Variety Training of Human Sensitivity to Changing Contingencies: The Influence of Response-rate History and Discriminative Schedule Properties

by

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A Dissertation Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

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Winnipeg, Manitoba

ISBN 0-612-13534-9

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VARIETY TRAINING OF HUMAN SENSITIVITY TO CHANGING CONTINGENCIES: THE INFLUENCE OF RESPONSE-RATE HISTORY AND DISCRIMINATIVE SCHEDULE PROPERTIES

BY

LAINE J. TORGRUD

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

Acknowledements

Sincere thanks to the members of my examining committee: Drs. Stephen Holborn, Rayleen DeLuca, Joseph Pear, John Walker, and Philip Chase. This final manuscript benefited a great deal from their constructive comments.

Steve, thank you for all your support over the years (How many there have been!!). I consider you a terrific role model as a researcher, teacher, and person - it would be hard for me to overstate the positive influence you have had on my life.

To my mother Karen and father Ray: Now that I am a doctor I can say with the full ring of authority that you are the best parents I could possible wish to have. Without your consistent support throughout my life (which I do not take for granted), I would never have gone this far.

Finally, thank you Jackie, for giving me the time and space to work when I needed it, and love and support in those rare periods between deadlines. It cannot have been easy and it is more than appreciated.

Abstract

Undergraduates pressed keys for token points under a variety of reinforcement schedules (variety training) or under a single schedule. Accurate instructions described each schedule component. Response rates on a fixed-interval (FI) test schedule were then assessed. Experiment 1 compared variety training inclusive of FI-optimal rates (Functional) to training excluding such rates (Nonfunctional). Subjects given Functional training showed low test rates relative to Nonfunctional and single-instruction training, implicating response-rate history as a determinant of variety-trained sensitivity. Experiment 2 manipulated Functional and Nonfunctional variety training, and the match of test-phase point densities with those of high-, low-, or both high- and low-rate training components, in a 2 X 3 factorial design. Subjects matched for low-rate training densities responded at low rates during FI, suggesting discriminative control of response rate by point density. Specific low rates were optimal or nonoptimal depending on response-rate history (Functional or not). These findings identify variables that affect variety-trained sensivity, including the discriminative properties of the reinforcement schedules.

Variety Training of Human Sensitivity to Changing Contingencies: The Influence of Response-rate History and Discriminative Schedule Properties

Human behavior often differs from the behavior of other species under schedules of reinforcement. In addition to certain discrepancies between human and nonhuman response patterns (e.g., Bijou, 1958; Hutchinson & Azrin, 1961; Leander, Lippman, & Meyer, 1968; Weiner, 1964, 1969), human behavior may be relatively unaffected by changes in the prevailing contingencies of reinforcement (e.g., Galizio, 1979; Matthews, Shimoff, Catania, & Sagvolden, 1977; Shimoff, Catania, & Matthews, 1981). Particularly because of the latter outcome, human responding on schedules of reinforcement has been characterized as "insensitive" (cf. Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; LeFrancois, Chase, & Joyce, 1988). Insensitive human performances are prevalent in the laboratory, raising the possibility that more naturalistic human behavior shares this quality.

If insensitivity is commonly a property of human behavior, it is important that behavior analysts address it. Insensitivity can result in a failure to earn available reinforcers or to avoid preventable punishers and thus can be conceived as a problematic aspect of human behavior (cf. Weiner, 1970). More fundamentally, insensitive performances lack an important behavioral attribute, that of adapting to the current environment (cf. Skinner, 1969, p. 194). Indeed, Weiner (1965, 1970, 1982) suggests that much of psychotherapy involves the modification of behavior that is insensitive or inefficient with respect to current environmental conditions (see also Zettle & Hayes, 1982, for a discussion of cognitive-behavior therapy and rule-governed insensitivity). Fortunately, a burgeoning empirical literature has elucidated factors that influence human schedule sensitivity, including prior reinforcement histories (e.g., Weiner, 1969, 1970), and externally or self-generated instructions (e.g., Baron & Galizio, 1983; Buskist & Miller, 1986; Catania, Matthews, & Shimoff, 1982; Flora, Pavlik, & Pittenger, 1990; Galizio, 1979; Rosenfarb, Newland, Brannon, & Howey, 1992).

The study of instructional effects adds to converging evidence that human verbal behavior contributes in the production of schedule insensitivity (but see Weiner, 1983, for an interpretation based on reinforcement histories of nonverbal responding). Provision of instructions about reinforcement schedules can produce marked insensitivity to the changing consequences of responding (e.g., Hayes et al., 1986; Shimoff et al., 1981) and completely determine the form of responding on a given schedule (e.g., Kaufman, Baron, & Kopp, 1966). However, when instructions are minimized, either by shaping the relevant response or by using nonspecific instructions, insensitivity is reduced (e.g., Matthews et al., 1977; Shimoff et al., 1981). Self-instructions may exert effects similar to those of external instructions: post-hoc samples of verbal behavior suggest a correlation between inaccurate self-instruction and insensitive performance (e.g., Leander et al., 1968; LeFrancois et al., 1988).

Studies of humans incapable of producing or responding to verbal stimuli also suggest that verbal behavior influences insensitivity. The schedule performances of preverbal infants resemble those of animals (Lowe, Beasty, & Bentall, 1983), while for older children the resemblance diminishes (Bentall, Lowe, & Beasty, 1985). Similarly, the performances of adult humans become more animal-like when their verbal capacities are engaged by a concurrent task (e.g., Laties & Weiss, 1963). Combined with data on instructional effects, these results support the view that both externally-provided and self-generated instructions can contribute to human schedule insensitivity.

If, as argued earlier, insensitivity is a maladaptive property of human behavior, then behavior analysts would be well advised to explore the conditions allowing for its reduction. These conditions may eventually be deduced from accounts of instructed sensitivity, several of which have been offered (Galizio, 1979; Hayes et al., 1986; Shimoff et al., 1981). One parsimonious explanation is that instructions can produce response patterns that prevent contact with changes in contingencies (Buskist & Miller, 1986; Galizio, 1979). This failure to contact

new conditions may be mediated by the reduced variability of instructed responding (Joyce & Chase, 1990). However, data showing maintenance of instructional control in the presence of extensive schedule contact suggest that social contingencies also play a role in the production of insensitivity. Such contingencies may support compliance even with instructions that reduce the density of reinforcement obtained on the operative schedule (e.g., Hayes et al., 1986). The relative contribution to insensitivity of poor schedule contact and social contingencies will undoubtedly vary with the nature of the instructions and the conditions of the experiment.

When conditions support social contingencies on compliance, the promotion of sensitivity will depend on variables such as the capacity of the instructing agent to monitor compliance (Barrett, Deitz, Gaydos, & Quinn, 1987; Zettle & Hayes, 1982) and the magnitude of non-socially mediated consequences for the instructed behavior (Cerutti, 1989). However, reducing instructed insensitivity that is mediated by poor schedule contact and restricted behavioral variability may require other procedures. One strategy may be to provide a history of instructed behavior such that contact is made with all contingencies to which sensitivity will be assessed (Hayes et al., 1986). Then, when contingencies change, the repertoires necessary for sensitivity will have been established. A second approach may be to provide strategic instructions, either to increase response variability (Joyce & Chase, 1990) or to behave in other ways that highlight the consequences of responding (Catania, Shimoff, & Matthews, 1989). A third method may be to provide a large variety of instructed schedule exposures, with the expectation that such experience will render behavior sensitive to novel conditions (LeFrancois et al., 1988).

LeFrancois et al. (1988) tested the possibility that a variety of instructed schedule exposures may facilitate sensitivity to a novel schedule. Subjects were exposed to one of six "training" histories: a Specific Instruction variable interval condition (SIVI), a Specific Instruction variable ratio condition (SIVR), a Minimal Instruction VI condition (MIVI), a Minimal Instruction VR condition (MIVR), or one of two Variety of Instructions conditions

(Var 1 and Var 2). Subjects in the first four groups were exposed to a single instruction of either a minimal ("Figure out how to best earn points") or specific (e.g., "Press the earn button approximately 80 times for each point" for SIVR subjects) nature prior to training on a VI or VR schedule. Both groups of Variety subjects, by contrast, were trained on eight different schedules of reinforcement, each preceded by an accurate instruction (e.g., "Wait X seconds before pressing the earn button for each point" for differential reinforcement of low rate [DRL]). The Variety instructions and schedules were selected to produce high, moderate, and low rates of responding, to describe and provide experience with response-dependent and response-independent schedules, and to describe and provide experience with both fixed and variable schedules of varying parameters. All groups subsequently were exposed to the same novel "test" schedule (FI 30-s) with the instruction to "Figure out how best to earn points." An unsignalled change to extinction followed the FI test phase.

The most crucial data were those from the FI test phase, where sensitivity is typically ascribed to low-rate performances (Joyce & Chase, 1990; Matthews et al., 1977). The majority of subjects in both Variety groups responded at low rates, suggesting that the Variety of Instruction conditions (henceforth, referred to as variety training) produced highly sensitive FI performance. Their FI rates were markedly lower than subjects' average rates during training, which had varied according to schedule. The majority of subjects in the MIVI, MIVR, and SIVR groups, by comparison, continued to respond at the high rates produced by their initial training. Subjects in the SIVI group responded with the same low rate efficiency as did variety trained subjects, but this apparent "sensitivity" was attributed to the low rate established in training. The insensitivity of these subjects was revealed during extinction, when their trained response rates persisted. Subjects given variety training, by contrast, showed an abrupt change in rate during extinction, again attesting to their sensitivity to the changing consequences of responding.

The central conclusion supported by the LeFrancois et al. (1988) study is that a variety of

instructed schedule performances can bring about sensitivity to changing contingencies. This finding adds to evidence that instructions can increase sensitivity under certain conditions (cf. Hayes et al., 1986) and extends the demonstration to an instance where the test schedule had not been previously encountered. In addition, these findings raise an interesting question: How does variety training operate to produce increased sensitivity to novel schedules of reinforcement? This question is of theoretical interest, since the answer may define the essential aspects of variety training.

LeFrancois et al. (1988) offer two prospective explanations for the effect of variety training on sensitivity. One possibility is that variety training involves changing response patterns, which results in changing response patterns when novel circumstances occur. This hypothesis accords with evidence that enhancing response variability contributes to schedule sensitivity (Joyce & Chase, 1990). Perhaps variety training promotes sensitivity by supporting response variation under novel conditions. Varied responding may then be more likely to make effective contact with a novel contingency. A second possibility is that variety training teaches specific response patterns that are tried out under novel conditions until an appropriate one is selected. According to this latter hypothesis, variety training is effective primarily because it trains rates that "overlap with efficient behavior under....changing conditions" (LeFrancois et al., 1988, p. 391), a conclusion apparently endorsed by these investigators. The LeFrancois et al. (1988) findings, however, do not definitively support either of these two theories.

The current study sought to evaluate these two explanations for variety-trained sensitivity: (a) that the changing response patterns involved in variety training induce changes in responding that facilitate contact with, and control by, novel schedules, and (b) that variety training engenders specific response patterns that are efficient under novel conditions. Two forms of variety training were compared. One form was designed to include training of response rates that would overlap with efficient behavior under test conditions (Functional variety training). A second form was designed to provide a comparable variety of schedule and

instruction types, but not train rates that would overlap with efficient behavior under test conditions (Nonfunctional variety training). Both forms of variety training were followed by presentation of a novel schedule (FI 30-s) to test for sensitivity. Similar degrees of test schedule sensitivity across the two variety conditions would be consistent with theory "A," since both types of training entail changing response patterns. Alternatively, a finding of greater sensitivity for Functional variety training would favor theory "B," which posits that training of overlapping (functional) rates produces sensitivity. A single instruction VR group was included to provide a baseline measure of sensitivity with which to compare the variety groups.

In the process of exploring the means by which variety training produces sensitivity, the present study sought to systematically replicate the phenomenon under conditions more stringent than have previously been assessed. Specifically, the forms of variety training employed were richer in "high-rate" schedules than those of LeFrancois et al. (1988), and consistently reinforced high-rate responding at the end of training. In this way, the robustness of variety-trained sensitivity to less favorable schedule selections and orders was evaluated.

Experiment 1

Method

Participants

Forty-five male and female undergraduates were solicited from introductory psychology classes at the University of Manitoba. Participants were paid based on a performance-dependent lottery and were provided with one experimental credit for their participation.

Apparatus

The study was conducted in a microcomputer laboratory of the University of Manitoba's Psychology Department. The 5.0 by 13.0 m room contained 30 Commodore PC-10 microcomputers, arranged in six rows of five units. Up to 10 units were used concurrently to

provide experimental instructions, record relevant data, and dispense points. On each computer keypad, circular stickers of green, red, yellow and blue hue were attached to the right shift, return, space bar, and Esc keys, respectively. The right shift key functioned as an "earn" key; the return key as an "accept" key. Presses on the earn key, and only that key, participated in the programmed schedule contingencies. When a point was earned, the computer emitted a "beep" sound, following which a press on the accept key added the point to a cumulative point display in the center of the computer screen. Presses on the earn key had no programmed consequences until the previously earned point was accepted. Presses on keys other than those labeled "earn" and "accept" had no programmed consequences throughout the experimental session, except for the ESC key and Space Bar which served to scroll through instructions and to initiate schedule components (see Procedure). The operative computers were spatially arranged so that a seated subject could not observe fellow participants.

Design

An independent groups design was employed to ensure that each subject received only one type of laboratory training history. Subjects were randomly assigned to one (N = 15/group) of three training conditions: a Functional Variety condition (FV), a Nonfunctional Variety condition (NFV), or a Specific Instruction VR condition (SIVR). The SIVR training condition provided a baseline measure of the sensitivity produced by single-instruction training with which to compare the effects of variety training. Of the four single- or minimal-instruction conditions employed by LeFrancois et al. (1988), only SIVR was included in the present study. This decision was made for two reasons: (a) the MIVR and MIVI conditions appeared to generate a degree of sensitivity similar to the included SIVR group and, therefore, would have been redundant, and (b) the SIVI condition would train optimal FI rates that could not meaningfully be evaluated for FI sensitivity.

Following a 32 min training phase, all subjects received a 25 min test phase. Both phases occurred in a single session of approximately one hour's duration.

The extinction phase employed by LeFrancois et al. (1988) was not included in the present study. This phase was included in the former study as a means of elucidating the insensitivity of those subjects (in the SIVI condition) whose apparent FI sensitivity could either have been due to true sensitivity, or to the perseveration of rates established during training. Since all subjects in the present study ended training responding at high rates, FI sensitivity cannot be attributed to the maintenance of trained rates and, thus, inclusion of an extinction phase would not have served this purpose.

Procedure

The general procedures were modelled after those of LeFrancois et al. (1988), except that sessions were conducted in small groups. All subjects (to a maximum of 10) participating in a given session were escorted into the laboratory by the experimenter and were instructed to sit facing a computer unit. The experimenter then provided a brief set of introductory instructions (see Appendix A) ending with the prompt to "Please begin the experiment now...".

At the outset of a session, the computer screen displayed the message "Welcome to the human behavior lab! Get comfortable and when you are ready to read the general instructions, press the space bar." Following a press of the space bar, the computer provided the remainder of the general instructions (see Appendix A) and allowed subjects to engage in practice trials. The screen display during practice trials was identical to the display during schedule components (see Appendix B), except that the screen was entitled "Practice Session."

