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Susan M. Snycerski
Western Michigan University

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by

Susan M. Snycerski

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LEVER-PRESS ACQUISITION BY RATS: EFFECTS OF SOME HISTORICAL VARIABLES

Susan M. Snycerski, Ph.D.

Western Michigan University, 2002

Traditionally, behavior analysts and behavioral pharmacologists have emphasized the study of steady-state behavior, while neglecting behavior in transition. In the last 10 years, researchers in these fields have begun to investigate behavioral transitions, particularly the transition from near-zero to above-zero responding involved in response acquisition. This research has focused on variables (e.g., reinforcement delay) that affect acquisition and on procedures (e.g., resetting vs. nonresetting delays) used to assess acquisition. Most studies of acquisition have provided their subjects with behavioral histories prior to testing for acquisition, but few have systematically investigated the importance of historical variables. Consequently, the present study examined the effects of several historical variables on response acquisition with immediate, delayed, and conditioned reinforcement. Specifically, 17 groups of 16 water-deprived rats each received 1 of the 7 following behavioral histories: (a) no exposure to the experimental chamber or to a variable-time (VT) 60-s schedule of water delivery (hereafter termed VT exposure); (b) a single 1-hr (no VT) exposure to the experimental chamber with response levers present; (c) a single 1-hr (no VT) exposure to the experimental chamber with response levers absent; (d) a single 1-hr VT exposure session with response levers present; (e) a single 1-hr VT exposure session with response levers absent; (f) five 1-hr VT exposure sessions with levers present; and (g) five 1-hr VT exposure sessions with levers absent. All groups then received a single 6-hr acquisition session in which consequences (4-s access to a water-dipper cup) for lever-press responses occurred immediately or after a 15-s resetting delay. For 14 groups, the dipper cup delivered 0.1 ml tap water, while for the control group and two conditioned-reinforcement groups the dipper delivered no water. Rats that received 5 VT exposure sessions had a higher probability of acquiring the operant response than rats that received other behavioral histories. Further analyses of results are provided and recommendations are made for future research.

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Susan M. Snycerski

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The experimental analysis of behavior has a long history of examining behavior under steady-state conditions (e.g., Sidman, 1960). Students aspiring to become behavior analysts are typically trained to establish stable behavioral baselines before introducing variables meant to change (e.g., increase, decrease) the behavior of interest (Kazdin, 1982; Mazur, 1998; Poling, Methot, & LeSage, 1995). Behavioral pharmacology, a discipline that shares a close history with the experimental analysis of behavior, likewise has adopted this steady-state methodology for studying drug effects on operant behavior (Thompson & Schuster, 1968; Thompson & Pickens, 1971). Nevertheless, researchers in both the experimental analysis of behavior and behavioral pharmacology have begun to study behavior in transition, most often in the form of response acquisition. This research has focused on variables affecting the initial acquisition of an operant response (e.g., lever-pressing), and on the procedures used to assess acquisition. Indeed, over the past decade there has been a continuous increase in the interest of the behavioral phenomena of response acquisition with immediate and delayed reinforcement.

One of the first studies examining response acquisition with delayed reinforcement demonstrated that, in the absence of shaping or autoshaping, rats and pigeons could learn to bar-press or key-peck, respectively, when food delivery was delayed by 30 s relative to the response that produced them (Lattal & Gleeson, 1990). Since this seminal work, a sizable number of studies investigating variables affecting response acquisition have appeared in the literature. For example, several researchers have examined the effects of physiological or genetic variables such as species and sex on response acquisition with immediate and delayed reinforcement. Thus far, response acquisition has been demonstrated in rats, pigeons, monkeys, and Siamese fighting fish (Lattal & Gleeson, 1990; Miller & Murphy, 1979; Lattal & Metzger, 1994), and in both males and females (rats) (van Haaren, 1992).

In addition to physiological or genetic variables, researchers have also investigated experimenter-manipulated variables, such as body weight, on response acquisition. For example, Lattal and Williams (1997) systematically compared the effects of 70%, 80%, and 90% of ad libitum body weight on response acquisition. They found that all rats in the 70% ad libitum weight group emitted the operant response (i.e., pressed the lever) during the first session following magazine training. However, some rats in the 80% weight group did not press the lever until the second session, and only 4 of 5 rats in the 90% weight group pressed the lever at least once by the twelfth session; one rat in this group never pressed the lever. Thus, body weight affected the number of experimental sessions necessary to produce lever-pressing, with a stronger motivative operation (i.e., 70% ad libitum body weight) resulting in faster acquisition of the operant response. Although lever-pressing in rats is one of the more common topographies examined in response acquisition studies, other operant responses have been examined in other species including key-pecking in pigeons, photo beam breaking in rats (where the photobeam was located in the top corner of an operant chamber), lever-pressing in monkeys, and swimming through a ring in fish (Critchfield & Lattal, 1993; Lattal & Gleeson, 1990; Lattal & Metzger, 1994; Miller & Murphy, 1979).

The most notable differences, however, in studies examining response acquisition with immediate and delayed reinforcement are the procedures employed to assess the initial acquisition of the operant behavior of interest. In fact, researchers have demonstrated that a variety of procedural variables can affect the initial acquisition of a novel behavior (Lattal, 1987; Snycerski, Laraway, Byrne, & Poling, 1998; Wilkenfield, Nickel, Blakely, & Poling, 1992). For example, when arranging delays, some earlier studies employed nonresetting delays where the first response on the appropriate operandum initiates a delay followed by delivery of the putative reinforcer (e.g., food or water), and responses during the delay interval have no programmed consequences (Alvila & Bruner, 1995; Lattal & Gleeson, 1990; Wilkenfield, et al., 1992). Under this procedure obtained delays can be shorter than nominal delays, and the nominal delay value may rarely occur. Resetting delay procedures where the first response on the appropriate operandum initiates a delay, and each response during a delay resets the delay interval, ensure that nominal and obtained delay values equal. Given this, resetting delay procedures have been employed more often than nonresetting procedures in studies of response acquisition with delayed reinforcement (e.g., LeSage, Bryne, & Poling, 1996; Lattal & Gleeson, 1990; Snycerski, Laraway, Byrne, & Poling, 1999; Sutphin, Byrne, & Poling, 1998; van Haaren, 1992). There have been many other procedural differences among studies of response acquisition with delayed reinforcement including the number of operanda in the experimental chamber, the schedules of reinforcement arranged on operanda, and whether delays are signaled or unsignaled. Some common procedural differences, including behavioral history, may have substantial effects on subsequent response acquisition.

To date, almost all studies on response acquisition have included explicit magazine training sessions to ensure that subjects reliably eat or drink from the food apparatus. At minimum, a single 1-hr exposure to a response-independent schedule of food or water delivery has been arranged (e.g., LeSage, et al., 1996; Miller & Murphy, 1979; Sutphin, et al., 1998; Snycerski, et al., 1999). Response-independent presentations of a stimulus (i.e., food or water) that is subsequently to be used as a positive reinforcer is often termed "magazine training" (e.g., Pierce & Epling, 1999), and magazine training is commonly arranged prior to shaping an operant because the procedure (a) establishes the sound of the food or water delivery as a conditioned reinforcer, and (b) establishes a stable chain of responses (staying near the source of food or water delivery, approaching food or water rapidly when they are presented) that is extended through shaping (Skinner, 1938; Kelleher & Gollub, 1962; Sidman, 1960). Some studies on response acquisition have included magazine training criteria that subjects must meet before being exposed to the response-acquisition procedure of interest (e.g., Critchfield & Lattal; 1993; Lattal & Gleeson, 1990). Although magazine training has been arranged in most studies of response acquisition with delayed reinforcement, Lattal and Williams (1997, Experiment 3) demonstrated that magazine training is not necessary for establishing new behavior with delayed reinforcement. In this study, 3 of 4 rats without prior exposure to response-independent food delivery acquired and reliably emitted lever-press responses that produced food after a 15-s resetting delay. Responding developed slowly, however, and evidence of response acquisition was not apparent until the 10th, 13th, and 15th 2-hr session for Rats 19, 20, and 21, respectively. Magazine-trained rats in Experiments 1 and 2 began responding in substantially fewer sessions. Thus, it appears that magazine training increases the likelihood of subsequent response acquisition.

