response rate during each probe session was expressed as a percentage of the response rate obtained during the preceding 1 s < IRT ≤ 2 s baseline session. Each data point represents the median of the values of the three probe sessions. "FI," "VI," and "FR" below the abscissa identify FI 20-s, VI 20-s, and FR 145 schedules being in effect, respectively. Filled circles, triangles, squares, diamonds, and inverted triangles represent responding for Participants 1, 3, 5, 8, and 10, respectively, who were exposed to an FR 145 schedule in the remote history condition, whereas open circles, triangles, squares, diamonds, and inverted triangles respectively represent responding for Participants 2, 4, 6, 7, and 9, who were exposed to a DRL 20-s schedule in the remote history condition.

participants with the FR history than for any with the DRL history under the FI schedule, and for four (Participants 4, 6, 7 and 9) of the five DRL history participants under the VI schedule. Under the FR schedule, by contrast, the rates for the FR history participants were higher than those for only two (Participants 6 and 9) of the DRL history participants. The differences between the two groups were significant under the FI ($p < .01$) and VI ($p < .05$) schedules, but not under the FR. These results suggest that remote histories comprised of exposure to FR and DRL schedules affected responding under the FI and VI schedules.

Despite no systematic differences on the median of the three probe FR sessions, a session-by-session analysis suggested short-lived effects. During the first FR probe session, unlike the median results in Figure 1, the percentages for all participants with the FR history were higher than those for all but one (Participant 2) with the DRL history ($p < .05$). During the next two sessions, the differences between the two groups were not systematic nor significant, consistent with the results combined across sessions.

Although median response rates during the 1 s < IRT ≤ 2 s baseline sessions did not differ significantly in participants with FR and DRL histories, Table 1 suggests that the median response rates for the former individuals were generally higher. To examine a possibility that this modest difference might confound with the probe rates, the response rate during each probe session was expressed as a percentage of the response rate obtained during the preceding baseline session. Response rates after this percent control (right panel of Figure 1) were similar to the rates before the control (left panel of Figure 1). Results of statistical tests of the percentages exactly replicated the results of the actual response rates. The differences between the FR and DRL history groups were significant under the FI ($p < .01$) and VI ($p < .05$) schedules. The differences were not significant on the median of the three probe FR sessions but significant only during the first FR probe session ($p < .05$). These results do not indicate that the systematic differences in the probe rates between the two groups were an artifact of differences in the baseline rates between them.

Figures 2, 3, and 4 show cumulative responses of each participant during successive 2-min periods of the FI, VI, and FR probe sessions. These within-session data generally were consistent with the summary data in Figure 1. With the exception of Participants 4 and 8 during the second probe and Participants 7 and 8 during the third probe, all participants with the FR history emitted more responses than the DRL participants did throughout the FI probe sessions (see Figure 2). When the VI schedule was in effect, all participants with the FR history emitted more responses than did all participants with the DRL history, except Participants 2 and 7 during the last two probes (see Figure 3). The data for Participant 4 during the first FR probe are not shown because the data file necessary for this analysis was accidentally lost (left panel of Figure 4). With the exception of this participant, all participants with the DRL history, including Participant 2, who showed an exceptionally high response number in the overall session, emitted fewer responses than the FR participants did during the first 8 min. Participant 4 spent more than 11 min before receiving the first reinforcer during this session, suggesting that less than 145 responses were emitted during the first 10 min. During the second and third FR probes, there was no systematic difference in cumulative responses between the two groups