Training. At the end of the introductory instructions, the computer displayed the message: "Here is an instruction for you to follow: (see Table 1 for the specific instructions). When you are ready to follow this instruction, press the ESC key. Begin when you hear the beep." A press of the ESC key produced the message "Get Ready" in the center of the screen for 3 s, followed immediately by the beep and presentation of the first (or only) training schedule component. The earning screen display (see Appendix B) appeared for the duration of a given schedule component. The message "Stop!" appeared for 3 s at the end of each schedule

Table 1

Schedule Instructions for Training Conditions in Experiment 1

Condition	Schedule	Instruction
SIVR	VR 80	Press the earn key approximately 80 times for each point.
FV NFV	FR x	Press the earn key x times for each point.
	DRL x	Wait x seconds before pressing the earn key for each point.
	VI x	Press the earn key approximately every x seconds for each point.

component, followed by presentation of the next instruction. The training phase extended for 32 min for all subjects in all conditions.

For the Specific Instruction Variable Ratio condition (SIVR), one reinforcement schedule (VR 80) operated during the entire 32-min training phase (see Table 2). The specific instruction provided to subjects in this condition is listed in Table 1. This instruction was followed by the prompt: "When you are ready to follow this instruction, press the space bar. Begin when you hear the beep."

For both the Functional Variety (FV) and Nonfunctional Variety (NFV) conditions, a different instruction and schedule was presented every 4 min for a total of eight training components. The ordering of schedule presentations for both conditions is shown in Table 2. A specific instruction was displayed on the video screen prior to the onset of each schedule (see Table 1). Each instruction was followed by the prompt: "When you are ready to follow this instruction, press the space bar. Begin when you hear the beep."

The defining feature of the FV condition was the inclusion of instruction/schedule pairings to train a variety of response rates that would overlap with efficient behavior under the test conditions (under FI 30-s, one response every 30 s). The selected training components were expected to produce, in addition to rapid rates of responding, rates that were slower (DRL 45-s, VI 40-s) or nearly as slow (DRL 15-s, VI 20-s) as the optimal test rate (see Table 1). The specific schedule sequence adopted was modelled after a particular order (Order 3, Variety 1 condition) employed by LeFrancois et al. (1988). This order was selected because it reinforced high-rate responding (under a fixed-ratio [FR] schedule) during the final 4 min of training (see Table 2), thus requiring that response rates change significantly from the end of training to the test phase in order to show sensitivity. Establishing high rates immediately prior to testing was believed to present a more stringent test of sensitivity than was the case in the LeFrancois et al. (1988) study. In the earlier study, the final 4 min of training was designed to produce low- or zero-rate responding for 50% of subjects -- the final 12 min for one subject in

Table 2

Order of Schedule Presentations for Training Conditions in Experiment 1

	Condition		
	SIVR	FV	NFV
Training Schedules*	VR 80 (32 min)	FR 40 DRL 15 s FR 100 VI 40 s DRL 45 s FR 20 VI 20 s FR 60 (4 min each)	FR 40 DRL 2 s FR 100 VI 4 s DRL 6 s FR 20 VI 2 s FR 60 (4 min each)
Test Schedule	FI 30 s (25 min)	FI 30 s (25 min)	FI 30 s (25 min)

* Values for all variable schedules were randomly selected from a rectangular distribution ranging from 1 to 2x-1, where x is the designated schedule value.

six. Thus, many subjects could appear sensitive to the FI test schedule without altering their behavior substantially from the pattern established by their most recent training experiences. An additional challenge to sensitivity was invoked by replacing two fixed-time (FT) schedules (FT 45 s and FT 15 s) from the original study with two FR schedules (FR 40 and FR 20). This alteration equated the proportion of instruction/schedule pairings expected to produce high-rate responding (FR) to the proportion expected to produce low-rate responding (DRL, VI), ensuring that the overall training experience favored neither sensitive, nor insensitive, FI performance (see Table 2). Elimination of FT schedules was also required to establish the NFV condition (see below). Thus, these schedules were also eliminated from FV training to avoid introducing a confounding variable.

The defining feature of the NFV condition was the inclusion of instruction/schedule pairings to train a variety of response rates that would not overlap with efficient behavior under test conditions. Thus, the DRL and VI values were reduced in size relative to those employed in FV training (see Table 2). In addition, the two FT schedules employed in LeFrancois et al.'s (1988) procedure, which might have produced very low rates of responding, were eliminated. These alterations ensured that even the slowest instructed response rate (for DRL 6 s: "Wait 6 seconds before pressing the earn key for each point") well exceeded the rate of maximally efficient FI responding (1 response every 30 s). A manipulation check (see Appendix C, Table C1) confirmed that the minimum pressing rates established by NFV training were indeed nonfunctional (i.e., significantly higher than 2 responses/min, the optimal rate on the FI 30-s test schedule), while FV rates were generally functional (i.e., near or below 2 responses/min).

At the end of training, the computer informed subjects that the session would continue in 30 s (see Appendix A). A display beneath the instruction counted down from 30 to 0 s. This interval between the training and test phases mimicked the delay imposed by LeFrancois et al. (1988) when the experimenter initiated the test phase. When the counter reached zero, the test

phase instructions were presented (see Appendix A).

Testing. The testing phase of the current study paralleled that of LeFrancois et al. (1988). An FI 30-s schedule was initiated as a test for sensitivity. This schedule remained in effect until responding satisfied the following stability criterion. After the first 25 minutes of FI responding, the computer calculated the mean response rate of the previous six FI cycles (with a cycle defined as the period from one earned point to the next), and calculated the mean response rate of both the first three cycles and the last three cycles. Each three-cycle mean was then compared to the six-cycle mean. The stability criterion was reached when each three-cycle mean fell within 5% of the six-cycle mean. If the criterion was not achieved by the initial calculation, FI testing continued, with a new calculation made following each additional FI cycle. When the criterion was achieved the session ended, and final instructions to subjects were presented (see Appendix A).

Subjects were given experimental credit at the conclusion of the session and were paid for their participation. As payment, subjects drew one slip of paper from a drum for every complete multiple of 80 points earned. The drum contained slips with the following values: sixty 1-cent, fifty 5-cent, forty 10-cent, thirty 25-cent, sixteen 1-dollar, two 5-dollar, one 10-dollar and one 20-dollar. The theoretical mean earning per draw was 71 cents (actual was 82 cents), and all subjects earned between two and four draws.

Results

The outcome of primary interest in the current study, sensitivity to FI, has been indexed by two related dependent measures: (a) the number of responses per minute, and (b) the number of responses emitted per available reinforcer (efficiency). These measures constituted the major dependent variables in the current study, as was the case in the most directly comparable research (cf. LeFrancois et al., 1988; Joyce & Chase, 1990). The data were analyzed both graphically and statistically, by group and for individual subjects.

Figure 1 shows the mean number of responses per minute for all subjects in a given group

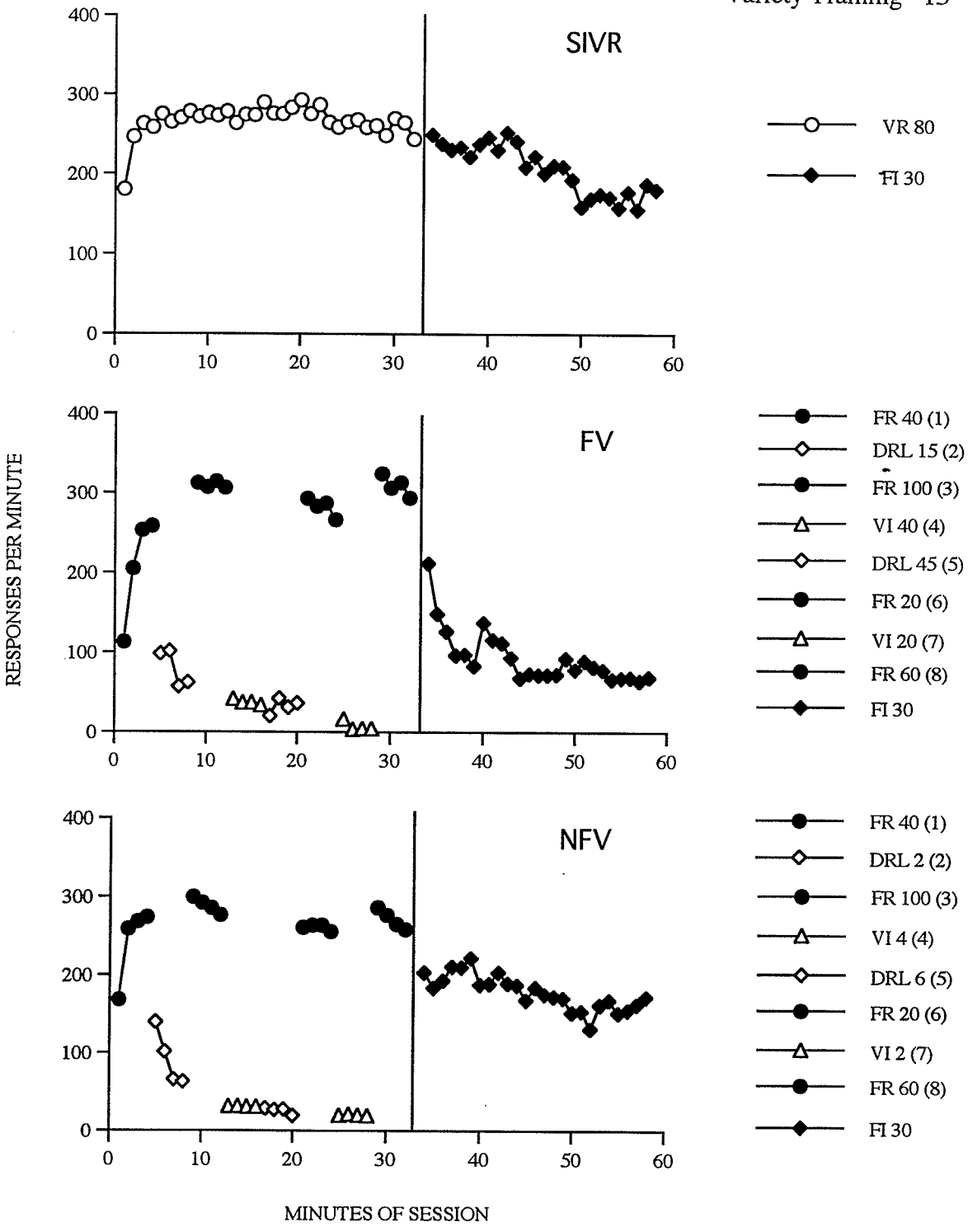

Figure 1. Mean number of responses per minute across all subjects in each group of Experiment 1 (training and test phases). Numbers in parentheses indicate order of training schedule presentation.

during training and test phases. Although the test phase was longer than 25 min for those subjects not meeting the stability criterion, only the 25 min common to all subjects are displayed: Responses per minute data beyond this point would be systematically biased through elimation of subjects satisfying the criterion. For the SIVR group, mean pressing rates were high during the entire VR 80 phase (indicated by open circles). For both the FV and NFV groups, pressing rates were high during FR components of training (filled circles) and low during DRL and VI training components (open diamonds and triangles, respectively). These data suggest that, on average at least, training produced differential effects: consistently high rates for the SIVR group; low and high rates for both forms of variety training.

Of principal interest was performance during the FI test phase, as isolated in Figure 2. Pressing rates for all three groups were similar at the outset of testing, averaging over 200 responses/min. Pressing rate for the FV group rapidly diverged from those of the SIVR and NFV groups, however, declining precipitously over the first four minutes of testing, and then gradually declining to a terminal rate of approximately 70 responses/min. Pressing rates for the SIVR and NFV groups remained similar and relatively high. Both of these groups showed a gradual decline from over 200 responses/min at the outset of testing to approximately 175 by the final minute. A mixed factorial ANOVA with three levels of the between-subjects factor (group membership) and 25 levels of the within-subject factor (responses/min for the first 25 min of the FI test phase) was conducted. The interaction of group membership with minutes of test phase was not found to be statistically reliable, $F(48, 1008) = 1.30$, $p = .084$; therefore, the responses/min data were collapsed across minutes of test phase for additional analyses.

Table 3 shows the mean number of responses/min collapsed across the first 25 min of the test phase for all subjects in Experiment 1. The ANOVA revealed statistically reliable differences among the three groups, $F(2, 42) = 6.66$, $p = .003$. The mean response rate for the FV group ($M = 93.2$, $SD = 89.2$) was considerably lower than the rates for the SIVR ($M = 206.1$, $SD = 87.4$) and NFV ($M = 178.0$, $SD = 87.9$) groups, suggesting greater FI sensitivity

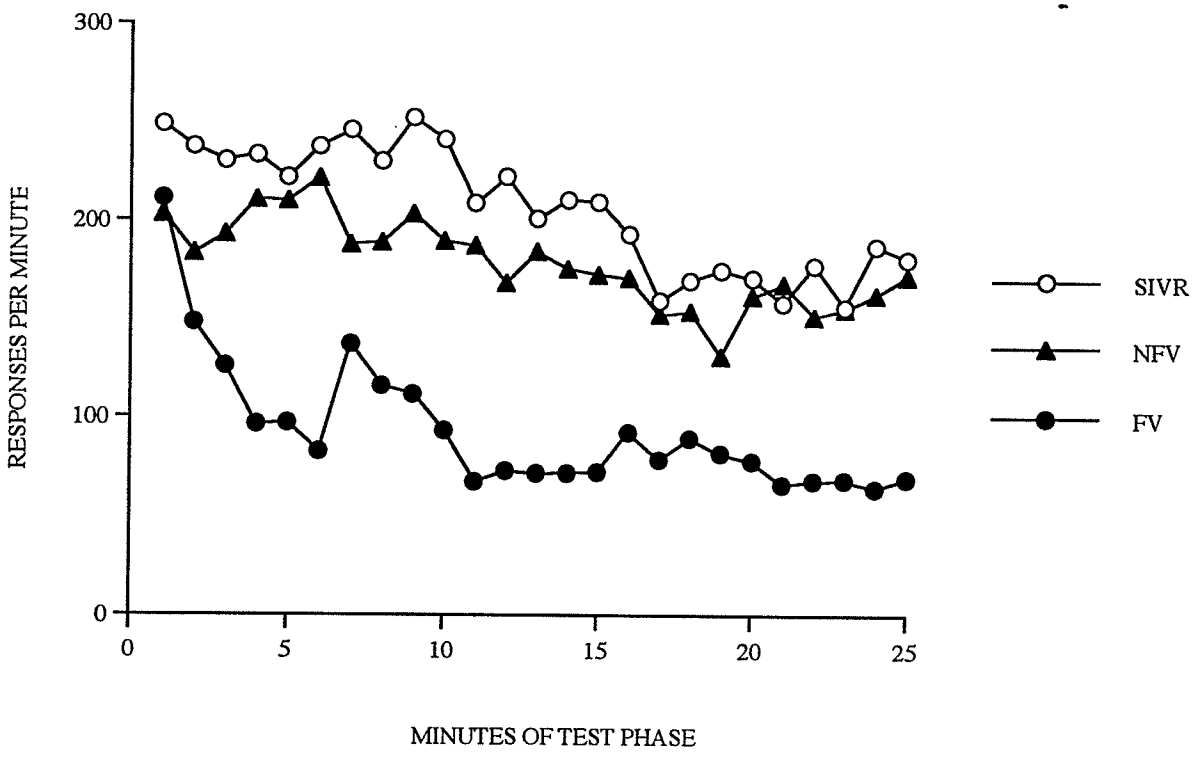

Figure 2. Mean number of responses per minute across all subjects in each group of Experiment 1 (test phase).