As in the seminal work of Lattal and Gleeson (1990), many researchers investigating response acquisition with immediate and delayed reinforcement have assessed acquisition across several (i.e., 10 - 30) experimental sessions (Critchfield & Lattal, 1993; Lattal & Metzger, 1994; Lattal & Williams, 1997; Snycerski, et al., 1999; van Haaren, 1992). Examining behavior in transition raises theoretical as well as practical problems. For example, at some point during these investigations involving numerous sessions, the study of *response acquisition* may have been confounded with the study of *response maintenance*. Furthermore, the operational definition of response acquisition has varied across investigations and no single definition of acquisition has appeared to be preferred or agreed upon. For example, in a study of response acquisition comprising 20 experimental sessions, Critchfield & Lattal (1993) defined acquisition as, "an increase in response rates over low but nonzero baselines not resulting from programmed sources of contingent reinforcement" (p. 374). However, the number of sessions allowed, and how much of an increase in response rates over baselines is necessary to define acquisition, was not addressed. Snycerski et al. (1999) defined response acquisition according to the number of water deliveries rats earned under a resetting/cancellation procedure. Rats that earned 10 water deliveries in a single session were said to have acquired the operant response. In this study, 16 experimentally-naive rats were exposed to 30 4-hr sessions in which responses on one lever, termed the *reinforcement lever*, produced water under a resetting delay of 60 s and responses on a second lever, termed the *cancellation lever*, canceled any scheduled water deliveries. After the first session 10 of 16 rats earned at least 10 water deliveries, and responded more on the reinforcement lever than on the cancellation lever. During the final session, however, only two of those rats emitted more responses on the reinforcement lever than on the cancellation lever and earned at least 10 water deliveries. In addition, none of the rats that failed to acquire the reinforcement-lever response during the initial session did so over subsequent sessions. While both of these studies adequately examined response acquisition with delayed reinforcement, they demonstrate the variability in how response acquisition has been defined.

Thus far, the study of response acquisition with immediate and delayed reinforcement has been broad and has varied along many dimensions. As mentioned previously, magazine training, with and without experimenter-imposed criteria, is a common procedure implemented prior to response acquisition sessions and studies have demonstrated that responding is acquired faster when magazine training has occurred, although magazine training is not necessary to produce response acquisition (Lattal & Williams, 1997). To examine further historical variables that may influence subsequent response acquisition with immediate and delayed reinforcement the effects of several such variables (i.e., preexposure to the experimental chamber, exposure to response independent deliveries of the putative reinforcer) were examined in the present study.

The purpose of the present study was to identify some of the historical variables that are necessary and sufficient to produce acquisition with immediate and delayed reinforcement, and to further explore the utility of the resetting/cancellation response acquisition procedure for assessing acquisition. As in previous studies from this laboratory, the present study employed a resetting/cancellation response acquisition procedure with both immediate and delayed reinforcement. Under this procedure two response levers are present in the experimental chamber during the response acquisition session. For groups exposed to immediate reinforcement a fixed-ratio 1 (FR 1) schedule of water delivery is in effect on the reinforcement lever. For groups exposed to delayed reinforcement a tandem FR 1 differential-reinforcement-of-pausing (FR 1 DRP) is in effect on the reinforcement lever. Under this schedule, the first response on the reinforcement lever initiates a delay of specified length, after which a dipper cup is raised for 4 s. Responses on this lever during the delay interval reset the interval ensuring that nominal and obtained delays are equal. Responses on the cancellation lever that occur during a delay interval (initiated by a reinforcement-lever response) end the delay interval and cancel the scheduled water delivery. For groups exposed to immediate reinforcement, responses on the cancellation lever have no programmed consequences. This resetting/cancellation procedure has been shown to be useful for examining the effects of perturbations, such as drugs, on response acquisition with delayed reinforcement and its advantages have been discussed further elsewhere (viz., Snycerski, Laraway, Byrne, & Poling, 1998). A single, relatively long response acquisition session was examined in the present study in an attempt to avoid confounding the assessment of response acquisition with that of response maintenance.

A between-groups design was employed to determine the effects of several historical variables on response acquisition with immediate and delayed reinforcement. Specifically, 17 groups of 16 rats each (*N* = 272) were exposed to 1 of the following 7 training conditions: (a) no exposure to the experimental chamber and no exposure to a variable-time 60-s schedule of water delivery (hereafter referred to as VT exposure); (b) one 1-hr exposure to the experimental chamber with response levers present; (c) one 1-hr exposure to the experimental chamber with response levers absent; (d) one 1-hr VT exposure session with response levers present; (e) one 1-hr VT exposure session with response levers absent; (f) five 1-hr VT exposure sessions with response levers present; and (g) five 1-hr VT exposure sessions with response levers absent. To examine whether the sound of dipper activation could serve as a conditioned reinforcer, two groups of rats were exposed to one 1-hr VT exposure training condition (one group with response levers present, the other group with response levers absent). During the subsequent response-acquisition session responses on the reinforcement lever for these two groups resulted in immediate operation of the dipper (i.e., immediate reinforcement) but no water was present in the dipper reservoir.

METHOD

Subjects

Experimentally naive male Sprague-Dawley rats (Charles River, Portage, MI) between 50 and 53 days old at the beginning of the experiment served as subjects (N = 272). Rats were water deprived for 23.5 hr prior to all training and experimental sessions and were housed in pairs with unlimited access to food in a colony area with a 12-hr light/dark cycle (light cycle: 7:00 a.m. - 7:00 p.m.).

Apparatus

Eight Med Associates (St. Albans, VT) operant test chambers were used. The chambers were 28 cm long by 21 cm wide by 21 cm high. During response-acquisition sessions, two response levers separated by 8.5 cm were mounted on the front panel 7 cm above the chamber floor. A minimum force of 0.14 N was required to operate the levers. A receptacle located in the center of the front panel 3 cm above the chamber floor allowed access to a dipper cup filled with 0.1 ml of tap water. A 7-W white bulb located on the ceiling illuminated the operant chamber. An exhaust fan in each chamber masked extraneous noise and provided ventilation. An IBM-compatible microcomputer equipped with MED-PC software controlled all experimental events and recorded data.

Procedure

Figure 1 depicts historical and experimental conditions for all groups of rats and lists names for groups that will be used throughout the remainder of this report. Rats were randomly assigned to 1 of 17 groups of 16 rats each. For all groups, the white bulb located in the ceiling of the chamber was lighted when the specified session began and darkened when it ended.