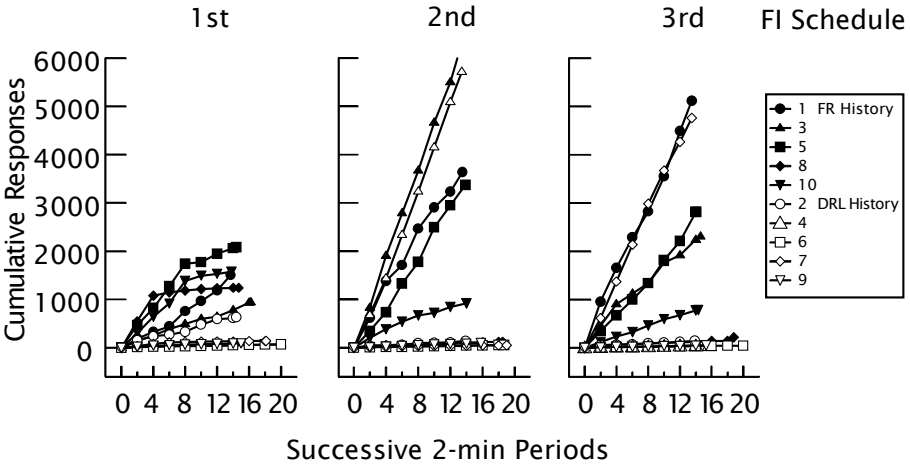

Figure 2. Cumulative frequency of responses of each participant during the first (left), second (center), and third (right) probe sessions under an FI 20-s schedule as a function of time in 2 min. Filled circles, triangles, squares, diamonds, and inverted triangles represent responding for Participants 1, 3, 5, 8, and 10, respectively, who were exposed to an FR 145 schedule in the remote history condition, whereas open circles, triangles, squares, diamonds, and inverted triangles respectively represent responding for Participants 2, 4, 6, 7, and 9, who were exposed to a DRL 20-s schedule in the remote history condition. Each probe session lasted until 40 reinforcers occurred or 20 min elapsed, whichever came first. When the session terminated before 20 min, the final data point was plotted as a function of the total session time. Final data are not shown during the second session for Participant 3 because of the large number of her responses, 6,483 responses during 821.0 s.

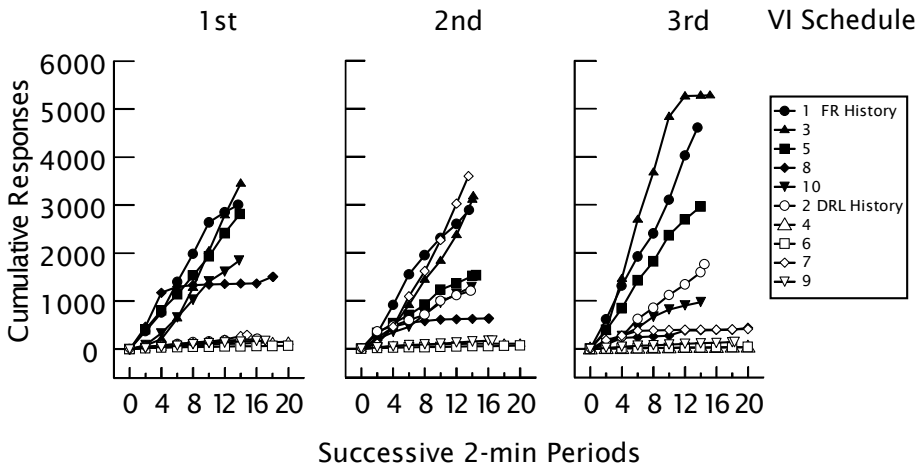

Figure 3. Cumulative frequency of responses of each participant during the first (left), second (center), and third (right) probe sessions under a VI 20-s schedule as a function of time in 2 min. Details are as in Figure 2.