Table 3

Mean Number of Responses per Minute During the FI Test Phase for Subjects in Experiment 1

Subject	SIVR	Subject	FV	Subject	NFV
001	322.3	016	290.1	031	303.8
002	307.7	017	238.2	032	303.0
003	298.9	018	176.8	033	277.3
004	281.9	019	175.2	034	265.3
005	264.8	020	126.8	035	253.2
006	248.3	021	84.6	036	228.6
007	244.9	022	77.3	037	197.0
008	225.8	023	72.2	038	171.5
009	185.7	024	43.5	039	129.8
010	161.8	025	31.6	040	118.5
011	161.7	026	21.9	041	105.3
012	159.3	027	21.6	042	91.9
013	130.5	028	16.6	043	91.6
014	57.0	029	13.3	044	67.0
015	41.0	030	8.6	045	66.9
Mean:	206.1		93.2		178.0
Median:	225.8		72.2		171.5

by the FV group. The differences between all pairs of group means were evaluated using a Tukey Honestly Significant Difference (HSD) test with an alpha level of .05. This analysis confirmed a statistically reliable difference between the FV group and both the SIVR and NFV groups. The difference between the SIVR and NFV groups was not statistically significant.

Sensitivity at the end of the test phase was assessed by examining the last 3 minutes of FI responding. In order to obtain a "pure" measure of sensitivity, the number of responses occurring in this time period was divided by the number of reinforcers potentially available (six, for an FI 30-s schedule). This ratio yielded a measure of the mean number of responses per available reinforcer, a measure for which the optimal value would be one (LeFrancois et al., 1988). A responses per reinforcer measure represents a "purer" index of sensitivity than responses/minute, because maximum sensitivity values for the latter measure vary with test schedule value. Table 4 (scores before slash) shows this measure for all subjects in Experiment 1, averaged over the final 3 min of testing. An ANOVA revealed the presence of statistically reliable differences among the three groups, $F(2, 35) = 6.74$, $p = .003$. The differences between all possible pairs of means for the three groups were evaluated using a Tukey HSD test with an alpha level of .05. This analysis confirmed a statistically reliable difference in responses per scheduled reinforcer between the FV group ($M = 39.7$, $SD = 51.6$) and both the SIVR ($M = 102.6$, $SD = 49.9$) and NFV groups ($M = 102.6$, $SD = 48.6$). The difference between the SIVR and NFV groups was not statistically significant. Due to the loss of terminal data for seven subjects, a second analysis was conducted for minutes 23 to 25 of the test phase. These data (Table 4; scores after slash) were available for all subjects and provided a sensitivity measure at a common time from the onset of the test phase. The second analysis confirmed the results of the first. An overall ANOVA revealed a statistically reliable difference among the group, $F(2, 42) = 4.90$, $p = .012$. A Tukey HSD test between all possible pairs of means confirmed a difference between the FV group ($M = 33.5$, $SD = 45.1$) and both the SIVR ($M = 87.3$, $SD = 54.2$) and NFV ($M = 81.5$, $SD = 55.0$) groups.

Table 4

Mean Number of Responses per Scheduled Reinforcer During the Last 3 min of FI and During Minutes 23 to 25 of FI for Subjects in Experiment 1

Subject	SIVR Last 3/23-25	Subject	FV Last 3/23-25	Subject	NFV Last 3/23-25
001	150.3/165.0	016	139.5/139.5	031	151.3/151.3
002	131.7/131.7	017	107.8/107.8	032	152.8/153.7
003	148.2/148.2	018	119.5/90.3	033	144.7/144.7
004	136.0/136.0	019	44.3/44.3	034	150.3/150.3
005	137.3/137.3	020	68.6/54.3	035	124.3/116.2
006	119.7/119.7	021	1.0/2.0	036	137.6/114.0
007	128.2/128.2	022	17.2/17.2	037	94.8/94.8
008	118.3/94.7	023	4.8/3.3	038	73.5/73.5
009	****/18.8	024	6.8/26.3	039	91.5/72.7
010	24.5/24.7	025	****/9.3	040	****/3.8
011	101.6/70.5	026	4.0/4.0	041	****/40.2
012	****/16.8	027	0.8/0.8	042	55.8/50.5
013	104.0/65.0	028	****/1.3	043	****/3.5
014	29.5/29.5	029	1.2/1.3	044	7.7/34.2
015	4.2/23.0	030	0.7/0.7	045	46.3/18.7
Mean:	102.6/87.3		39.7/33.5		102.6/81.5
Median:	119.7/94.7		6.8/9.3		116.2/73.5

**** data missing.

The foregoing data suggest that the FV group exhibited greater sensitivity to the FI test schedule than did either the SIVR or NFV groups. However, the potentially misleading nature of averaged data has been well articulated by behavior analysts (e.g., Johnston & Pennypacker, 1980, p. 91; Sidman, 1960, p. 274), prompting analysis of the individual subject data.

Individual subject graphs of responses/minute are presented in Appendix D. In the training phase, rates for individual subjects generally resemble the means for their respective group. However, the sensitivity (test-phase) data for individual subjects were more variable and sometimes dissimilar from their respective group means. In order to provide an objective comparison of individual subject sensitivity across training experiences, subjects were classified based on their mean response rates during the FI test phase (see Table 3). The following categories were established: 180+, 120-179.9, 60-119.9, and 0-59.9 responses/min, corresponding to rates of >3, <3, <2, and <1 responses/second. The numbers of subjects falling into each category are shown in Figure 3. For both the SIVR and NFV groups, the predominant number of subjects fall into the most FI-insensitive category (>180 responses/min, shown in black). The reverse is true for the FV group: the largest number of subjects are highly sensitive (0-59.9 responses/min, shown in white). The data were collapsed across the top three categories to compare the number of sensitive (defined as 0-59.9 responses/min) and insensitive (> 59.9 responses/min) subjects for each group (see Appendix E, Table E1). Chi-square comparisons (with a Bonferroni-corrected alpha level of .025 for each of two tests) revealed a statistically reliable difference between the FV and NFV groups, $\chi^2(1, N = 30) = 9.13$, $p = .003$, but not between the FV and SIVR groups, $\chi^2(1, N = 30) = 3.97$, $p = .046$.

In order to evaluate sensitivity at the end of the test phase, subjects were also categorized based on their response rates during minutes 23-25 of the test phase (see Table 5). The following categories were established: >180, 121-179.9, 60-119.9, 20-59.9, 5-19.9, and

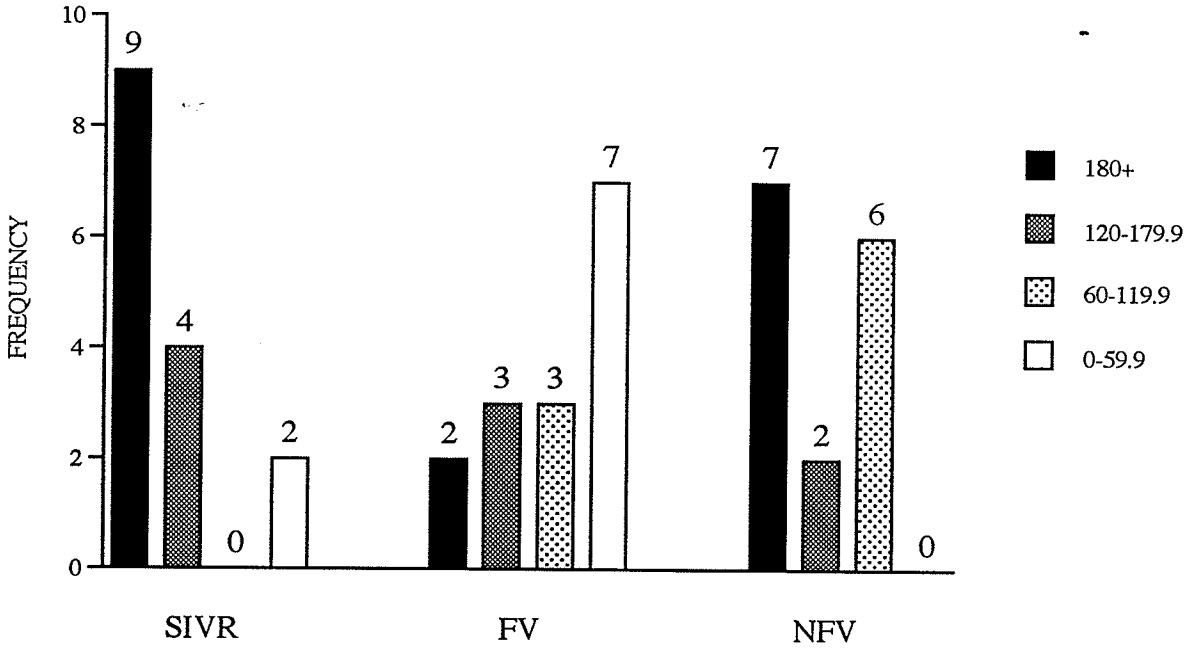

Figure 3. Frequency distribution of mean responses per minute during the FI test phase for all subjects in Experiment 1.

Table 5

Mean Number of Responses per Minute During Minutes 23 to 25 of the FI Test Phase for Subjects in Experiment 1

Subject	SIVR	Subject	FV	Subject	NFV
001	330.0	016	279.0	031	302.6
002	263.4	017	215.6	032	307.4
003	296.4	018	239.0	033	289.4
004	272.0	019	88.6	034	300.6
005	274.6	020	108.6	035	232.4
006	239.4	021	4.0	036	228.0
007	256.4	022	34.4	037	189.6
008	189.4	023	6.6	038	147.0
009	37.6	024	52.6	039	145.4
010	49.4	025	18.6	040	7.6
011	141.0	026	8.0	041	80.4
012	33.6	027	1.6	042	101.0
013	130.0	028	2.6	043	7.0
014	59.0	029	2.6	044	68.4
015	46.0	030	1.4	045	37.4
Mean:	174.5		70.9		163.0
Median:	189.4		18.6		147.0

0-4.9 responses/min. Selection of the 0-4.9 category was designed to bracket response rates that would be near optimal on an FI 30-s schedule (2 responses/min) yet exclude the minimum rates typically produced by Nonfunctional training (see Appendix C, Table C1). The 5-19.9 category was designed to include response rates typically produced by the low-rate schedules of NFV training. The frequency data for numbers of subjects falling into each category are shown in Figure 4. The greatest number of subjects fall into the most FI-insensitive category for both the SIVR and NFV groups, while the majority of FV subjects fall into the most sensitive category. Indeed, only the FV group, which involved the training of functional rates, included subjects who responded with this degree of sensitivity. The data were collapsed across category to compare the number of sensitive (defined as 0-19.9 responses/minute) and insensitive (> 19.9 responses/minute) subjects in each group (see Appendix E, Table E2). A chi-square comparison at alpha .025 revealed a statistically reliable difference between the FV and NFV groups, $\chi^2(1, N = 30) = 5.40$, $p = .020$. Unlike the analysis of the full-phase data, this analysis also revealed a significant difference between the SIVR and FV groups, $\chi^2(1, N = 30) = 10.91$, $p = .001$. Application of a more stringent test of sensitivity at a later point in time may explain this discrepancy. Apparently, two SIVR subjects give relatively low response rates over the test phase as a whole (Appendix E, Table E1). None, however, achieved the highly sensitive response rates adopted by some FV subjects after extended exposure to the FI schedule (Appendix E, Table E2). Overall, the individual subject data confirm the differences revealed by analysis of the group data: greater sensitivity to FI for subjects exposed to FV training than for those receiving SIVR or NFV training.

Discussion

Experiment 1 had two main purposes: (a) to assess the schedule sensitivity produced by variety training under more stringent conditions than have previously been employed, and (b) to investigate the way in which variety training enhances sensitivity through comparison of alternative forms (Functional vs Nonfunctional). With respect to the first purpose, variety

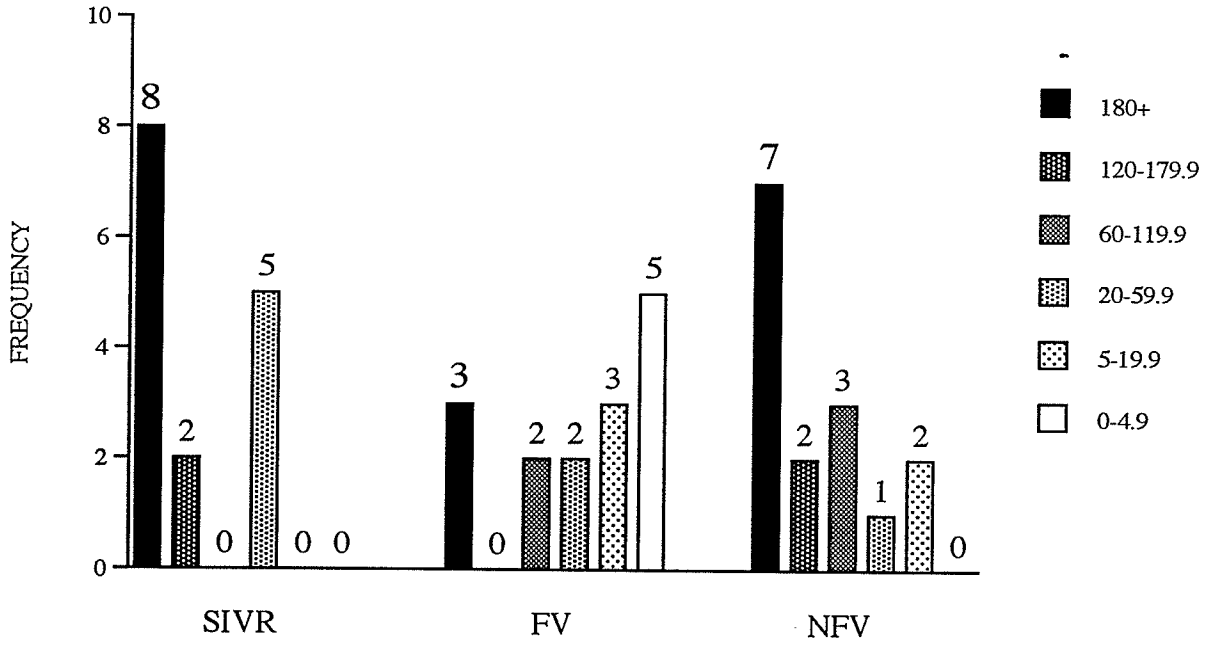

Figure 4. Frequency distribution of mean responses per minute during minutes 23 to 25 of the FI test phase for all subjects in Experiment 1.

training produced a greater degree of sensitivity than single instruction training under the conditions of this experiment. These conditions included the training of high-rate responding immediately prior to test phase initation, and a balanced proportion of high- and low-rate training. Thus, these data systematically replicate the phenomenon of variety-trained sensitivity (LeFrancois et al., 1988).

With respect to the second purpose, the data suggest that the specific response rates established by variety training are an important determinant of sensitivity. Variety training of rates that overlapped with efficient behavior under the test condition resulted in greater sensitivity than variety training that did not include such rates. These data are most consistent with theory "b," as described in the introduction. The notion that the changing response patterns of variety per se facilitate contact with novel schedules was not supported (theory "a"). If variety intrinsically facilitates sensitivity to novel conditions, perhaps by promoting variability in responding, then the data for the FV and NFV groups should have been similar. As it was, the performances of subjects in the NFV group often resembled the insensitive performances of the SIVR group. The generality of this finding is a matter for further investigation: It remains possible that a different Nonfunctional variety of instructions and schedules (perhaps producing rates that more closely approximate optimal test rates) could result in sensitivity to a novel contingency.