Historical Conditions

Three groups of rats received no exposure to the experimental chamber prior to the acquisition session. Four groups of rats received one 1-hr exposure to the experimental chamber. For two of these groups the response levers were present and for the other two groups the response levers were absent. Six more groups of rats received one 1-hr VT exposure session, and for three of these groups the response

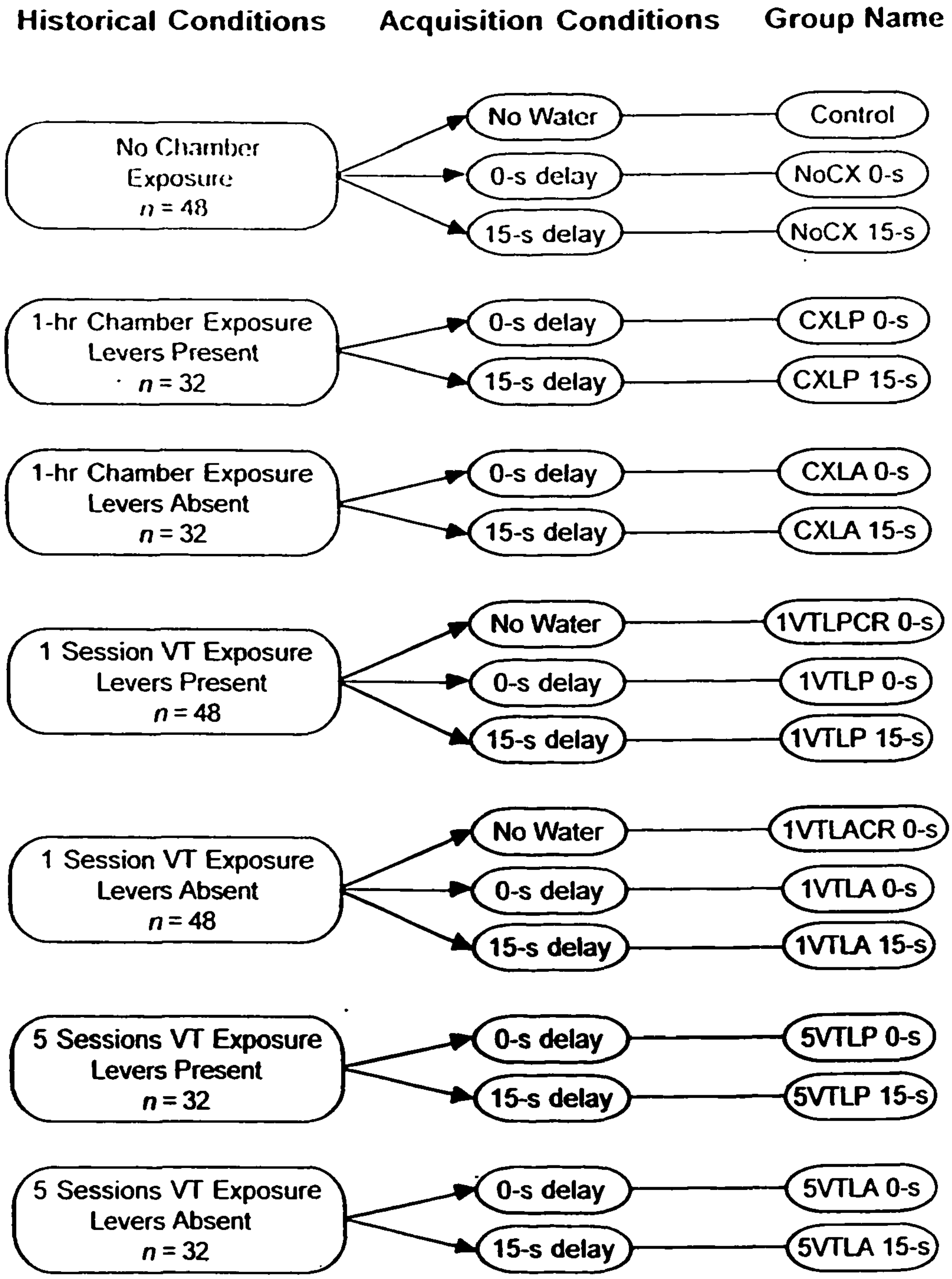

Figure 1. Historical Conditions and the Number of Subjects in Each Condition, Experimental Conditions, and Group Names.

levers were present and for the other three groups the response levers were absent. Another four groups of rats received five 1-hr VT exposure sessions, and for two of these groups the response levers were present and for the other two groups the response levers were absent. The amount of water remaining in the dipper reservoir was measured and recorded immediately after VT sessions.

Response Acquisition Conditions

All groups of rats from each of the seven historical conditions were exposed to a resetting/cancellation response acquisition procedure with one of the following consequences: (a) immediate reinforcement (0-s delay), delayed reinforcement (15-s resetting delay), and (c) immediate delivery of an empty dipper (No Water). Two response levers were present during these sessions and lever assignment (i.e., reinforcement lever vs. cancellation lever) was determined via random assignment. Response-acquisition sessions lasted 6 hr. For all groups, the white bulb located in the ceiling of the chamber was lighted when the response acquisition session began and darkened when it ended. For all groups except the control group, and those in the No Water conditions, reinforcement-lever responses produced 4-s access to a dipper cup filled with 0.1 ml tap water.

Seven of 17 groups of rats were exposed to an immediate reinforcement condition where responses on the reinforcement lever immediately produced dipper access. For these groups, responses on the cancellation lever had no programmed consequences and responses on both levers were recorded. Another seven groups of rats were exposed to a delayed reinforcement condition (i.e., FR 1 DRP 15-s schedule) where responses on the reinforcement lever produced dipper access after 15 s elapsed. Responses on the reinforcement lever occurring during a delay interval reset the interval to the initial value. Responses on the cancellation lever occurring during a delay interval canceled the scheduled water delivery and terminated the delay, in which case another reinforcement-lever response was necessary to start a new delay interval. Responses on the cancellation lever at other times had no programmed consequences. Three more groups of rats were exposed the same acquisition conditions as the immediate reinforcement groups, except that responses for these three groups immediately produced 4-s access to an empty dipper cup; one of these three groups was the control group which received no chamber or VT exposure prior to the response acquisition session.

Dependent Measures

During response-acquisition sessions, the following dependent measures were collected in 10-min bins: (a) number of responses on the reinforcement lever, (b) number of responses on the cancellation lever, (c) number of reinforcement-lever responses that reset the delay interval, (d) number of cancellation-lever responses that canceled scheduled water deliveries, and (e) number of dipper presentations. For groups receiving water during the acquisition session, the amount of water remaining in the dipper reservoir at the end of the session was measured immediately and recorded.

RESULTS

Acquisition was defined as 2 *SD* above the mean number of reinforcement-lever responses made by rats in the control group. The mean number of reinforcement-lever responses for the control group was 7, with a *SD* of 5. Therefore, if the number of reinforcement-lever responses by a rat in any other group was equal to or greater than 17 (7 + 2[5]), that rat was considered to have acquired the lever-press response. Table 1 provides a summary of response measures for groups exposed to immediate and delayed reinforcement. Table 2 provides group means for the amount of water consumed by rats during VT exposure sessions.

Figures 2 and 3 show individual and group mean cumulative reinforcement-lever (R-L) responses during the response-acquisition session for all groups exposed to immediate reinforcement and delayed reinforcement, respectively. For each condition, the number of rats that acquired the lever press is provided. The cumulative records from the Control Group represent the expected operant level of responding. For figure 2, the top row depicts the Control Group and the NoCX 0-s group, in which only 3 of 16 rats acquired the lever-press response. The second row depicts the CXLP 0-s and

Table 1

Descriptive Measures for Experimental Groups

	Reinforcement Lever		Cancellation Lever		Resets		Cancels		Water Deliveries	
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
NoCX 0-s	38	69	14	16	—	—	—	—	—	—
NoCX 15-s	18	14	12	11	8	7	1	2	10	6
CXLP 0-s	78	112	18	20	—	—	—	—	—	—
CXLP 15-s	39	57	16	12	17	29	2	3	21	28
CXLA 0-s	77	114	45	104	—	—	—	—	—	—
CXLA 15-s	34	62	35	63	14	25	2	5	18	33
1VTLPCR 0-s	76	72	75	161	—	—	—	—	—	—
1VTLP 0-s	152	122	27	21	—	—	—	—	—	—
1VTLP 15-s	109	162	32	35	54	102	2	3	53	62
1VTLACR 0-s	82	79	51	42	—	—	—	—	—	—
1VTLA 0-s	112	99	112	99	—	—	—	—	—	—
1VTLA 15-s	87	79	60	56	32	29	5	8	50	50
5VTLP 0-s	231	50	41	33	—	—	—	—	—	—
5VTLP 15-s	56	62	33	38	16	19	2	2	38	44
5VTLA 0-s	204	72	48	32	—	—	—	—	—	—
5VTLA 15-s	156	69	69	59	62	36	7	8	87	38