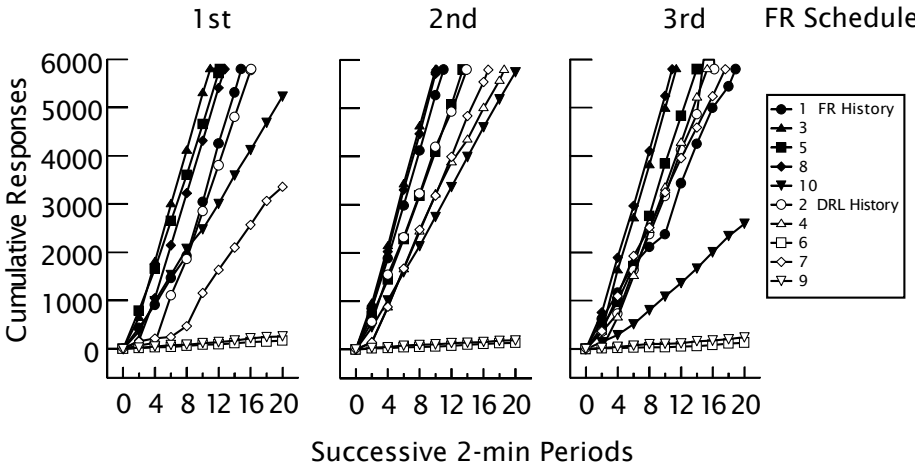

Figure 4. Cumulative frequency of responses of each participant during the first (left), second (center), and third (right) probe sessions under an FR 145 schedule as a function of time in 2 min. The data during the first session for Participant 4 are not shown because the data file necessary for this analysis was accidentally lost (left panel). Each probe session lasted until 40 reinforcers (5,800 responses) occurred or 20 min elapsed, whichever came first. Details are as in Figure 2.

(center and right panels of Figure 4), again consistent with the results of the molar data (see Figure 1). These molecular analyses, therefore, also suggest that effects of remote histories of FR and DRL schedules were short lived but occurred under the FR schedule.

Discussion

Responding under FI and VI schedules was different between human participants who had been exposed to FR and DRL schedules in the remote past. These results are (a) the first replication of Weiner's (1969) results that responding under FI schedules was affected by a remote history and (b) the first demonstration that such remote history effects occurred under a VI schedule.

Results under the FR probe schedule, by contrast, need careful consideration. First, one might wonder whether results of the FR probes represent a history effect. Because half of the participants previously were exposed to the *same* schedule, their results rather may manifest a simple return to the FR baseline. At present, we do not have any evidence to answer this novel, conceptually interesting question, possibly because this should be idiosyncratic to experiments on remote, not immediate, history effects that have hardly been investigated. Second, the effects under the FR probes were only transient. In previous experiments, response rates under an FR schedule for participants with the remote FR history were higher than those for participants without such a remote history during at least the initial three sessions (Weiner, 1982) or those for participants with a DRL history during both probe sessions (Okouchi, 2007). In the present experiment, such a systematic difference was found during the first probe session. Thus, the present results replicate those of Weiner and Okouchi that showed that remote history effects *occurred* under an FR schedule across different

procedures, including schedules of the immediate history condition (T_1 < IRT ≤ T_2 vs. DRO) and schedule parameters of the testing condition (FR 145 vs. FR 40 or 25), but do not replicate the finding that the effects *persisted*. It should be noted, however, that these findings of remote history effects coincide with those on immediate ones: Immediate history effects have occurred consistently, but their persistence has been inconsistent across experiments (e.g., Baron & Leinenweber, 1995; Wanchisen et al., 1989; but see also Cole, 2001).

A next step from the present findings would be identifying variables that contribute to the appearance of remote history effects. These variables may be suggested by a comparison on four levels between the previous and present experiments. A first level of the comparison relates to the sequence of the schedules presented. Because no precedence has used pacing schedules in the immediate history condition, comparisons were made only on the sequence of remote history and testing schedules. Roughly speaking, the present experiment found remote history effects when the sequence of remote history and testing schedules was (a) FR and FI, (b) FR and VI, (c) FR and FR, (d) DRL and FI, (e) DRL and VI, or (f) DRL and FR. These results are consistent with previous studies in which the effects were found when the sequence was FR and FR (Okouchi, 2007; Weiner, 1982), DRL and FI (Weiner, 1969), or DRL and FR (Okouchi, 2007). By contrast, the present results are inconsistent with previous studies that indicated that the effects were *not* found when the sequence was FR and FI (Cole, 2001; Okouchi, 2007; Weiner, 1969), FR and VI (Okouchi, 2007), DRL and FI (Cole, 2001; LeFrancois & Metzger, 1993; Okouchi, 2007), or DRL and VI (Okouchi, 2007). Thus, this conspicuous inconsistency does not support a view that the sequence of schedules presented determines the manifestation of the remote history effects.

Secondly, it is also implausible that schedules in the testing condition solely explain the manifestation. The present results under an FI schedule replicate Weiner's (1969) results but are inconsistent with others' (Cole, 2001; LeFrancois & Metzger, 1993; Okouchi, 2007), and the present results under a VI schedule are inconsistent with Okouchi's (2007).