The form of insensitivity displayed by NFV subjects is an intriguing aspect of the current findings. It is perhaps not surprising, since they lacked the training experience, that these subjects all failed to respond at optimal rates during the test phase. However, NFV subjects might reasonably have been expected to adopt the most efficient rate for which they had received training. Only two of fifteen subjects did so. The majority (Subjects 031-038) emitted high rates more consonant with their FR training experiences. One possible explanation is that a repertoire including moderately efficient response patterns (NFV training) may be more susceptible to influence by historical variables than a repertoire including patterns

of optimal efficiency (FV training). Human subjects apparently have considerable extra-experimental reinforcement histories for high-rate responding (cf. Weiner, 1970) that may come to bear under such circumstances. A second possibility is that the stimulus properties generated by responding on the FI schedule in some way resembled those encountered under the FR schedules. The high rates previously reinforced in the presence of such stimuli might then be occasioned in the test phase.

The second possibility accords with evidence that the discriminative, rather than reinforcing, properties of a contingency can produce insensitivity (Cerutti, 1991). In Cerutti's research, subjects were instructed to prevent response-independent tones by pressing panels at varying rates. Tones were presented on a mixed random-, mixed fixed-, or fixed-time basis. Many subjects in the former two conditions, where the inter-tone interval varied, complied with instructions to respond rapidly and reported that they had prevented tones. Fewer subjects did so under the fixed-time schedule, where tones occurred regularly. These findings were attributed to stimulus properties of the respective schedules: The mixed schedules involved stimulus fluctuations that gave the appearance of a contingency, whereas the fixed schedule did not do so. In other words, the formal similarity between properties of the mixed schedules and actual contingencies in the subjects' histories made these properties discriminative of compliance.

If the discriminative properties of response-independent schedules can participate in the control of responding, it seems reasonable that response-contingent stimuli could do the same. In other words, stimulus properties of a reinforcement schedule could come to occasion particular forms of responding based on their prior association with reinforcement of those rates. However, in order for a discriminative control analysis to explain the difference between the FV and NFV groups, some property of the FI schedule would have to acquire differential control of response rate as a result of each group's training experiences. A property deserving of consideration may be reinforcement density.

Table 6 shows the density of point delivery associated with each schedule component, averaged across all subjects in a given group. Schedule components are classed as high-rate or low-rate depending on the rates they typically produced. Although densities during training and testing are only slightly dissimilar for the SIVR group, this is unlikely to matter: No alternative to high-rate responding has been trained for the stimulus properties of FI to occasion. Discriminative properties of point density may be more important where response alternatives are available, as was the case for the FV and NFV groups. For subjects receiving FV training, the mean point density associated with the DRL and VI schedules (1.0) more closely approximates density under test conditions (1.8) than does the mean density for the FR schedules (6.8). Indeed, the density for one schedule (VI 20) is identical to that of FI. If point density under DRL and VI acquires a degree of discriminative control over low-rate responding during training, the similarity of point density under FI might occasion low rates. The predominance of low-rate FI performances among FV subjects is consistent with this account. The predominantly high-rate responding of NFV subjects also conforms to this theory. The average density associated with high-rate (6.5) and low-rate (9.1) responding are both dissimilar to the FI mean (1.9). However, the high-rate schedule value is the more comparable of the two. In addition, the only single-component density to closely approximate the FI test density is associated with high-rate responding (2.8 for FR 100). Thus, an analysis in terms of the discriminative control of FI point density would predict high-rate FI responding for the NFV group. For many subjects, this is what occurred.

An account of schedule sensitivity in terms of the discriminative properties of point density appears plausible. However, this explanation must be regarded as tentative with respect to the current findings. For the FV and NFV groups, differences in point density are confounded with differences in minimal rate trained. The NFV group, for example, experiences closer correspondence between high-rate schedule point densities and test-phase point densities. However, this group also lacks training in rates that would be functional in the test phase.

Table 6

Point Densities per Minute by Schedule Component in Experiment 1

	Condition			
	FV		NFV	
	High-rate	Low-rate	High-rate	Low-rate
	5.1 (FR 40)	0.8 (DRL 15 s)	5.9 (FR 40)	8.6 (DRL 2 s)
	3.0 (FR 100)	0.9 (VI 40 s)	2.8 (FR 100)	8.8 (VI 4 s)
	14.0 (FR 20)	0.5 (DRL 45 s)	12.9 (FR 20)	5.1 (DRL 6 s)
	5.0 (FR 60)	1.8 (VI 20 s)	4.4 (FR 60)	13.9 (VI 2 s)
Mean:	6.8	1.0	6.5	9.1
Range:	3.0-14.0	0.5-1.8	2.8-12.9	5.1-13.9
	Test: 1.8 (FI 30 s)		Test: 1.9 (FI 30 s)	

	SIVR
	High-rate
	3.3 (VR 80)
Mean:	3.3
Range:	-
	Test: 1.9 (FI 30 s)

Perhaps low rates that are nonfunctional are simply overcome by high-rates with a greater history of reinforcement. Without independent manipulation of variables such as response rate and point density, their relative contribution to schedule sensitivity cannot be assessed.

Experiment 2 explored the contribution of both response-rate history and the discriminative properties of reinforcer density to the sensitivity produced by variety training. As in Experiment 1, Functional and Nonfunctional response-rate histories were established by manipulating the parameters associated with a variety of reinforcement schedules. Discriminative control of response rate by point density was manipulated by establishing three relationships between (expected) training- and test-phase point densities: (a) correspondence between the FI test schedule and the high-rate (FR) training schedules, (b) correspondence between the test schedule and low-rate (DRL and VI) training schedules, and (c) correspondence between the test schedule and both high-rate and low-rate training schedules. It was predicted that response rates on FI would vary according to the type of training schedule (high- vs low-rate) with which FI point densities had been "matched." Presumably, correspondence with FR point densities would generally occasion high rates, correspondence with DRL/VI densities would occasion low rates, and correspondence with both would produce an intermediate result. Such a result would implicate density of points as the discriminative schedule property that is potentially an important determinant of the effectiveness of variety training. The effect of response-rate history was expected to be less pronounced than was observed in Experiment 1, where it was confounded with differences in point density.

Experiment 2

Method

Participants

Subjects were 150 male and female undergraduates selected in the same manner as for Experiment 1.

Apparatus

The apparatus and setting were similar to those of Experiment 1. The study was conducted in a new 7.7 X 15.2 m microcomputer laboratory containing seven rows of 486 AT clone computers, with seven units in each row. Up to seven computer units were employed in a given experimental session. As was the case in Experiment 1, the operative units were arranged so that a seated subject could not observe fellow participants.

Design

A between-subjects factorial design was employed for experimental groups, with two levels of response-rate history (Functional vs. Nonfunctional), and three levels of correspondence between expected training- and test-phase point densities: FR densities matched with FI density (abbreviated FR), DRL and VI densities matched with FI density (abbreviated DRL), and the densities of both high-rate and low-rate training schedules matched with FI densities (abbreviated BOTH). As in Experiment 1, a Specific Instruction VR (SIVR) control group provided a baseline measure of the sensitivity produced by single-instruction training. Subjects were randomly assigned to each of the seven condtions (N = 21 or 22 for each group).

All subjects received a 24 min training phase followed by a 10 min test phase. Both phases occurred in a single session of approximately 45 min duration.

Procedure

The general instructions (see Appendix A) and procedures were identical to those of Experiment 1. However, due to practical and empirical considerations, the overall duration of session was decreased from 57 min (32 training, 25 testing) to 34 min (24 training, 10 testing). The practical consideration was subject availability. Briefer sessions allowed participants to more easily fit the experiment into their timetables, thus enhancing attendance. An empirical consideration was the disquieting number of Experiment 1 subjects who described the sessions as "boring" and "too long." In light of such reports, it seems possible that lengthy sessions

threaten the control of performance by task-relevant variables (in contrast to Hayes et al., 1986). Indeed, instances where apparently FI-sensitive performance abrupty varied (e.g., Subjects 009, 011, 024, 039, 045) may reflect a loss of experimental control due, in part, to variables associated with the length of the test phase. A second empirical consideration was the rapidity with which many sensitive subjects came under the control of the FI schedule. Visual inspection of Figure 2, and of the individual subject graphs, reveals that the substantive group differences in sensitivity were established early. Thus, a lengthy session appeared to add little to the experimental demonstration. A final factor favoring use of an abbreviated test phase was the reduced FI test parameter required for Experiment 2 (see Training). A smaller FI value allowed for the delivery, in a shorter time period, of a number of consequences similar to the number provided in Experiment 1.

Empirical considerations also supported the omission of the the test-phase stability criterion employed in Experiment 1. Use of the criterion allowed for an open-ended session length, increasing the possibility of boredom. Furthermore, the criterion occasionally failed in its intended purposes: to identify stable responding (Subject 045, for example, made 14, 13, 122, 135, 1, and 9 responses per reinforcer, respectively, in satisfying the stability criterion) and to terminate the session at a point characterizing a subject's FI sensitivity (e.g., Subject 009, Appendix D).

Training. Training components were presented in the same manner as in Experiment 1, with two exceptions. First, variety components were reduced from 4 to 3 min in duration. This change contributed to a reduced session length. Second, subjects in Experiment 2 received an instructional prompt when they responded too rapidly on the DRL schedules (see Appendix A). This prompt was designed to ensure the rapid acquisition and maintenance of schedule-appropriate response rates. Without this instruction, subjects might earn points inefficiently on the DRL schedules, reducing the density of point delivery (In the FV group of Experiment 1, for example, 6 of 15 subjects earned zero points on the DRL-45 s schedule).

Since a goal of Experiment 2 was to control the density of point delivery through selection of particular schedules (see below), it was essential to ensure that subjects earn points in a relatively efficient manner. The instructional prompt increased the probability that this would occur for each DRL schedule: Only 3 of the 129 subjects exposed to DRL schedules in Experiment 2 failed to earn points on any one DRL component, and most earned points efficiently.

The Specific Instruction Variable Ratio condition (SIVR) employed the same instruction (see Table 7) and schedule as was used for this group in Experiment 1. For the variety conditions, a different instruction (Table 7) and schedule (see Table 8) were presented every 3 min for a total of eight training components. The schedule values for each training condition were selected to produce a match between (expected) point densities earned during testing and during particular components of training (designated FR, DRL, or BOTH), and to produce functional or nonfunctional rates (designated as F or N).

Functional and nonfunctional rates were established in the same manner as in Experiment 1. For all conditions designated as F (Functional), the DRL and VI training components were designed to produce rates that were slower, or nearly as slow, as the optimal test rate (under FI 15-s, one response every 15 s). The DRL/VI values for the FR-F group (DRL 30-s, VI 50-s, DRL 60-s, and VI 40-s) differed from those selected for the DRL-F and BOTH-F groups (DRL 5-s, VI 20-s, DRL 25-s, and VI 10-s) because of constraint imposed by the density-match factor (see below). For all conditions designated as N (Nonfunctional), the DRL/VI values were smaller, such that the slowest instructed response rate (for DRL 5-s: "Wait 5 seconds before pressing the earn key for each point") well exceeded the rate of maximally efficient FI responding. The DRL/VI schedules for the DRL-N and BOTH-N groups participated in a tandem arrangement to accommodate the density-match variable (see below).

Selection of particular schedules also allowed for manipulation of the density-match factor.

Table 7

Schedule Instructions for Training Conditions in Experiment 2

Condition	Schedule	Instruction
SIVR	VR 80	Press the earn key approximately 80 times for each point.
Variety Conditions	FR x	Press the earn key x times for each point.
	DRL x	Wait x seconds before pressing the earn key for each point.
	tandem DRL x	Wait x seconds before pressing the earn key for each point. When you have done this 5 times, the computer will give you one point.
	VI x	Press the earn key approximately every x seconds for each point.
	tandem VI x	Press the earn key approximately every x seconds for each point. When you have done this 5 times, the computer will give you one point.

Table 8

Order of Schedule Presentations for Variety Training Conditions in Experiment 2

	Condition		
	FR-F	FR-N	DRL-F
Training Schedules	FR 50 DRL 30 s FR 125 VI 50 s DRL 60 s FR 25 VI 40 s FR 100 (3 min each)	FR 50 DRL 1 s FR 125 VI 4 s DRL 5 s FR 25 VI 2 s FR 100 (3 min each)	FR 10 DRL 5 s FR 25 VI 20 s DRL 25 s FR 5 VI 10 s FR 20 (3 min each)
	DRL-N	BOTH-F	BOTH-N
Training Schedules	FR 10 5X DRL 1 s FR 25 5X VI 4 s 5X DRL 5 s FR 5 5X VI 2 s FR 20 (3 min each)	FR 50 DRL 5 s FR 125 VI 20 s DRL 25 s FR 25 VI 10 s FR 100 (3 min each)	FR 10 5X DRL 1 s FR 25 5X VI 4 s 5X DRL 5 s FR 5 5X VI 2 s FR 20 (3 min each)
Test Schedule (all groups)	FI 15 s (10 min)	FI 15 s (10 min)	FI 15 s (10 min)

The expected point densities associated with the test schedule and each training schedule are shown in Table 9. These values are based on the theoretically perfect performance for all low-rate schedules (e.g., two points per minute for a DRL 30-s schedule) and an estimated response rate of five responses/second during high-rate components (e.g., one point every 10 seconds on FR 50, for a density of six points per minute). The five responses/second value was based on the results of Experiment 1, and represents an approximation of the FR rates achieved by most subjects.

For groups designated FR, schedule values were designed to match point density earned on the FI 15-s test schedule with those earned on the FR (high-rate) training schedules. The range of point densities expected under the high-rate schedules (2.4-12.0) overlapped the density expected for the FI test schedule (4.0). In addition, the most comparable individual component density (for FR 100) was associated with a high-rate schedule. By contrast, the ranges of point densities for the low-rate schedules (1.0-2.0 for FR-F; 12.0-60.0 for FR-N) did not overlap the expected test density. These schedules were expected to bring high-rate responding under the discriminative control of point densities similar to those that would be encountered during testing. Unlike the other two density match conditions (DRL and BOTH), point density ranges for the low-rate schedules could not be held equivalent. Low-rate schedule values for the FR-F and FR-N conditions had to be large (e.g., DRL 60-s) or small (e.g., DRL 5-s), respectively, in order to ensure that the low rates were appropriately functional or nonfunctional.