Table 2

Total Volume (ml) of Water Consumed by Rats in VT Expsoure Sessions

Group	VT #1	VT #2	VT #3	VT #4	VT #5
1VTLP 0-s	30.2	—	—	—	—
1VTLA 0-s	27.0	—	—	—	—
1VTLPCR 0-s	24.0	—	—	—	—
1VTLP 15-s	26.6	—	—	—	—
1VTLA 15-s	21.2	—	—	—	—
1VTLACR 0-s	37.6	—	—	—	—
5VTLP 0-s	56.8	94.6	109.0	109.6	112.2
5VTLA 0-s	52.8	75.0	97.2	103.4	108.7
5VTLP 15-s	40.4	83.2	95.0	104.0	81.2
5VTLA 15-s	48.4	80.0	87.0	104.0	109.6

CXLA 0-s groups, in which 5 and 6 rats acquired, respectively. The third row shows the 1VTLP 0-s and 1VTLA 0-s groups, in which 10 and 9 rats acquired, respectively. The last row in this figure shows the 5VTLP 0-s group, which is the only group in the study where all 16 rats acquired the lever-press response, and the 5VTLA 0-s group where 15 rats acquired the response. As demonstrated by comparing the rows of graphs in Figure 2, the number of rats per group acquiring lever-press responding systematically increased as a function of the intensity of their behavioral histories. That is, the number of rats that acquired the lever-press response was 3, 11, 19, and 31 for groups in rows 1, 2, 3, and 4, respectively. Groups in row 1 were control subjects and those that received no chamber exposure, those in row 2 received chamber exposure only, those in row 3 had a single VT session and those in row 4 had 5 VT sessions. In general, variability across groups in the number of reinforcement-lever responses systematically decreased as a function of delay. For groups exposed to immediate reinforcement, the presence or absence of response levers during exposure to the experimental chamber or to VT sessions did not appear to substantially affect the performance of rats during the response-acquisition.

For figure 3 the first row depicts the Control Group and the NoCX 15-s group, in which 7 rats acquired the lever-press response. The second row depicts the CXLP 15-s and CXLA 15-s groups, in which 8 and 3 rats acquired, respectively. The third row shows the 1VTLP 15-s and 1VTLA 15-s groups in which 9 and 12 rats acquired, respectively. The last row in this figure shows the 5VTLP 15-s and 5VTLA 15-s groups where 8 and 15 rats acquired the lever-press response, respectively. For the delayed reinforcement groups, the number of rats per group acquiring lever-press responding systematically increased with the intensity of their behavioral history. However, there was more variability in the number of rats acquiring the response in the delayed reinforcement groups than in the immediate reinforcement groups. For groups exposed to delayed reinforcement, the presence or absence of response levers during exposure to the experimental chamber or to VT sessions did not appear to greatly affect

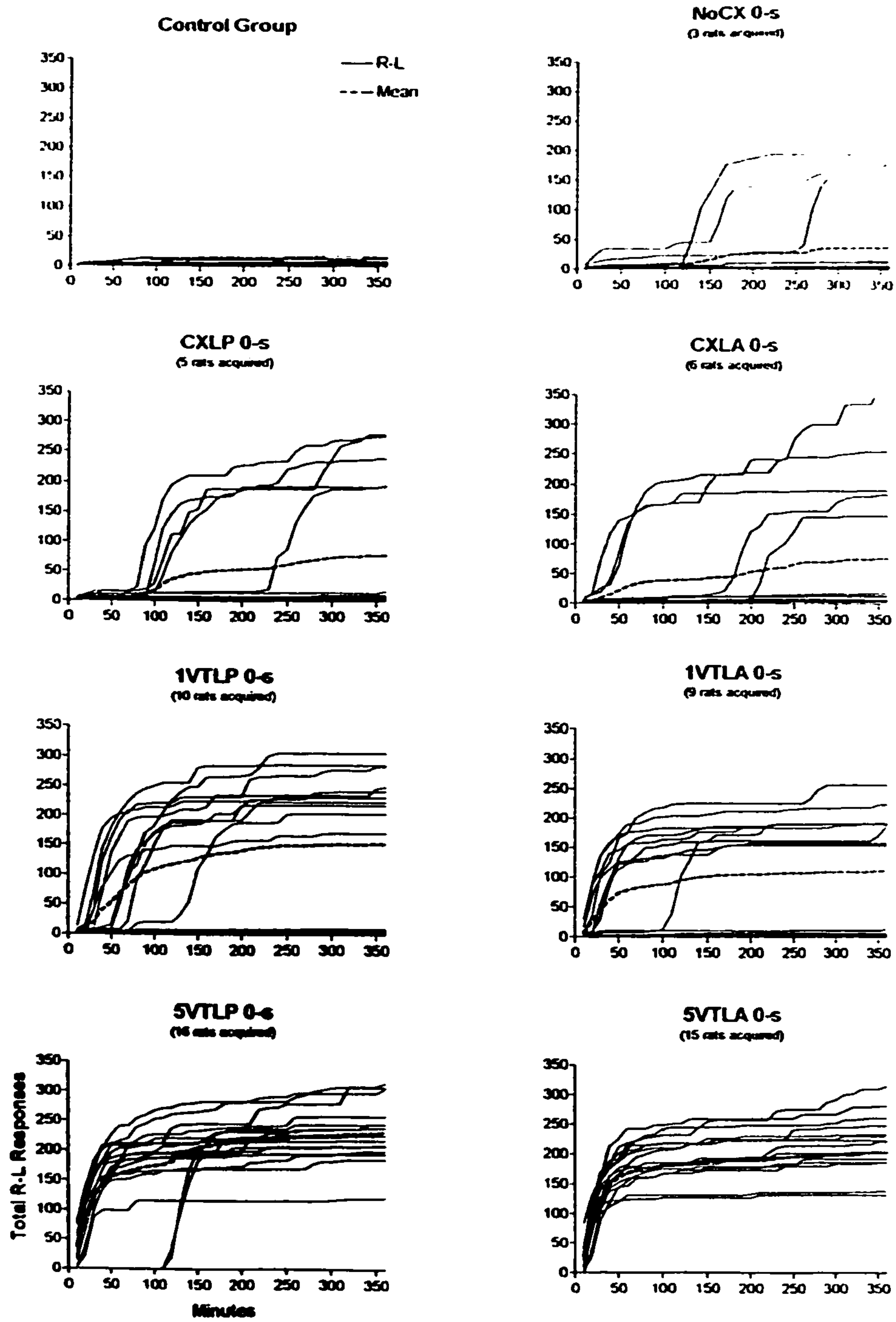

Figure 2. Individual and Group Mean Cumulative Records for Reinforcement-Lever Responses (R-L) During the Response-Acquisition Session for Groups Exposed to Immediate Reinforcement. Rat 7 in the CXLA 0-s Group Made a Total of 364 Responses.