A third level of comparison between the previous and present experiments on remote history effects relates to differences in IRIs across conditions. Okouchi (2007) did not control IRIs, which consequently were approximately equal between the immediate history and testing conditions, and found remote history effects under neither FI nor VI schedules. The present experiment set the IRIs of the testing schedules longer than those of the immediate history schedule and found the remote history effects under both FI and VI schedules. This contrast, therefore, seems to support a view that an increase in IRIs from the immediate history to testing conditions is critical for the appearance of the effects (Okouchi, 2007). The length of IRIs was not, however, the only procedural difference between the present experiment and Okouchi's. For example, the immediate historical schedule also differed (1 s < IRT ≤ 2 s vs. DRO 5 s in Okouchi, 2007).

Fourth, schedules used for building immediate histories should be compared. The present experiment used a 1 s < IRT ≤ 2 s schedule in the immediate history condition, with an expectation that this schedule might produce a baseline that could increase or decrease, free from both ceiling and floor effects. Although it is difficult to show that the baseline was free from these contaminating effects, some of the present results indicate

that changes in response rates from the baseline to the probes varied from increasing to decreasing. If data in FI and VI schedules in the right panel of Figure 1, which indicate statistically significant effects, are taken as an example, response rates increased from the 1 s < IRT ≤ 2 s baseline to the probe schedule (FI or VI) for 8 of 20 cases and decreased for the remainder. Such a wide range of changes has not been found in previous experiments. Response rates decreased from DRO to FI or VI schedules only for 1 of 9 participants (Okouchi, 2007), or they increased from DRL to FI and decreased from FR to FI in all cases (Cole, 2001). Thus, it is not implausible to hypothesize that the possible range of changes in response rates from immediate to testing conditions relates to manifestation of the remote history effects.

While remote history effects occurred under each of the testing schedules, the persistency seems shorter under the FR schedule than under the FI and VI schedules. Such a differential persistence is unlikely to be due to the order of the probe schedules because the order was reversed in every round (i.e., FI, VI, FR, FR, VI, FI, FI, VI, and FR).

In terms of differential persistency of history effects across testing schedules, we know only that immediate history effects persisted for some time under FI schedules but were less persistent under VI schedules (Freeman & Lattal, 1992; Poling et al., 1980; Urbain et al., 1978). Poling et al. speculated that the range of response rates producing available reinforcers would determine the persistence. Under FI schedules, a wide range of responding produces all of the available reinforcers; therefore, the response rates are affected strongly by indirect variables such as behavioral histories. Under VI schedules, by contrast, low-rate and inconsistent patterns of responding are relatively ineffective with respect to reinforcers earned, and then the performance is constrained more tightly than that under the FI schedule. This explanation undoubtedly fits the case of FR schedules, under which the range of the response rates producing reinforcers is definitely narrower than that under the FI and VI. One limitation of this explanation, however, is that the present performances were not different between the FI and VI probes. This is possibly due to the small number of sessions during which testing schedules were in effect—only three sessions. The identical schedules were in effect in at least 43 (Poling et al.), 59 (Urbain et al.), and 60 (Freeman & Lattal) sessions in previous experiments that found the differential persistence of immediate history effects between the FI and VI schedules.

The present success in discovering remote history effects demonstrates that the probe procedure was sound for testing these effects and replicates previous successes of probe practices on history effects (e.g., Barrett, 1977; Doughty et al., 2005; Egli & Thompson, 1989; Johnson et al., 1991; Okouchi, 2003, 2007). As described, however, the probe technique cannot identify longevity of the effects. Whether effects of past schedules persist indefinitely or are eliminated by current schedules is one of the controversial issues in the study of immediate history effects (e.g., Baron & Leinenweber, 1995; Cole, 2001; Wanchisen et al., 1989). With the exception of a comparison under FR schedules between previous (Okouchi, 2007; Weiner, 1982) and present results, by contrast, this issue has not been examined in the study of remote history effects. Thus, a direction for future experiments may be replicating the present results through successive sessions during which identical schedules are in effect and identifying the longevity of the remote history effects.

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