For groups designated DRL, schedule values were selected to produce a correspondence between point density earned on the FI 15-s test schedule and on the DRL and VI (low-rate) training schedules. The range of point densities expected under the low-rate schedules (2.4-12.0) overlapped with the density expected for the FI test schedule (4.0). Furthermore, the most comparable individual component density (for VI 20) was associated with a low-rate schedule. Point densities for the high-rate schedules (range: 12.0-60.0) were greatly dissimilar

Table 9

Estimated Point Densities per Minute by Schedule Component for Experiment 2

	Condition			
	FR-F		FR-N	
	High-rate	Low-rate	High-rate	Low-rate
	6.0 (FR 50)	2.0 (DRL 30 s)	6.0 (FR 50)	60.0 (DRL 1 s)
	2.4 (FR 125)	1.2 (VI 50 s)	2.4 (FR 125)	15.0 (VI 4 s)
	12.0 (FR 25)	1.0 (DRL 60 s)	12.0 (FR 25)	12.0 (DRL 5 s)
	3.0 (FR 100)	1.5 (VI 40 s)	3.0 (FR 100)	30.0 (VI 2 s)
Mean:	5.9	1.4	5.9	29.3
Range:	2.4-12.0	1.0-2.0	2.4-12.0	12.0-60.0
	Test: 4.0 (FI 15 s)		Test: 4.0 (FI 15 s)	
	DRL-F		DRL-N	
	High-rate	Low-rate	High-rate	Low-rate
	30.0 (FR 10)	12.0 (DRL 5 s)	30.0 (FR 10)	12.0 (5X DRL 1 s)
	12.0 (FR 25)	3.0 (VI 20 s)	12.0 (FR 25)	3.0 (5X VI 4 s)
	60.0 (FR 5)	2.4 (DRL 25 s)	60.0 (FR 5)	2.4 (5X DRL 5 s)
	15.0 (FR 20)	6.0 (VI 10 s)	15.0 (FR 20)	6.0 (5X VI 2)
Mean:	29.3	5.9	29.3	5.9
Range:	12.0-60.0	2.4-12.0	12.0-60.0	2.4-12.0
	Test: 4.0 (FI 15 s)		Test: 4.0 (FI 15 s)	

Table 9 (continued)

	Condition			
	BOTH-F		BOTH-N	
	High-rate	Low-rate	High-rate	Low-rate
	6.0 (FR 50)	12.0 (DRL 5 s)	6.0 (FR 50)	12.0 (5X DRL 1 s)
	2.4 (FR 125)	3.0 (VI 20 s)	2.4 (FR 125)	3.0 (5X VI 4 s)
	12.0 (FR 25)	2.4 (DRL 25 s)	12.0 (FR 25)	2.4 (5X DRL 5 s)
	3.0 (FR 100)	6.0 (DRL 10 s)	3.0 (FR 100)	6.0 (5X VI 2 s)
Mean:	5.9	5.9	5.9	5.9
Range:	2.4-12.0	2.4-12.0	2.4-12.0	2.4-12.0
	Test: 4.0 (FI 15 s)		Test: 4.0 (FI 15 s)	

from the expected test density. Thus, these schedules were expected to bring low-rate responding under the discriminative control of point densities similar to those that would be encountered during testing. The DRL-N and DRL-F groups differed in one respect: The low-rate schedule components for the DRL-N group consisted of tandem schedules. Under these schedules, subjects earned a single reinforcer point after satisfying the requirements of a given schedule five times. Expected point densities under these schedules were the same as for their non-tandem counterparts in the DRL-F group. For example, a DRL-N subject responding with optimal efficiency would earn 12.0 points per minute on a tandem 5X DRL 1-s schedule, as would a DRL-F subject responding on a DRL 5-s schedule. However, the response rate required of DRL-N subjects would be five fold greater. Thus, the tandem arrangement functioned to preserve the correspondence between the FI and the low-rate schedule point densities, while ensuring that subjects were trained to respond at nonfunctional rates.

For groups designated BOTH, schedule values were selected to produce a correspondence between point density earned on the FI 15-s test schedule and on both the FR (high-rate) and DRL/VI (low-rate) training schedules. The range of point densities expected under the low-rate and high-rate schedules (2.4-12.0) both overlappedwith the density expected for the FI test schedule (4.0). These schedules were designed to bring both high-rate and low-rate responding, each to a similar degree, under the discriminative control of point densities similar to those expected during the test phase. The low-rate schedules included a tandem requirement for the BOTH-N group. As was the case for the DRL-N group, this arrangement preserved the correspondence between the FI and the low-rate schedule point densities, while ensuring that subjects were trained to respond at nonfunctional rates.

Two manipulation checks ensured that the various training histories produced their designated effects. Calculation of each subject's lowest response rates during a single 4-min schedule component revealed that these minimum rates were functional (approximating or falling below 4 responses/min, the optimal rate on the FI 15-s test shedule) for all subjects in

the Functional groups (see Appendix C, Table C2). The minimum response rates for subjects in the Nonfunctional groups were typically over 7 responses/min. The success of the density match manipulation was judged based on the densities associated with each schedule component, averaged across all subjects in a given group (Appendix F). Comparison of these densities with those obtained under FI revealed that the appropriate matches in point density were generated.

Testing. The parameter of the FI test schedule was changed from 30 s to 15 s for Experiment 2. This change was driven by the need, for the FR conditions, to establish a variety of FR point densities corresponding to those available during the test phase. Use of an FI 30-s test schedule would have required the selection of fixed ratios averaging 150 responses (assuming a typical FR response rate of approximately 300 responses per minute). Some FR values would have been higher. Extremely high FR values would have invoked the risk of ratio strain; hence, the smaller FI value was adopted. The FI 15-s schedule remained in effect for 10 minutes.

As in Experiment 1, subjects were given experimental credit at the conclusion of the session and participated in the performance-based lottery. The theoretical mean earning per pick was 71 cents (actual was 41 cents), and all subjects earned between one and four picks.

Results

Figure 5 shows the mean number of responses per minute across all subjects in a given group during the training and the test phases. Pressing rates for the SIVR group were consistently high throughout training, consistent with the results of Experiment 1. For all forms of variety training, pressing rates were high during FR components of training and low during DRL and VI training components, also consistent with Experiment 1.

Test phase performances for each group are isolated in Figure 6. The upper panel displays the mean response rates for the three Functional groups, along with the SIVR group. Pressing rates for the SIVR group are high at the outset of testing (over 250 responses/min), and then

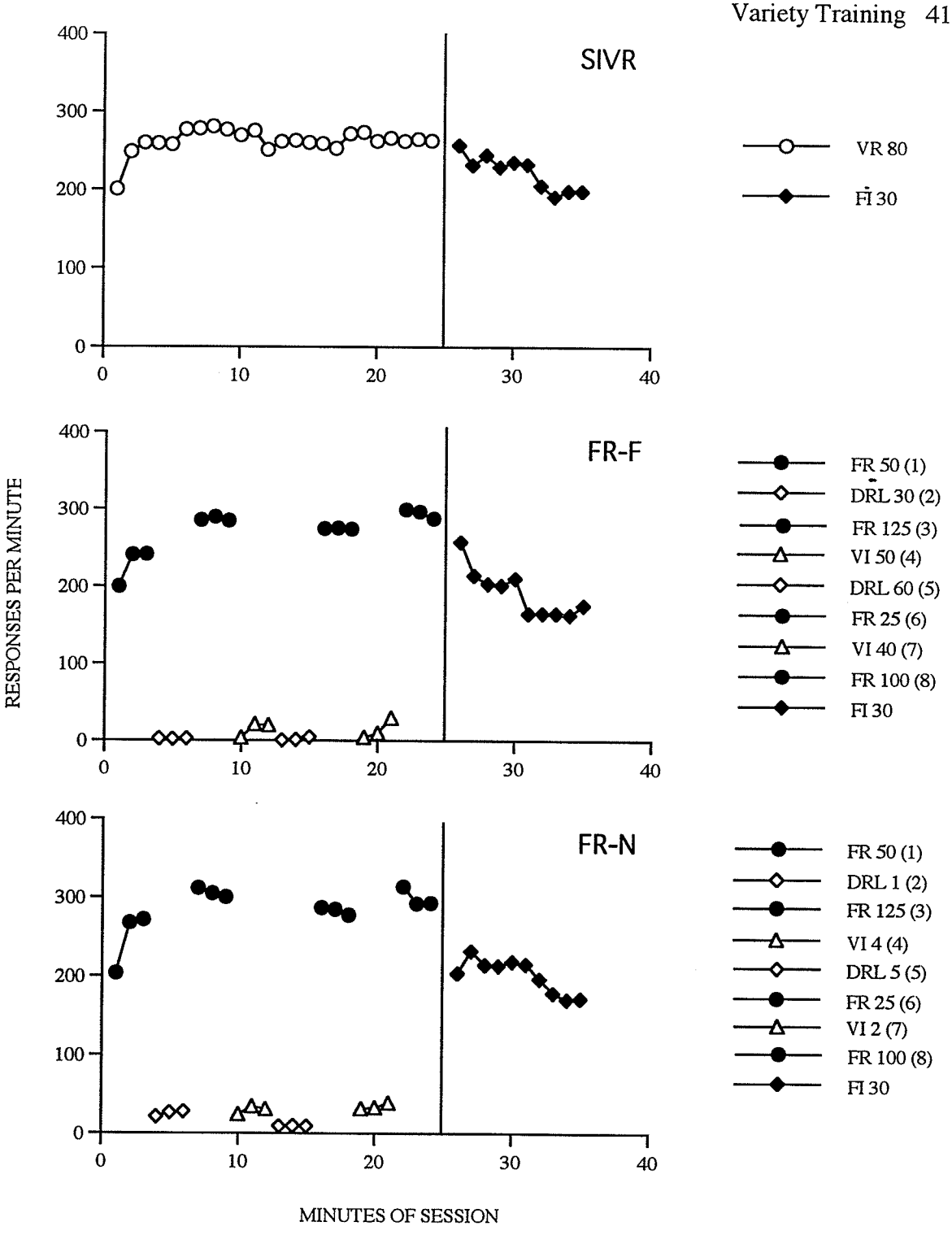

Figure 5. Mean number of responses per minute across all subjects in each group of Experiment 2 (training and test phases). Numbers in parentheses indicate order of training schedule presentation.

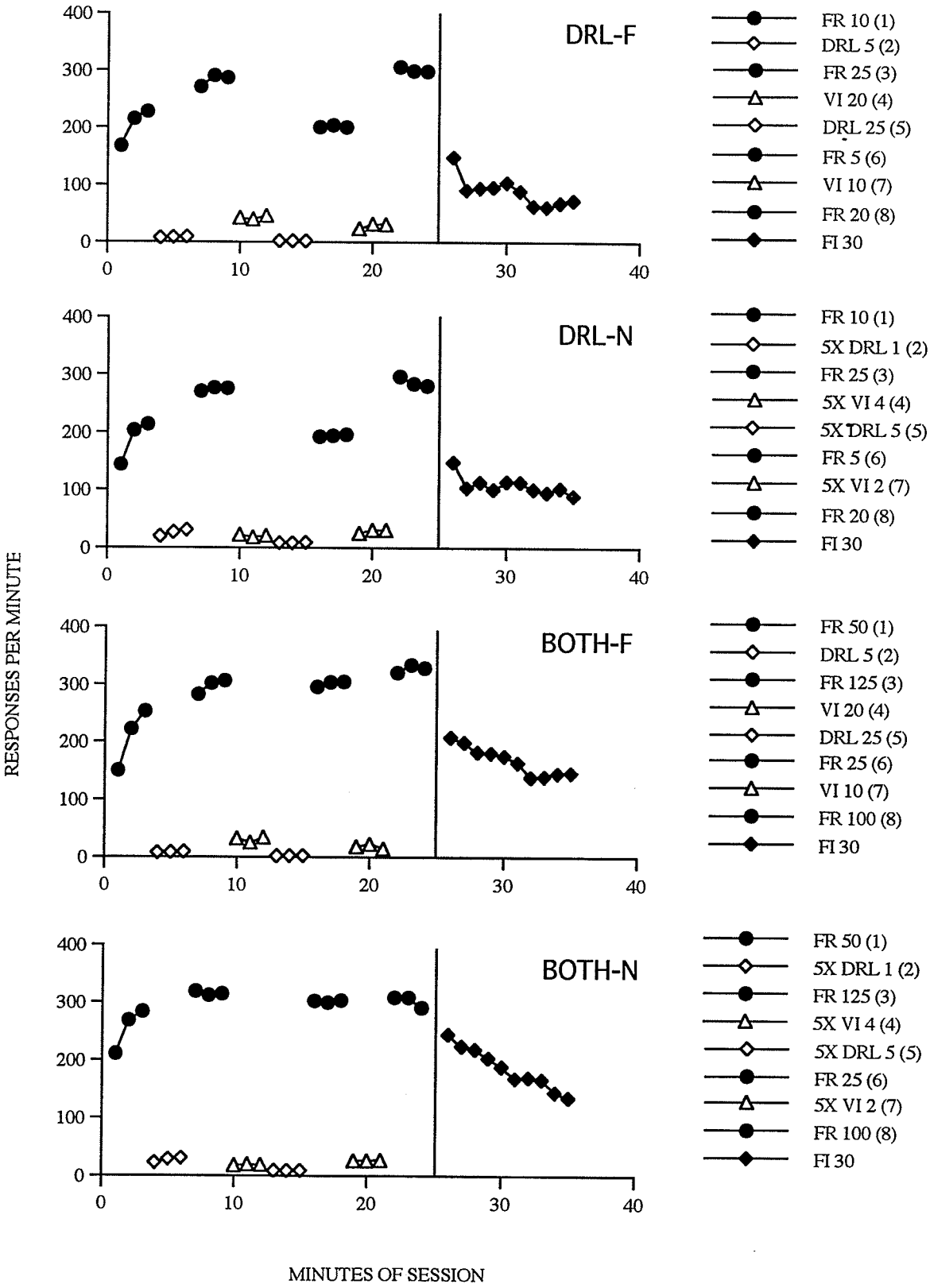

Figure 5 (continued)

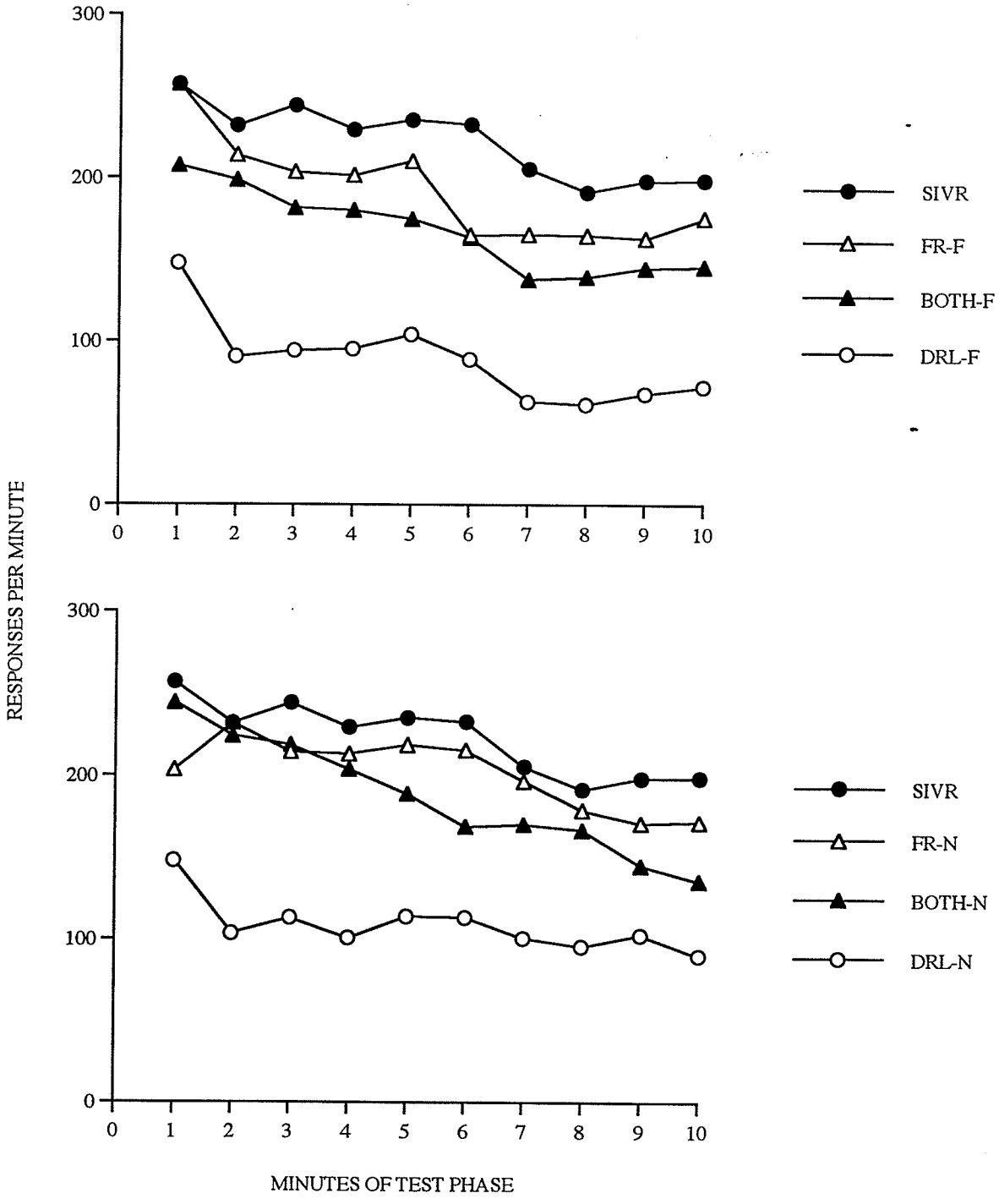

Figure 6. Mean number of responses per minute across all subjects in each Functional (upper panel) and Nonfunctional (lower panel) group of Experiment 2 (test phase). SIVR data are plotted in both panels.

decline slightly over time (to approximately 200 responses/min). The performances of the FR-F and BOTH-F groups follow a similar pattern, culminating in somewhat lower response rates. The lowest rates by far belong to the DRL-F group. Mean pressing rate for this group is lower than for all other groups at the outset of testing. Thereafter, the mean rate declines sharply, and shows a slight decreasing trend over the remainder of the phase. A similar pattern of results emerges among the Nonfunctional groups (lower panel), where the DRL-N group shows the lowest rates. For purposes of comparison, the SIVR data displayed in the upper panel are also shown in the lower panel.