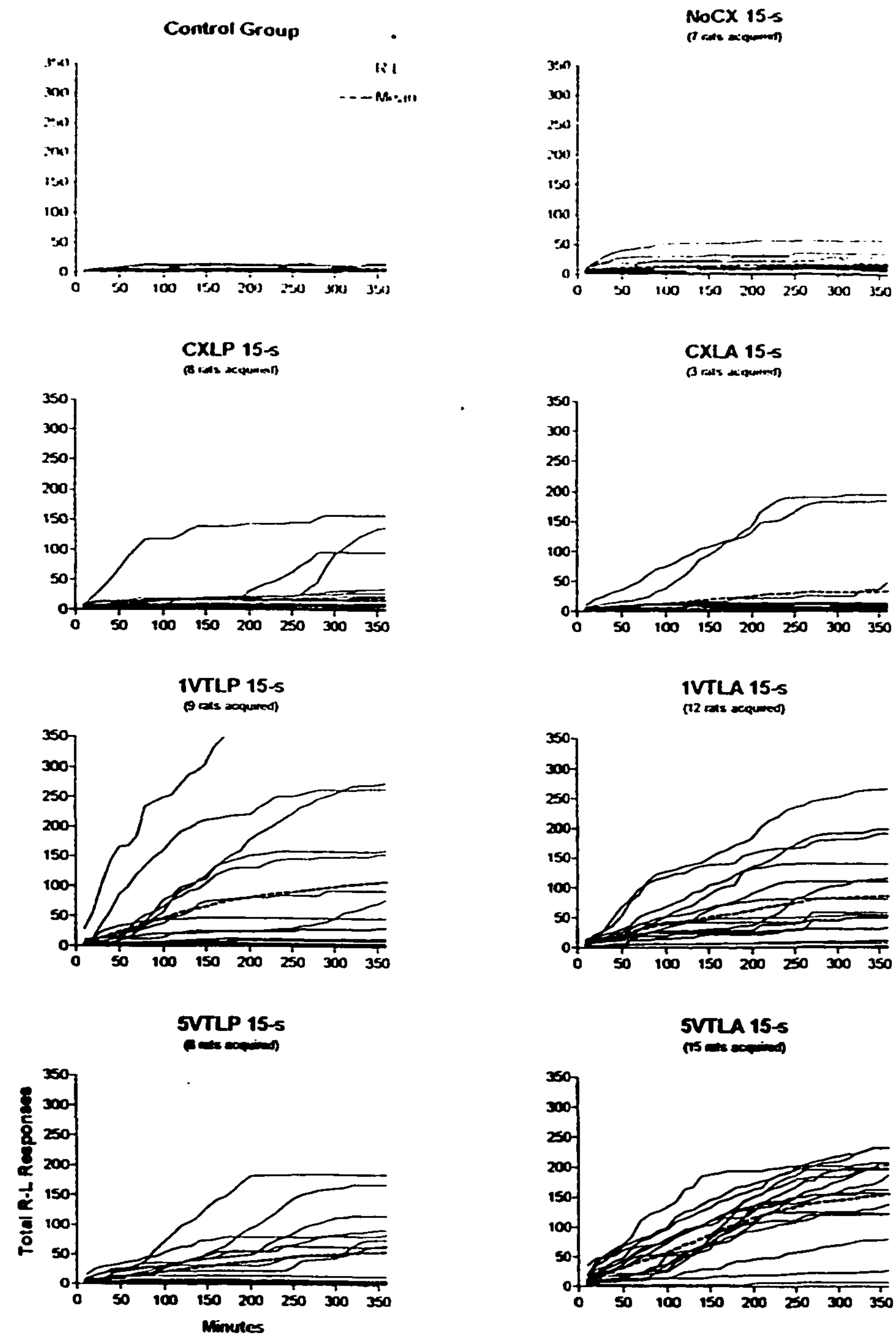

Figure 3. Individual and Group Mean Cumulative Records for Reinforcement-Lever (R-L) During the Response Acquisition Session for Groups Exposed to Delayed Reinforcement. Rat 15 in the 1VTLP 15-s Delay Group Made a Total of 607 Responses.

subsequent response acquisition, except for the two groups exposed to five VT sessions. In the 5VTLA 15-s group 15 rats acquired the lever-press response and in the 5VTLP 15-s group only 8 rats did so. In addition, the mean number of responses for the group with levers absent during the 5 VT sessions (*M* = 158) was much higher than for the group with levers present (*M* = 60).

Figures 4 shows group mean cumulative records for reinforcement- and cancellation-lever (C-L) responses during the acquisition session for groups exposed to immediate reinforcement. The top two rows depict the NoCX 0-s, CXLP 0-s, and CXLA 0-s groups. For all of these groups the mean number of reinforcement-lever responses is greater than the mean number of cancellation-lever responses, however, the time at which separation in the curves begins to appear is varied. In the NoCX 0-s group separation of the curves for responding on the two levers is not apparent until approximately 150 minutes into the session. A distinct separation in responding on the two levers occurs approximately 100 minutes into the session for the CXLP 0-s group and cancellation-lever responding stays at about the same level for the remainder of the session while reinforcement-lever responding continues to increase throughout most of the session. In the CXLA 0-s group reinforcement-lever responding is greater than cancellation-lever responding throughout the entire session but the separation between the two curves doesn't begin until approximately 170 min into the session and is greatest at the end of the session. The bottom two rows of figure 4 feature the groups that received VT exposure. There is clear separation in responding on the reinforcement- and cancellation-levers for all groups. Separation of the curves in responding on the two levers is greatest for the groups that received 5 VT exposures (i.e., 5VTLP 0-s and 5VTLA 0-s) with a substantial amount of the total reinforcement-lever responding occurring within the first 50 min of the session.

Figure 5 shows group mean cumulative records for: (a) reinforcement-lever responses, (b) cancellation-lever responses, (c) responses that reset the delay interval (Resets), (d) responses that canceled a scheduled water delivery (Cancels), and (d) water deliveries (H_2O) during the response-acquisition session for all groups exposed to

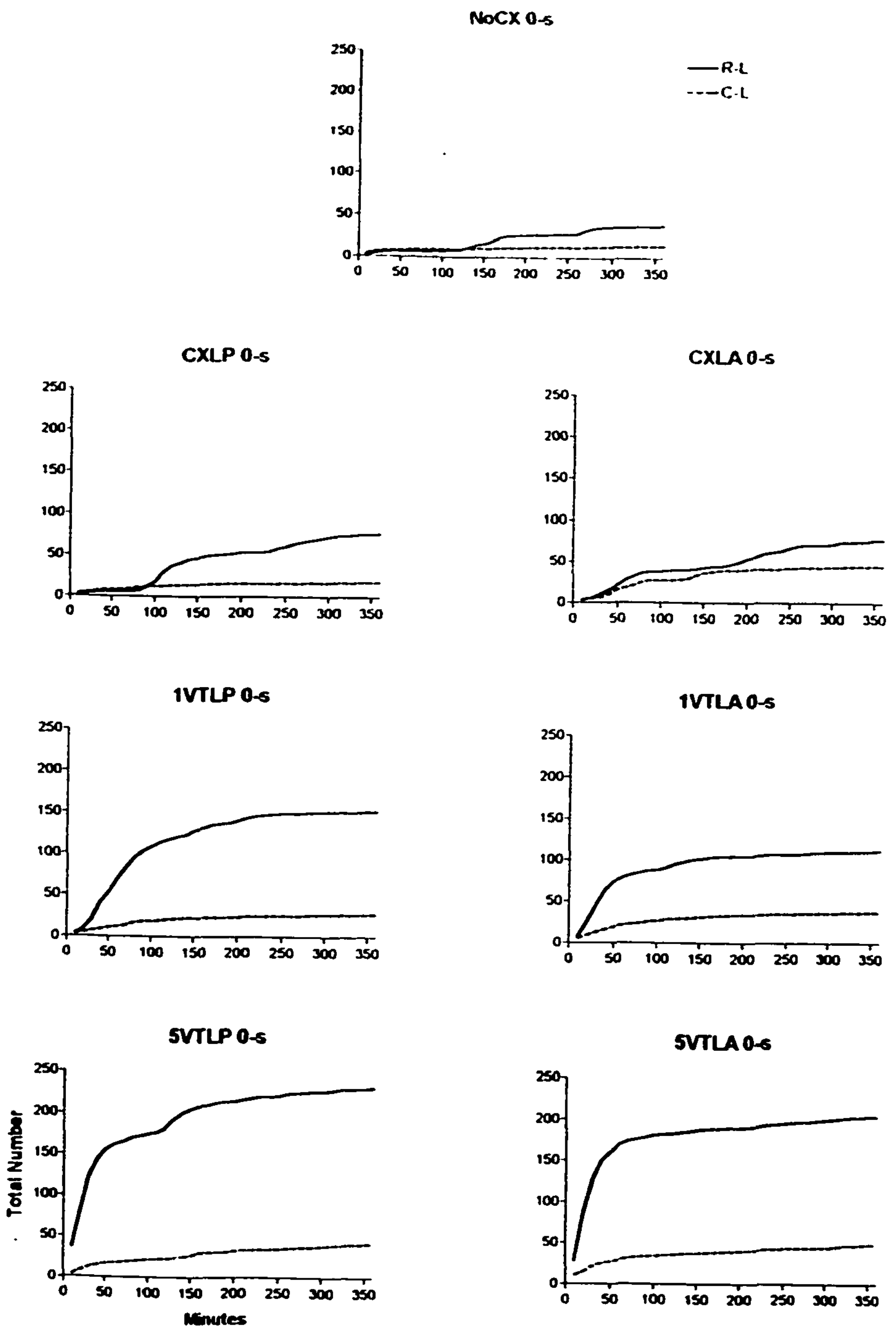

Figure 4. Group Mean Cumulative Records for Reinforcement- and Cancellation-Lever (C-L) Responses During the Response-Acquisition Session for Groups Exposed to Immediate Reinforcement.