A 2 X 3 X 10 mixed factorial ANOVA was conducted, with the two types of response-rate history (Functional or Nonfunctional) and three types of density match (FR, DRL, or BOTH) serving as between-subjects factors. Responses/min for each of the 10 minutes in the test phase was treated as a within-subjects factor. The three-way interaction among the variables was not statistically reliable ($F < 1$), nor were the interactions of minutes of test phase with response-rate history, $F(9, 1107) = 1.11$, $p = .351$, and with density match, $F(18, 1107) = 1.03$, $p = .425$. The analysis also failed to detect a difference in test-phase rates across the Functional and Nonfunctional variety groups ($F < 1$). Only the main effect of density match was statistically reliable, $F(2, 123) = 11.78$, $p < .001$. Consequently, the responses/min data were collapsed across minutes of test phase and response-rate history for analysis of the relative sensitivity at each level of density match.

Table 10 shows the mean number of responses/min collapsed across the first 25 min of the test phase for all subjects in Experiment 2. Among the three density match groups, the mean score for the DRL group ($M = 98.4$, $SD = 83.0$) is considerably lower than the scores of the FR ($M = 196.7$, $SD = 97.3$) and BOTH ($M = 176.6$, $SD = 113.2$) groups. The differences between all pairs of means for the density match groups were evaluated using a Tukey Honestly Significant Difference (HSD) test with an alpha level of .05. This analysis confirmed a statistically reliable difference between the DRL group and each of the FR and BOTH groups.

Table 10

Mean Number of Responses per Minute During the FI Test Phase for Subjects in Experiment 2

Subject	SIVR	Subject	FR-F	Subject	FR-N
046	377.0	067	346.8	088	374.1
047	319.2	068	304.9	089	334.6
048	305.1	069	304.6	090	309.6
049	304.7	070	300.9	091	288.1
050	282.8	071	298.6	092	272.1
051	282.0	072	282.1	093	269.7
052	272.2	073	278.1	094	256.2
053	263.8	074	276.3	095	246.0
054	249.2	075	275.5	096	232.5
055	248.8	076	193.4	097	221.5
056	244.3	077	171.6	098	214.8
057	218.9	078	166.7	099	201.6
058	213.9	079	161.1	100	201.5
059	202.9	080	145.7	101	201.3
060	178.1	081	143.6	102	198.4
061	157.6	082	135.8	103	120.8
062	156.5	083	71.4	104	112.4
063	132.7	084	56.3	105	110.2
064	126.7	085	49.7	106	79.5
065	124.1	086	39.4	107	78.5
066	6.6	087	24.4	108	76.4
				109	30.3
Mean:	222.2		191.8		201.4
Median:	244.3		171.6		208.2
			Mean (all FR):	196.7	
			Median (all FR):	201.5	

Table 10 (continued)

Subject	DRL-F	Subject	DRL-N	Subject	BOTH-F	Subjects	BOTH-N
110	274.9	131	295.9	153	336.9	175	369.7
111	200.7	132	290.1	154	322.0	176	327.3
112	196.4	133	260.6	155	311.0	177	314.9
113	158.0	134	221.0	156	310.4	178	310.8
114	157.4	135	201.4	157	304.3	179	308.5
115	139.0	136	144.6	158	299.4	180	304.6
116	118.9	137	128.3	159	283.6	181	267.8
117	103.1	138	122.0	160	277.5	182	252.0
118	84.8	139	104.7	161	253.9	183	229.5
119	84.4	140	98.2	162	156.0	184	197.9
120	77.3	141	69.1	163	126.0	185	156.0
121	71.2	142	61.9	164	122.3	186	144.5
122	52.2	143	58.7	165	103.4	187	132.5
123	39.7	144	46.4	166	89.3	188	121.3
124	29.0	145	44.4	167	81.0	189	101.3
125	18.0	146	42.9	168	67.4	190	91.0
126	14.3	147	42.8	169	66.2	191	73.9
127	11.7	148	39.4	170	62.3	192	62.6
128	10.8	149	28.5	171	43.0	193	57.9
129	7.7	150	25.1	172	38.3	194	54.0
130	6.3	151	25.1	173	22.4	195	33.4
		152	23.1	174	4.2		
Mean:	88.3		107.9		167.3		181.5
Median:	77.3		65.5		124.2		156.0

Mean (all DRL):	98.4	Mean (all BOTH):	176.6
Median (all DRL):	71.2	Median (all BOTH):	144.5

Thus, the DRL condition appeared to produce greater sensitivity to the FI schedule than either of the other two density match conditions. The difference between the FR and BOTH groups was not statistically significant.

The means for each type of density match were then compared to the mean for the SIVR group using t-tests. A Bonferroni correction was used to set the alpha level at .017 for the three tests, limiting the family-wise error rate to .05. Corrected degrees of freedom were employed when Levene's test for equality of variances was significant at an alpha of .05. A statistically reliable difference was found between the SIVR group (M = 222.2, SD = 85.0) and the DRL group, $t(62) = 5.56$, $p < .001$. No difference was found between the SIVR group and either the FR group, $t(62) = 1.02$, $p = .309$, or BOTH group, $t(51.3) = 1.80$, $p = .077$. Only the DRL density-match condition produced sensitivity that was statistically superior to that produced by SIVR training.

Sensitivity at the end of testing was assessed using the mean number of responses per scheduled reinforcer during minutes 8 to 10 of testing (see Table 11). A 2 X 3 factorial ANOVA was conducted on these data, with response-rate history (Functional or Nonfunctional) and density match (FR, DRL, or BOTH) serving as between-subjects factors. Statistically, the analysis revealed no interaction of rate history and density match ($F < 1$) and no difference between Functional and Nonfunctional variety training ($F < 1$). However, the main effect of density was statistically reliable, $F(2, 123) = 6.87$, $p = .001$. The differences between all possible pairs of means for the three density match conditions were evaluated using a Tukey HSD test with an alpha level of .05. This analysis confirmed a statistically reliable difference between the DRL group (M = 20 .4, SD = 22.9) and each of the FR (M = 42.7, SD = 30.5) and BOTH (M = 36.5, SD = 31.6) groups. The difference between the FR and BOTH groups was not statistically significant. Thus, at the end of testing, the DRL group showed superior sensitivity relative to the groups experiencing the other two types of density match.

Comparison of the means for each density match condition with that of the SIVR group

Table 11

Mean Number of Responses per Scheduled Reinforcer During Minutes 8 to 10 of the FI Test Phase for Subjects in Experiment 2

Subject	SIVR	Subject	FR-F	Subject	FR-N
046	93.6	067	79.9	088	94.6
047	79.4	068	70.8	089	80.2
048	70.0	069	71.1	090	78.8
049	73.3	070	72.1	091	70.1
050	69.2	071	73.8	092	78.8
051	68.5	072	74.4	093	68.3
052	62.8	073	68.6	094	65.1
053	63.2	074	65.0	095	68.4
054	62.5	075	67.6	096	49.3
055	61.6	076	42.3	097	8.8
056	55.9	077	28.2	098	8.2
057	64.9	078	48.3	099	77.3
058	51.3	079	7.1	100	55.9
059	49.3	080	23.2	101	9.7
060	12.7	081	16.1	102	64.9
061	6.3	082	26.0	103	13.2
062	32.8	083	30.3	104	3.6
063	32.8	084	9.4	105	9.5
064	5.7	085	1.2	106	2.2
065	11.0	086	1.3	107	28.7
066	1.6	087	3.9	108	17.9
				109	1.4
Mean:	49.0		41.9		43.4
Median:	61.6		42.3		52.6

Mean (all FR): 42.7

Median (all FR): 48.3

Table 11 (continued)

Subject	DRL-F	Subject	DRL-N	Subject	BOTH-F	Subjects	BOTH-N
110	63.2	131	74.3	153	83.5	175	89.2
111	1.0	132	69.3	154	80.0	176	78.8
112	67.3	133	66.7	155	76.4	177	76.2
113	49.6	134	53.7	156	74.3	178	80.7
114	3.7	135	21.8	157	73.8	179	76.4
115	52.3	136	3.6	158	72.4	180	75.4
116	18.3	137	44.8	159	65.4	181	70.0
117	1.5	138	40.8	160	63.9	182	59.5
118	16.5	139	35.4	161	37.7	183	4.7
119	16.0	140	21.9	162	31.5	184	35.4
120	11.8	141	14.1	163	15.1	185	3.4
121	22.7	142	11.3	164	26.5	186	25.3
122	2.6	143	13.1	165	1.4	187	21.3
123	8.6	144	3.7	166	1.3	188	4.9
124	10.1	145	9.2	167	21.3	189	11.7
125	0.9	146	16.3	168	6.8	190	16.8
126	1.2	147	2.6	169	39.4	191	1.7
127	1.0	148	6.4	170	1.7	192	13.0
128	1.6	149	4.5	171	6.6	193	16.8
129	0.8	150	4.5	172	6.0	194	13.5
130	0.8	151	4.4	173	1.6	195	6.7
		152	4.3	174	1.3		
Mean:	16.7		23.9		35.8		37.2
Median:	8.6		13.6		29.0		21.3

Mean (all DRL):	20.4	Mean (all BOTH):	36.5
Median (all DRL):	11.3	Median (all BOTH):	25.3

further supported the distinctive sensitivity of the DRL group (with alpha again set at .017). There was a statistically reliable difference between the SIVR group ($\underline{M}$ = 49.0, $\underline{SD}$ = 27.4) and the DRL group, $\underline{t}(62) = 4.39$, $\underline{p} < .001$. A statistically significant difference was not present between the SIVR group and either the FR group, $\underline{t}(62) = .80$, $\underline{p} = .426$, or BOTH group, $\underline{t}(62) = 1.55$, $\underline{p} = .127$.

As in Experiment 1, individual subject data were analyzed to corroborate the group analyses. Individual subject graphs of responses/minute are presented in Appendix G. In the training phase, response rates for individual subjects generally resemble the averages for their respective group. Training rates were high for SIVR subjects; high or low for subjects in all variety groups depending on the operative schedule. As designed, minimum response rates were functional (near or below 4 responses/min) for virtually all subjects in the Functional groups (see Appendix C, Table C2). The minimum response rates for subjects in the Nonfunctional groups were typically over 7 responses/min.

The test-phase data for individual subjects was more variable than the training-phase data. As in Experiment 1, subjects were categorized according to their mean response rates during the FI test phase (see Table 10), in order to provide an objective comparison of individual subject sensitivity across training experiences. The numbers of subjects falling into each category are shown in Figure 7. The largest number of subjects in the SIVR, FR, and BOTH groups averaged over 180 response/min over the FI test phase, suggesting poor sensitivity. By contrast, the predominant rate for DRL subjects was less than 60 responses/min. The data were collapsed across the top three categories to compare the number of sensitive (defined as 0-59.9 responses/min) and insensitive (>59.9 responses/min) subjects across group (see Appendix E, Table E3). With an alpha level of .017 (Bonferroni corrected for three comparisons), chi-square analyses revealed a statistically significant difference in the numbers of sensitive and insensitive subjects between the DRL group and each of the other three groups: the SIVR group, $\chi^2(1, \underline{N} = 63) = 10.21$, $\underline{p} = .001$, the FR group, $\chi^2(1, \underline{N} = 86) = 11.33$, $\underline{p}$

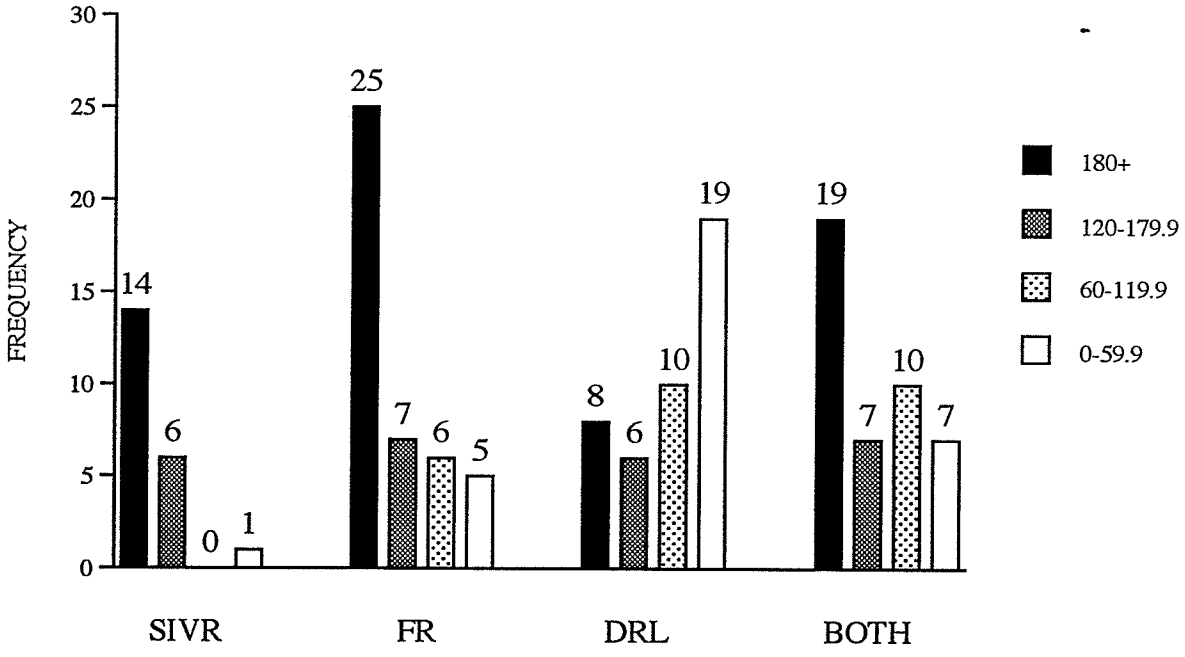

Figure 7. Frequency distribution of mean responses per minute during the FI test phase for all subjects in Experiment 2.

= .001, and the BOTH group, $\chi^2(1, N = 86) = 7.94$, $p = .005$. These data agree with the group results in showing a distinctly superior degree of FI sensitivity for the DRL forms of variety training.

In order to evaluate sensitivity at the end of the test phase, subjects were also categorized based on their response rates during minutes 8-10 of the test phase (see Table 12). The numbers of subjects falling into each category are shown in Figure 8. A 0-19.9 responses/min category was added to the four categories of Figure 7 in order to group those subjects responding at rates in the range typically trained under the low-rate schedules. As was the case for the full-phase data, the largest number of subjects in the SIVR, FR, and BOTH groups responded at rapid rates (>180 responses/min). The predominant rate among DRL subjects was much lower (0-19.9 responses/min) and consistent with their low-rate training. The data were collapsed across category to compare the number of sensitive (0-19.9 responses/min) and insensitive (>19.9 reeponses/min) subjects in each group (see Appendix E, Table E4). At an alpha level of .025, chi-square analyses revealed a difference in the number of sensitive and insensitive subjects between the DRL group and both the SIVR group, $\chi^2(1, N = 63) = 8.44$, $p = .004$, and the FR group, $\chi^2(1, N = 86) = 7.18$, $p = .007$. The difference between the DRL and the BOTH group did not reach statistical significance $\chi^2(1, N = 86) = 3.53$, $p = .06$.

Although the difference between the Functional and Nonfunctional group means was not statistically reliable, an individual subject analysis revealed a subtle group difference. Subjects in each group were classified using the same system as in Figure 8, except that an additional 0-6.9 responses/min category was added. This category was designed to bracket terminal rates that would be nearly optimal on an FI 15-s schedule (4 responses/min) while excluding the minimum rates typically produced by Nonfunctional training (see Appendix C, Table C2). The number of subjects showing this degree of sensitivity was much higher for the Functional group (15) than for the Nonfunctional group (2) (Figure 9). A chi-square comparison between the number of subjects falling into this category versus the other five combined (see Appendix

Table 12

Mean Number of Responses per Minute During Minutes 8 to 10 of the FI Test Phase for Subjects in Experiment 2

Subject	SIVR	Subject	FR-F	Subject	FR-N
046	374.3	067	319.7	088	378.3
047	317.7	068	283.0	089	320.7
048	280.0	069	284.3	090	315.3
049	293.0	070	288.3	091	280.3
050	276.7	071	295.3	092	315.3
051	274.0	072	297.7	093	273.3
052	251.0	073	274.3	094	260.3
053	252.7	074	260.0	095	273.7
054	250.0	075	270.3	096	197.3
055	246.3	076	169.0	097	35.0
056	223.7	077	112.7	098	32.7
057	259.7	078	193.0	099	309.0
058	205.3	079	28.3	100	223.7
059	197.3	080	92.7	101	38.7
060	50.7	081	64.3	102	259.7
061	25.0	082	104.0	103	52.7
062	131.3	083	121.0	104	14.3
063	131.3	084	37.7	105	38.0
064	22.7	085	4.7	106	8.7
065	44.0	086	5.3	107	114.7
066	6.3	087	15.7	108	71.7
				109	5.7
Mean:	195.9		167.7		173.6
Median:	246.3		169.0		210.5
			Mean (all FR):	170.7	
			Median (all FR):	193.0	

Table 12 (Continued)

Subject	DRL-F	Subject	DRL-N	Subject	BOTH-F	Subjects	BOTH-N
110	252.7	131	297.0	153	334.0	175	356.7
111	4.0	132	277.0	154	320.0	176	315.0
112	269.3	133	266.7	155	305.7	177	304.7
113	198.3	134	214.7	156	297.3	178	322.7
114	14.7	135	87.0	157	295.3	179	305.7
115	209.0	136	14.3	158	289.7	180	301.7
116	73.0	137	179.3	159	261.7	181	280.0
117	6.0	138	163.0	160	255.7	182	238.0
118	66.0	139	141.7	161	150.7	183	18.7
119	64.0	140	87.7	162	126.0	184	141.7
120	47.3	141	56.3	163	60.3	185	13.7
121	90.7	142	45.3	164	106.0	186	101.3
122	10.3	143	52.3	165	5.7	187	85.0
123	34.3	144	14.7	166	5.0	188	19.7
124	40.3	145	36.7	167	85.3	189	46.7
125	3.7	146	65.0	168	27.3	190	67.0
126	4.7	147	10.3	169	157.7	191	6.7
127	4.0	148	25.7	170	6.7	192	52.0
128	6.3	149	18.0	171	26.3	193	67.0
129	3.3	150	18.0	172	24.0	194	54.0
130	3.3	151	17.7	173	6.3	195	26.7
		152	17.0	174	5.0		
Mean:	66.9		95.7		143.3		148.8
Median:	34.3		54.3		116.0		85.0

Mean (all DRL):	81.6	Mean (all BOTH):	146.0
Median (all DRL):	45.3	Median (all BOTH):	101.3

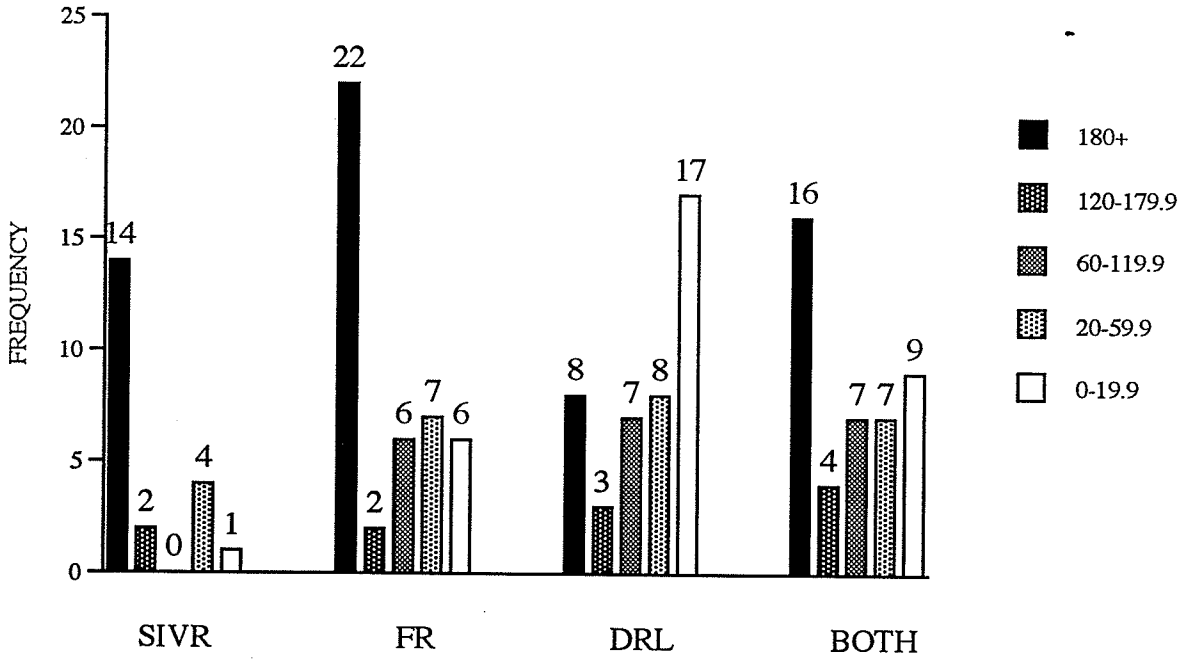

Figure 8. Frequency distribution of mean responses per minute during minutes 8 to 10 of the FI test phase for all subjects in Experiment 2.

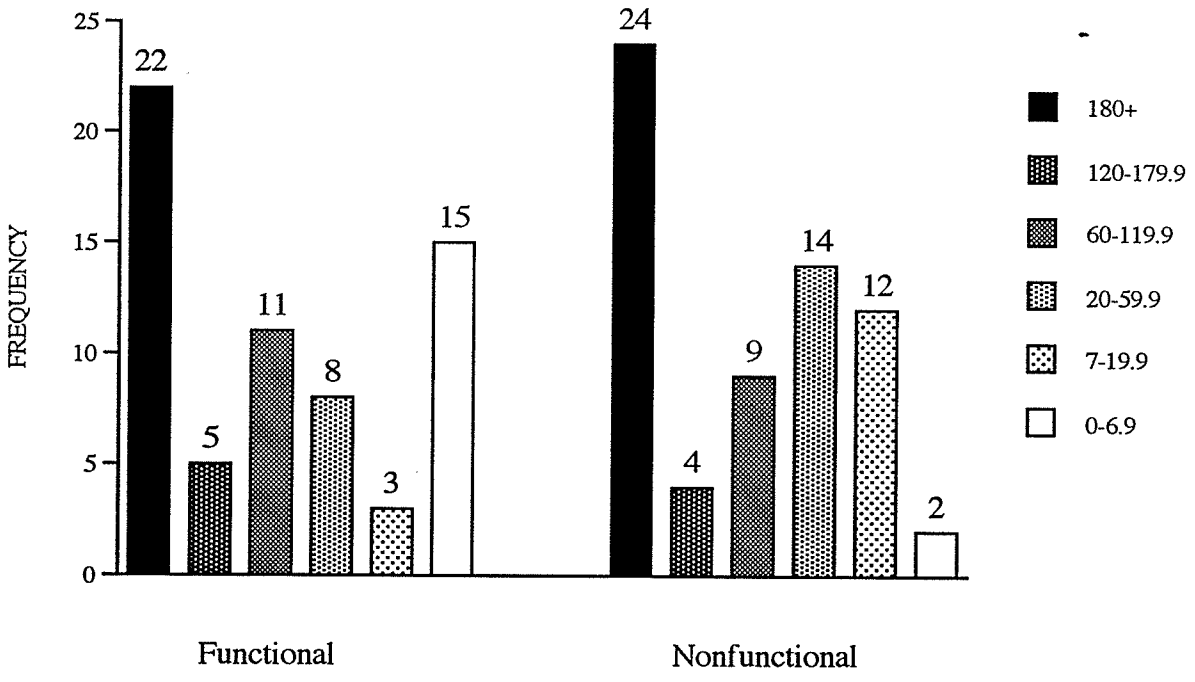

Figure 9. Frequency distribution of mean responses per minute during minutes 8 to 10 of the FI test phase for all subjects in Functional and Nonfunctional variety groups (Experiment 2).

E, Table E5) revealed a statistically reliable difference between the Functional and Nonfunctional groups, $\chi^2(1, N = 129) = 11.68$, $p = .001$. These data show that Functional training more frequently resulted in optimal test rates than did Nonfunctional training.

Discussion

The results of Experiment 2 suggest that a stimulus property of reinforcement schedules -- in this case density of reinforcer presentation -- can acquire discriminative control over response rate and thus affect the sensitivity produced by variety training. Low-rate FI performances appeared when the densities accompanying the training of low rates (as was the case for the DRL group) were matched to the FI density. When the densities accompanying high-rate, or both high- and low-rate training were matched to the FI density, low rates were less likely to occur. Comparisons of the variety training groups to single-instructions training further attest to the influence of discriminative schedule properties on variety-trained sensitivity. Only the DRL form of variety training appeared to produce greater sensitivity than single-instruction training. It is noteworthy that this effect cannot be attributed to the reinforcing, rather than discriminative, properties of the reinforcer points. For both DRL groups, the densities for the FR schedules were "unmatched" to expected FI density by employing small schedule values. The density of reinforcer delivery was therefore substantially higher during FR components than during DRL/VI components. Thus, the sensitivity produced by the low-rate density match occurred under conditions where an analysis of reinforcing effects would predict the opposite.

While the density match variable had a large influence on sensitivity by determining whether low or high rates were more frequently occasioned, the specific rates produced were constrained by subject's response-rate histories. Thus, when low-rate responding occurred, Functional subjects often responded with rates that were optimal on the FI test schedule. Nonfunctional subjects, who had not received training of such rates, did so rarely. This finding accords with the results of Experiment 1, and supports LeFrancois et al.'s (1988)

assertion that variety training may promote sensitivity "if the instructions prompt a range of behavior that overlaps with efficient behavior under the test conditions" (p. 391). A corollary of this assertion is that a variety of instructed performances per se may not enhance sensitivity to changing contingencies, if the rates required for sensitivity have never been trained.

A distinctive feature of the current findings was the presence of large and statistically reliable differences in sensitivity only between the DRL condition and the other groups in the study. A density-match analysis would also predict superior sensitivity for the BOTH group, where point density is nondifferentially discriminative of a particular rate, relative to the FR group, where point density should occasion high rates of responding. Statistically reliable differences between these two groups did not emerge, although existing differences were in the expected direction: The BOTH group showed more sensitivity on all measures. However, the absence of a significant difference between these groups is not necessarily surprising. Human subjects bring to the laboratory extensive reinforcement histories for high-rate responding (cf. Weiner, 1970). In the absence of strong discriminative control of low rates within the experimental context, these higher rates may prevail. Perhaps, where point density was differentially discriminative of neither low-rate nor high-rate responding, the rate with the more extensive reinforcement history simply dominated.

General Discussion

Human responding on schedules of reinforcement has been shown to be insensitive to changing contingencies, particularly when established through the use of instructions (e.g., Galizio, 1979; Hayes et al., 1986; Shimoff et al., 1981). However, instructed behavior may show sensitivity under certain conditions, as when a variety of instructed schedule performances have been experienced (LeFrancois et al., 1988). The current study sought to evaluate accounts of how such "variety training" produces sensitivity, and to explore variables that may determine its effects.

The results suggest that the sensitivity produced by variety training is at least partially

dependent on two variables: (a) the range of behavior that has previously been instructed and (b) the relationship between stimulus properties of the novel contingency and those associated with previously instructed forms of behavior. The first factor appears to delimit the forms of responding (e.g., rates) that may be occasioned under the changed conditions. In the current study, this factor was reflected in the almost exclusive appearance of maximally efficient FI rates among those subjects previously instructed and trained to respond at such rates (i.e., subjects receiving Functional training).

The second factor -- the relationship between stimulus properties of current and previous contingencies -- appears to influence which of the available rates is most likely to be occasioned under the changed conditions. Hence, low-rate FI performances, whether maximally efficient or slightly less so, were most likely to occur when test phase point density matched the point densities accompanying the training of low rates (as was the case for the DRL group). An implication of this finding is that a variety of instructed schedule exposures may be insufficient to produce sensitivity to novel contingencies, even when appropriate rates have been trained. The highly insensitive performance of the FR group is consistent with this suggestion. All subjects in this group received exposure to a variety of instructions and schedules, and many of these subjects (21 of 43) were trained to respond at FI-appropriate rates. However, the sensitivity of this group was so poor as to be virtually indistinguishable from the sensitivity of the group receiving a single instruction. Thus, while variety training may serve to produce sensitivity under certain circumstances, the relationship between stimulus properties of the current contingency and those associated with previously instructed forms of behavior must be considered. The present results add to evidence that the discriminative properties of schedules can support insensitivity (Cerutti, 1991), and extend the demonstration to response-contingent situations.