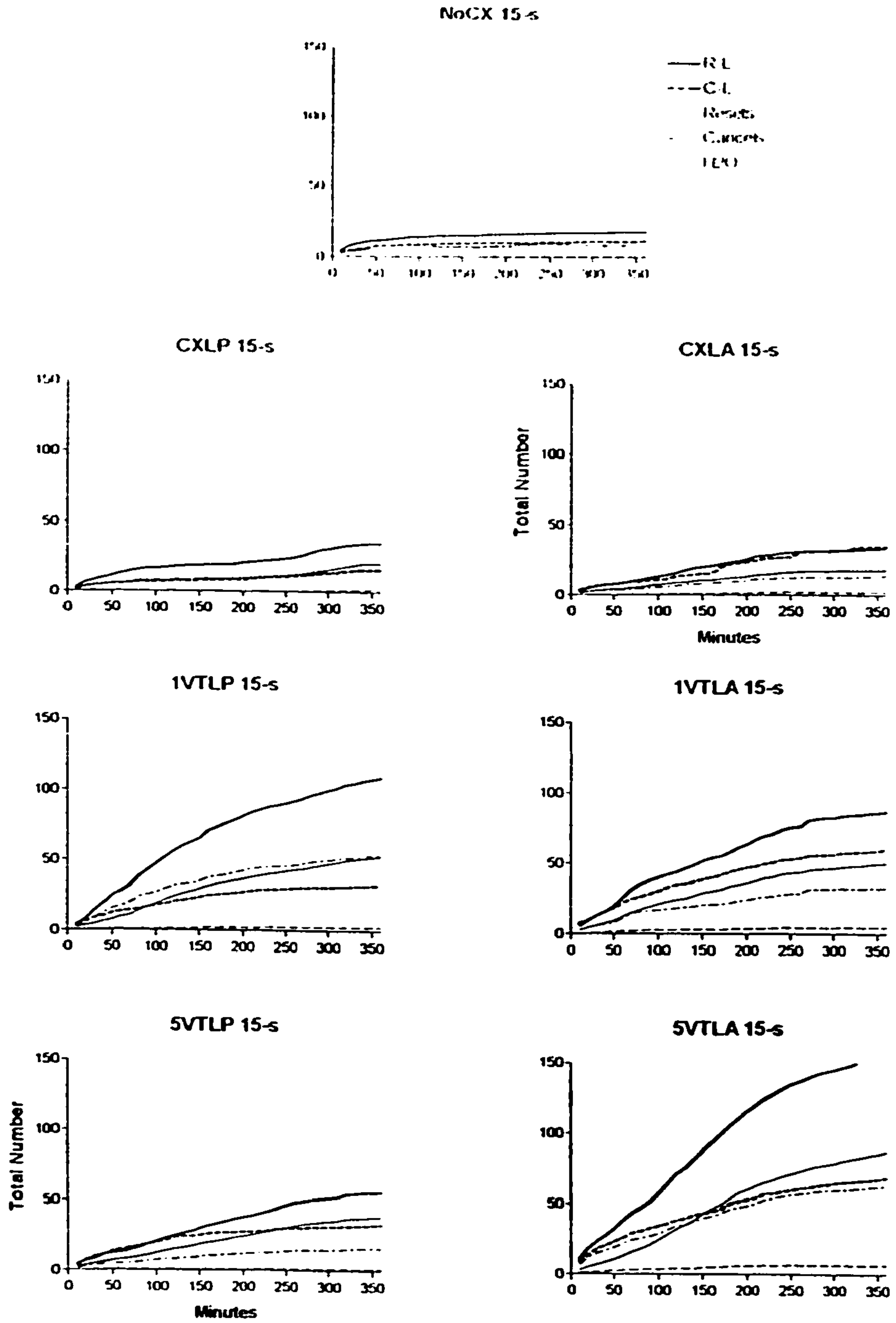

Figure 5. Group Mean Cumulative Records for: (1) Reinforcement-Lever Responses; (2) Cancellation-Lever Responses; (3) Responses that Reset the Delay Interval (Resets); (4) Responses that Canceled a Scheduled Water Delivery (Cancels); and (5) Water Deliveries (H_2O) During the Response-Acquisition Session for Groups Exposed to Delayed Reinforcement.

delayed reinforcement. The top two rows depict the NoCX 15-s and CXLP 15-s groups, which had more reinforcement-lever than cancellation-lever responses, and the CXLA 15-s group, which had one more cancellation-lever responses (35) than reinforcement-lever responses (34). For each of these three groups there was a moderate number of resets and very few canceled water deliveries. The bottom two row of figure 5 features the groups that received VT exposure. The 1VTLP 15-s group had more resets and fewer cancellation-lever responses than the 1VTLA 15-s group and both groups canceled very few water deliveries and earned the same number of water deliveries (*M* = 50). The 5VTLP 15-s and 5VTLA 15-s groups had substantial differences in responding on the two levers across the session. Separation in responding on the two levers does not occur until approximately 120 min into the session for the 5VTLP 15-s group, and reinforcement-lever responding increases slowly and levels off toward the end of the session with a mean total of 60 reinforcement-lever responses. For the 5VTLA 15-s group, separation in responding on the two levers occurs approximately 40 min into the session, and reinforcement-lever responding continues to increase steadily throughout the session with a mean total of 158 reinforcement-lever responses. Both of these groups canceled very few water deliveries and group 5VTLP 15-s had fewer cancellation-lever responses and resets than group 5VTLA 15-s. The top row of figure 6 depicts individual and group mean cumulative reinforcement-lever (R-L) responses during the response-acquisition session for the two groups exposed to conditioned reinforcement. In both groups 13 rats acquired the lever-press response. The bottom row of figure 6 shows group mean cumulative records for reinforcement- and cancellation-lever responses for these same two groups. For these conditioned reinforcement groups reinforcement-lever presses during the acquisition session produced immediate delivery of an empty dipper cup. The 1VTLPCR 0-s and 1VTLACR 0-s groups made approximately the same number of reinforcement-lever responses (76 and 81, respectively). However, rats in the 1VTLPCR 0-s group responded approximately equally on both the reinforcement and cancellation levers (*M* = 76 and 74, respectively), whereas rats in the 1VTLACR 0-s

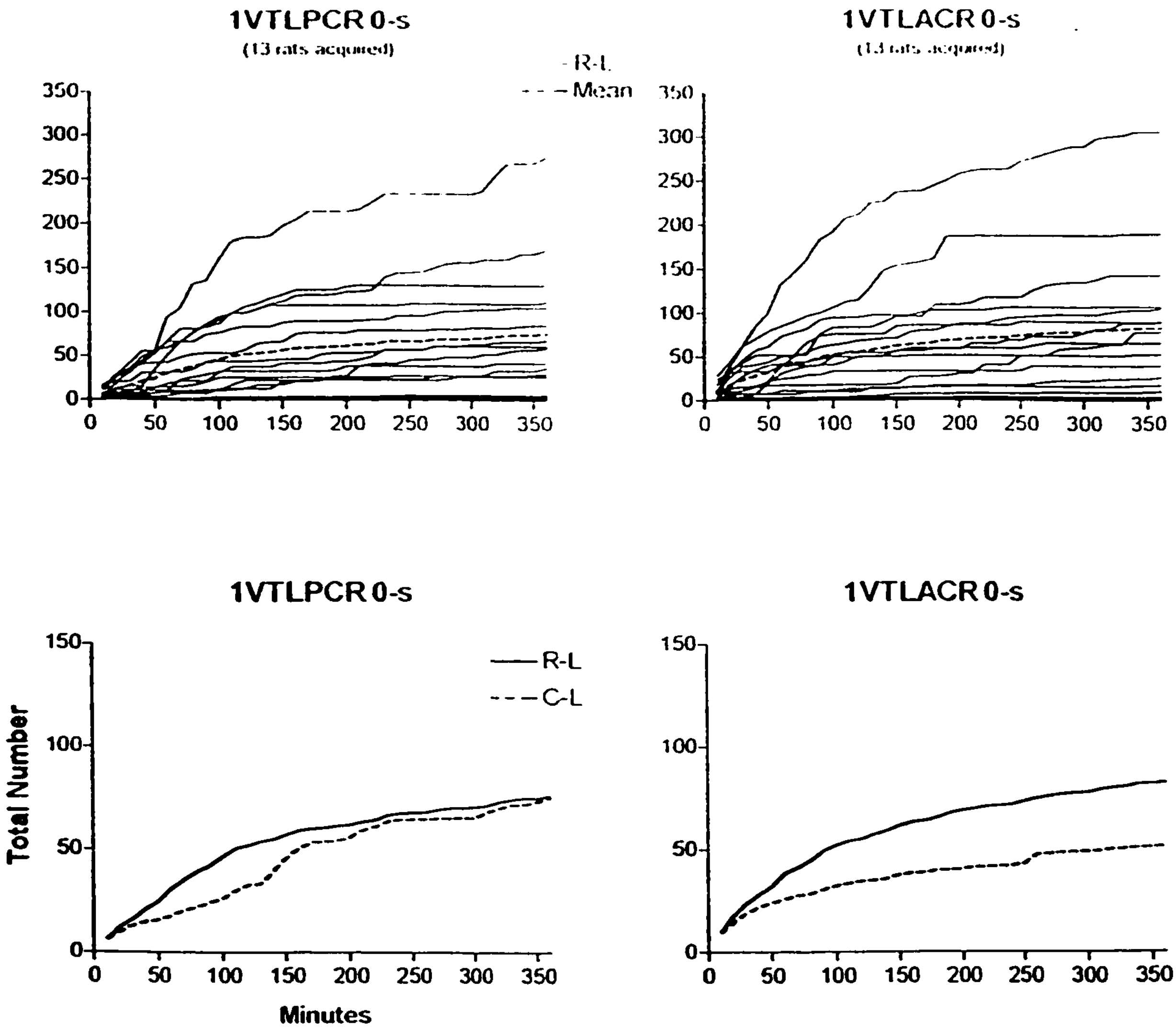

Figure 6. Individual and Group Mean Cumulative Records for Reinforcement-Lever Responses (R-L) During the Response-Acquisition Session for Groups Exposed to Conditioned Reinforcement. Group Mean Cumulative Records for Reinforcement- and Cancellation-Lever Responses for Groups Exposed to Conditioned Reinforcement.

group made more responses on the reinforcement lever than on the cancellation lever (81 and 51, respectively).

DISCUSSION

The present study systematically investigated the importance of behavioral history on response acquisition with immediate, delayed reinforcement and conditioned reinforcement. The purpose of this study was to identify some of the historical variables that are necessary and sufficient to produce lever-press responding in rats. Specifically, 17 groups of 16 rats each were exposed to 1 of the following 7 training conditions: (1) no exposure to the experimental chamber and no exposure to a variable-time 60-s schedule of water delivery (2) one 1-hr exposure to the experimental chamber with response levers present; (3) one 1-hr exposure to the experimental chamber with response levers absent; (4) one 1-hr VT exposure session with response levers present; (5) one 1-hr VT exposure session with response levers absent; (6) five 1-hr VT exposure sessions with response levers present; and (7) five 1-hr VT exposure sessions with response levers absent. Thus, conditions ranged from the absence of exposure to the experimental chamber prior to the response-acquisition session to 5 VT exposure sessions prior to the response-acquisition session.

The present study differs from other studies examining response acquisition with immediate and delayed reinforcement and offers some important contributions to the investigation of response acquisition. First, in terms of the number of subjects, this is the largest study to be conducted on response acquisition to date. The size of this study allowed for a detailed evaluation of seven different behavioral histories that may be influential in producing response acquisition. One of the historical conditions examined in the present study (1VTLA 0-s) has been used in previous investigations from this laboratory but the importance of exposure to this condition on subsequent response acquisition had not been determined previously (e.g., Byrne, et al., 1997; Sutphin, et al., 1998). For example, Snycerski et al. (1999) employed procedures identical to those of the 1VTLA 0-s group in the present study prior to exposing rats to a resetting/cancellation procedure in a response-acquisition session. All subjects were reported to have drunk from the dipper during VT exposure, however, the amount of water consumed during VT exposure was not recorded. It may be the case that the experimenter's observation of a rat drinking from the dipper was the only incidence, or one of few instances, where that particular rat drank from the dipper. Moreover, it could be the case that the rat appeared to drink from the dipper but actually did not. The present study measured the amount of water consumed by rats during VT exposure(s) to determine whether the rats actually were drinking from the dipper apparatus rather than just orienting toward the dipper. No criteria was in effect for water consumption before rats were exposed to the response-acquisition session but collecting these data allowed us to determine whether a rat had come into contact with the putative reinforcer. Results indicate that almost all rats in the VT exposure conditions drank from the dipper during these sessions. As depicted in Table 2, the amount of water consumed during VT sessions increased across sessions for groups given five VT exposure sessions (except for the 5VTLP 15-s group which consumed less during session 5 than during sessions 2, 3, and 4, respectively). The greatest increase in water consumption occurred between the first and second sessions for all groups, indicating that fewer than 5 sessions of VT exposure may be sufficient to produce acquisition. In any case, measuring the amount of water consumed during VT exposure(s) provides a quantitative method for determining whether rats drink during dipper presentations. This is an important consideration that was not addressed in previous studies employing these procedures.

A second important difference between the present study and others investigating response acquisition is that the present study quantitatively defined response acquisition. The control condition was designed to assess the operant level of lever-pressing during a 6-hr response acquisition session in which reinforcement-lever presses resulted in the immediate delivery of an empty dipper cup. The mean number of reinforcement-lever responses for the control group was 7 and rats in any other group that made enough reinforcement-lever presses to fall 2 *SD* above the mean of the control group were said to have acquired the lever-press response. That is, any rat that made 17 or more reinforcement-lever responses acquired the response (7 + 2|5| = 17). This criterion, while contrived and perhaps liberal, ensures that a specific response requirement is met before a subject is said to have acquired the operant response. Other studies of response acquisition have provided rather ambiguous definitions of acquisition. As mentioned previously, Critchfield and Lattal (1993) defined acquisition as, "an increase in response rates over low but nonzero baselines not resulting from programmed sources of contingent reinforcement" (p. 374). If their definition was adopted in the present study the number of rats per group that acquired the operant response would increase considerably. This perhaps suggests, that the criteria for acquisition used in the present study was somewhat conservative.

Using the quantitative criterion discussed above to define acquisition ($\geq$17 reinforcement-lever presses), at least 3 rats, and as many as 16 rats, in various groups acquired lever-press responding in a single 6-hr response-acquisition session. Results from the NoCX 15-s group confirm those of Lattal and Williams (1997) who found that magazine training is not necessary to establish lever-pressing in rats when reinforcement is delayed. Rats in both the NoCX 0-s and NoCX 15-s groups acquired lever-pressing, but the characteristics of responding in the two groups was substantially different. Only three rats met the acquisition criterion in the NoCX 0-s group, however, each of these rats responded substantially more often on the reinforcement lever than on the cancellation lever. These rats made a total of 157, 180, and 194 reinforcement-lever responses. Almost half of the rats in the NoCX 15-s group (7) met the acquisition criterion, but responding was much less robust for this group. Here, the highest number of reinforcement-lever responses was 58 and the lowest was 17, and there was not a clear difference in reinforcement- versus cancellation-lever responses, with means of 18 and 12, respectively.

As illustrated in the cumulative records in Figures 2 and 3, despite some variability, there are distinct patterns of responding on the reinforcement lever within and across groups throughout the session. For example, all three rats that acquired in the NoCX 0-s group had sigmoidal acquisition curves, with *runs* (i.e., the ascending limbs of the curves) which reach an asymptote and flatten. For these three rats, runs occurred in the 120th, 150th, and 260th minute of the session. Two rats in the CXLA 0-s group had this pattern of responding, but three rats in this group began responding at high levels as early as 10 min into the session and responding then either steadily increased, gradually increased, or ceased for the remainder of the session. No rat in the CXLP 0-s group responded at high levels until approximately 70 in into the session. This pattern of responding (depicted as a sigmoidal curve) was common within and across groups and appeared at some point during acquisition sessions for at least some rats in each of the following groups: CXLP 0-s, CXLA 0-s, 1VTLP 0-s, 1VTLA 0-s, 5VTLP 0-s, and 5VTLP 15-s.

In general, three distinct patterns of responding on the reinforcement-lever were evident in the present study. The first pattern, as described above, is depicted as a sigmoidal curve and resulted from low levels of responding early in the session, followed by a sharp increase to high levels of responding later in the session, and levels of responding eventually decreased or ceased for the remainder of the session. The second pattern of responding, most apparent in the the immediate reinforcement groups that received VT exposure, is illustrated in the last two rows of Figure 2. Here, most rats responded at high levels early in the session followed by little or no responding for the remainder of the session. The third pattern of responding was most evident in the delayed reinforcement groups that received VT exposure. As illustrated in the bottom two rows of Figure 3, most rats in these groups began responding at low levels early in the session and responding gradually increased throughout the session resulting in various degrees of a curvilinear lines.

The three general patterns of responding that occurred on the reinforcement lever were not evident on the cancellation lever. As illustrated in Figures 4 and 5 the mean number of cancellation-lever responses was less than that of reinforcement-lever responses for all groups except for the CXLA 15-s group. In this group the mean number of cancellation-lever responses was 35 and the mean number of reinforcement-lever responses was 34. There were fewer cancellation-lever responses than resets in all groups exposed to delayed reinforcement except for the two groups that received five VT exposures. These two groups had more cancellation-lever presses than resets during the response-acquisition session. For all groups, very few cancellation-lever presses resulted in the cancellation of a scheduled water delivery.

Previous studies from this laboratory (Byrne, Baker, & Poling, 2000; Snycerski et al., 1999; Sutphin et al, 1998;) have removed response levers from the experimental chamber during VT exposure sessions to prevent the possibility of adventitious reinforcement of lever-pressing, however, such an effect had not been documented and the importance of this variable on acquisition had not been determined. Therefore, the present study examined the effect of the presence or absence of response levers during chamber exposure and VT exposure sessions on subsequent response acquisition. Very few lever presses occurred during chamber exposure or VT exposure sessions for groups in conditions with response levers present and there did not appear to be adventitious reinforcement of lever-pressing. However, for the delayed reinforcement groups receiving five VT exposure sessions the presence of response levers appeared to impede subsequent response acquisition. Fifteen rats in the 5VTLA 15-s group acquired lever-pressing whereas only eight rats in the 5VTLP 15-s group did so. As illustrated in the bottom row of Figure 3, the pattern of responding for these two groups differ with fewer rats lever-pressing early in the session in the 5VTLP 15-s group than in the 5VTLA 15-s group. Moreover, the mean number of reinforcement-lever responding was much higher for the group that did not have levers present during the VT exposure sessions than for the group that did have levers present. However, for the immediate reinforcement groups receiving five VT exposure sessions the presence or absence of response levers did not appear to affect response acquisition in an adverse manner. In fact, the 5VTLP 0-s group is the only group in the present study in which all 16 rats acquired the operant response.

In addition to assessing response acquisition with immediate and delayed reinforcement the present study also examined response acquisition with conditioned reinforcement. Two conditions were designed to determine whether exposure to a single VT session could establish the sound of dipper activation as a conditioned reinforcer. Each of the 1VTLPCR 0-s and 1VTLACR 0-s groups received one VT exposure session and 24-hr later they were exposed to the response acquisition session in which reinforcement-lever presses resulted in the immediate delivery of an empty dipper. As illustrated in Figure 6, 13 rats in each of these two groups acquired lever-press responding indicating that the sound of the dipper functioned as a conditioned reinforcer. In fact, more rats in these two groups acquired the operant response than did rats in the 1VTLP 0-s and 1VTLA 0-s groups that had identical historical conditions and in which reinforcement-lever responses produced immediate delivery of 4-s access to water during the acquisition session. These findings are noteworthy given that this is the first study known to establish lever-press responding in rats in a response acquisition procedure using a conditioned reinforcer.

The present study systematically examined the influence of several historical variables on response acquisition with immediate, delayed, and conditioned reinforcement in rats. Seven conditions were arranged in attempts to determine the variables that were necessary and sufficient to produce acquisition. Rats from groups that received one or five VT exposures were more likely to acquire the lever-press response than rats from groups that received no chamber exposure or one session of chamber exposure. In general, the effects of delayed reinforcement did not substantially affect the total number of rats acquiring the operant response. However rats in the delayed reinforcement groups characteristically began responding later in the session and did not reach the high levels of responding found in rats in the immediate reinforcement groups.

In addition to determining some variables that are necessary and sufficient to produce response acquisition, the present study further attests to the adequacy of the resetting/cancellation procedure for assessing response acquisition with delayed reinforcement. Furthermore, quantitatively defining acquisition demanded that a specific response requirement before a subject can be said to have acquired the operant response, and to our knowledge, this is the first study to define acquisition in this manner under the resetting/cancellation procedure. The amount of data collected in the present study is impressive and more sophisticated analyses of these data, such as growth modeling, may provide additional information pertaining to the study of behavior in transition.

Appendix

Protocol Clearance From the Institutional Animal Care and Use Committee

WESTERN MICHIGAN UNIVERSITY
INVESTIGATOR IACUC CERTIFICATE

Title of Project ______

The information included in this IACUC application is accurate to the best of my knowledge. All personnel listed recognize their responsibility in complying with university policies governing the care and use of animals.

I declare that all experiments involving live animals will be performed under my supervision or that of another qualified scientist. Technicians or students involved have been trained in proper procedures in animal handling, administration of anesthetics, analgesics, and euthanasia to be used in this project.

If this project is funded by an extramural source, I certify that this application accurately reflects all procedures involving laboratory animal subjects described in the proposal to the funding agency noted above.

Any proposed revisions to or variations from the animal care and use data will be promptly forwarded to the IACUC for approval.

______ Disapproved ______ Approved ✓ Approved with the provisions listed below

Provisions or Explanations
see attached sheets

IACUC Chairperson — Date 2/9/00

Acceptance of Provisions
Alan Poling — 2/23/00

Signature: Principal Investigator — Date 2-10-00

IACUC Chairperson Final Approval — Date 2/10/00

Approved IACUC Number 00-01-02

Rev. 3/92

IAC-B

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