LeFrancois et al. (1988) note a third factor that may relate to sensitivity to changing conditions: the mean rate of responding during training. In their study, two forms of variety

training (Variety 1 and Variety 2) differed on the number of high-rate instructions and schedule contingencies (two of eight vs. three of eight, respectively). The resulting differences in mean training rates appeared to render the Variety 2 group slightly less sensitive to novel conditions than the Variety 1 group. The current study did not manipulate the number of high-rate schedule components, employing four across all variety conditions. However, it is worth noting that the DRL-F group, which displayed the greatest degree of sensitivity in the current study, was less sensitive than LeFrancois et al.'s (1988) Variety 1 group. This difference is consistent with the notion that mean training rate can influence sensitivity.

Previous research has shown that human insensitivity to changing contingencies can be overcome by providing a variety of instructed schedule exposures (LeFrancois et al., 1988). The present findings show that the success of such a procedure depends on variables already familiar to behavior analysts: the history of reinforced responding and the prevailing conditions of stimulus control. The findings also add to the literature by showing that stimulus features of the schedules themselves may influence variety-trained sensitivity through the process of discriminative control (cf. Cerutti, 1991). Indeed, these stimulus features appear sufficiently critical that a procedure (variety training) capable of producing sensitivity under certain conditions can be rendered largely ineffective through their manipulation. Future research may reveal additional stimuli (e.g., self-generated rules) that influence the sensitivity of human behavior following a variety of instructed schedule exposures. Whatever the source of stimulation (e.g., instructions, self-generated rules, discriminative properties of reinforcement schedules), careful experimental analysis based upon principles of stimulus control appears a particularly promising strategy for understanding and controlling human sensitivity to changing consequences of responding.

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Appendix A

Instructions Presented to All Subjects

Introductory spoken instructions

Welcome to the experiment Kindersley (Kelowna for Experiment 2)! Please do not touch the computer keypad while I give you some general information about the experiment.

First of all, If you are wearing a watch, please remove it and place it out of your view. A pocket would be a good place so that you do not leave it behind.

During the experiment, you will be trying to earn points that allow you to earn money. The more points you earn, the more picks you will get to take from this drum after the experiment is over (SHOW DRUM). It contains paper slips with money values ranging from 1 cent (SHOW TICKET AND PLACE IN DRUM) to 20 dollars (SHOW TICKET AND PLACE IN DRUM). The more points you earn, the greater the chance you will pick a large money value from the drum.

You are not in competition with each other in any way. Each on of you is working on a different program.

Before we begin, are there any questions?

Please begin the experiment now by typing in your name and student number. After you have done that, the computer will tell you what to do. If you get stuck, please raise your hand and I will try to assist you.

General Instructions

Welcome to the human behavior lab, Mr./Ms. (subject's name)!

You are about to participate in a study on how people learn to perform tasks. If you are wearing a watch, please remove it now, and conceal it in your pocket or purse. The entire experiment will be completed in approximately 65 min (45 min for Experiment 2), so there will be no need to be concerned about the time.

Appendix A (continued)

Get comfortable, and when you are ready to read the general instructions, press the <space bar>, marked in yellow.

In order to earn points, you must press the "Earn" key. The earn key is the <Shift> key, marked in green. You will hear a beep when you have earned a point.

In order to accept the point press the "accept" key. The "accept" key is the <Enter> key, marked in red. You must accept a point before you can earn another point. So, as soon as you have earned a point, accept it! Press the <Space Bar> to continue.

The next screen will give you a practice trial. During this practice trial, press the Earn key three (3) times. Then, when you hear the beep, press the "accept" key.

Press the <Space Bar> to begin the practice trial.

If you want to practice again, press the <ESC> key, marked in blue. Otherwise, press the <Space Bar> to continue.

Now you are ready to begin the session. Please concentrate on completing your task individually, since each workstation has a customized program.

Remember to earn and accept as many points as possible. For every 80 (100 in Experiment 2) points you earn during the session, you will be allowed one draw from the money prize drum. Press the <Space Bar> to continue.

Here is an instruction for you to follow: (see Tables 1 and 7 for specific instructions). When you are ready to follow the instruction, press the <ESC> key. Begin when you hear the beep.

<u>End of training instructions</u>

Good job (subject's name)! This portion of the session is over. You earned x points. The session will continue in 30 seconds.

Appendix A (continued)

Test phase instructions

Your training period is over. Now figure out how best to earn points. When you are ready to follow this instruction, press the <ESC> key and begin when you hear the beep.

End of experiment instructions

Good job (subject's name)! You earned x points.

The experiment is now over. Thank you for your participation. Remember to put your watch back on if you had removed it earlier. Please remain seated, and raise your hand to indicate to the experimenter that you are finished. The experimenter will visit you so that you may make your prize draws and receive experimental credit.

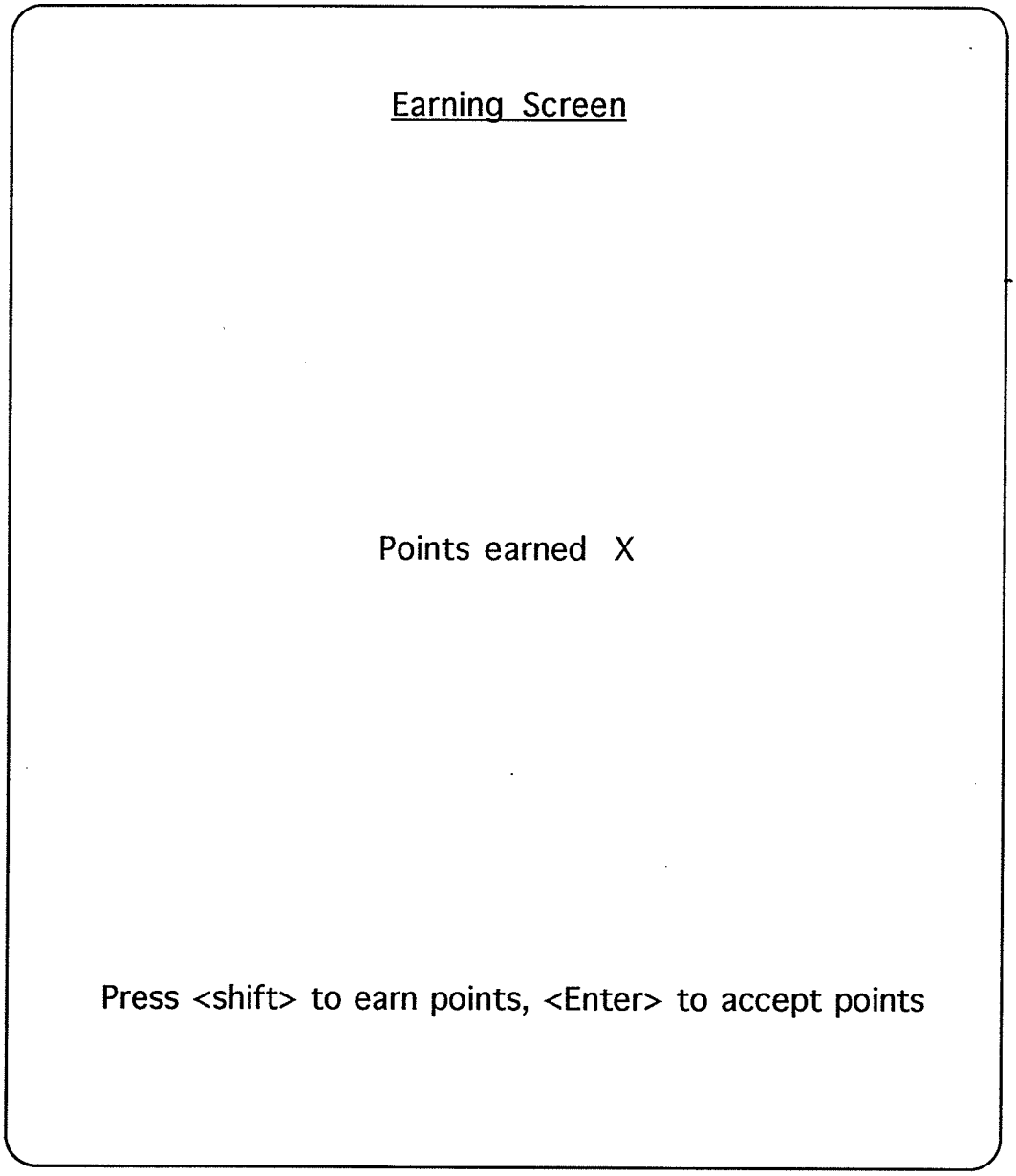
DRL Prompt (Experiment 2 only)

You pressed too soon (subject's name). Wait x seconds before pressing the earn key.

Press the <ESC> key to continue.

Appendix B

Screen Display During Schedule Components



Appendix C

Tables of Lowest Trained Rates

Table C1

Lowest Mean Number of Responses per Minute Over a Single 4-min Training Component for all Subjects in the FV and NFV Groups of Experiment 1

Subject	FV	Subject	NFV
016	3.5	031	8.5
017	1.3	032	7.3
018	186.5	033	112.0
019	33.0	034	10.3
020	3.5	035	11.3
021	1.0	036	19.0
022	1.8	037	6.5
023	1.0	038	9.3
024	1.0	039	7.0
025	83.5	040	16.8
026	1.0	041	5.0
027	1.3	042	14.3
028	1.3	043	7.0
029	1.0	044	8.3
030	3.0	045	6.5
Median:	1.3		8.5

Appendix C (continued)

Table C2

Lowest Mean Number of Responses per Minute Over a Single 4-min Training Component for all Variety Subjects in Experiment 2

Subject	FR-F	Subject	FR-N	Subject	DRL-F
067	0.7	088	10.0	110	1.7
068	0.3	089	9.7	111	2.0
069	0.7	090	10.7	112	2.7
070	1.0	091	9.7	113	2.0
071	0.7	092	10.0	114	1.3
072	1.0	093	9.3	115	2.3
073	1.3	094	9.3	116	2.3
074	1.3	095	9.0	117	2.0
075	0.7	096	9.7	118	2.7
076	0.3	097	8.3	119	2.3
077	0.3	098	9.7	120	2.0
078	1.3	099	8.0	121	2.7
079	0.7	100	8.0	122	2.0
080	0.7	101	9.7	123	2.0
081	1.0	102	8.0	124	2.3
082	0.7	103	8.0	125	2.3
083	0.7	104	8.7	126	2.0
084	1.3	105	10.3	127	2.3
085	1.0	106	10.0	128	1.3
086	1.3	107	8.0	129	1.7
087	0.7	108	1.7	130	1.7
		109	10.3		
Median:	0.7		9.5		2.0

Appendix C (continued)

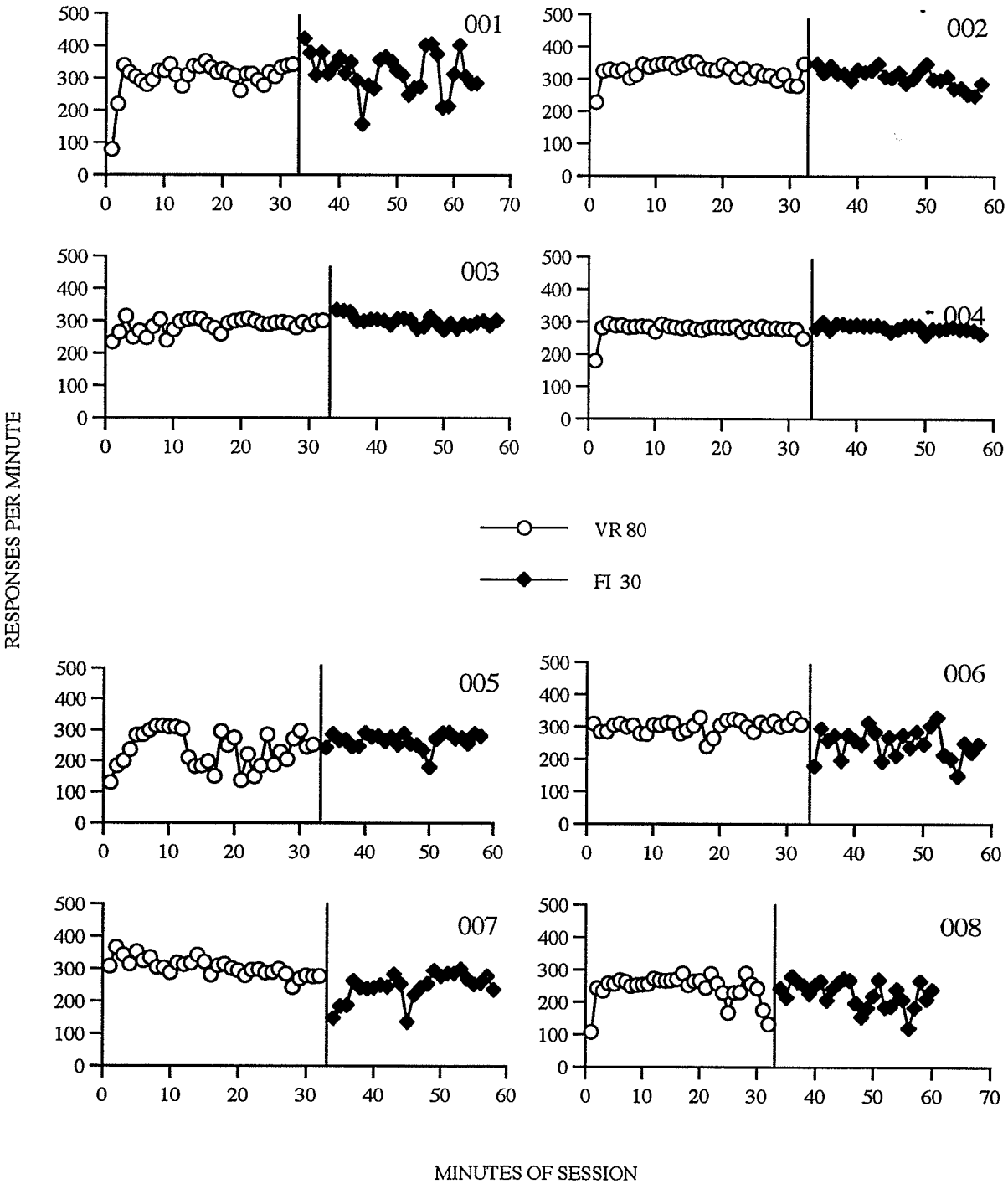
Table C2 (continued)

Subject	DRL-N	Subject	BOTH-F	Subject	BOTH-N
131	10.0	153	2.0	175	6.7
132	9.0	154	1.7	176	9.0
133	9.3	155	2.7	177	10.0
134	10.0	156	2.3	178	9.0
135	5.3	157	2.0	179	10.3
136	10.0	158	2.3	180	9.0
137	10.0	159	2.3	181	10.0
138	10.0	160	2.0	182	10.3
139	8.7	161	1.3	183	10.0
140	10.0	162	2.0	184	9.3
141	9.0	163	5.3	185	7.7
142	8.3	164	2.0	186	10.7
143	9.0	165	2.0	187	4.0
144	10.3	166	1.7	188	9.3
145	8.7	167	4.3	189	10.0
146	10.7	168	2.3	190	7.3
147	8.3	169	2.0	191	6.3
148	5.3	170	1.7	192	9.3
149	6.3	171	1.3	193	9.0
150	6.3	172	2.0	194	9.7
151	7.7	173	2.3	195	11.0
152	9.7	174	1.7		
Median:	9.0		2.0		9.3

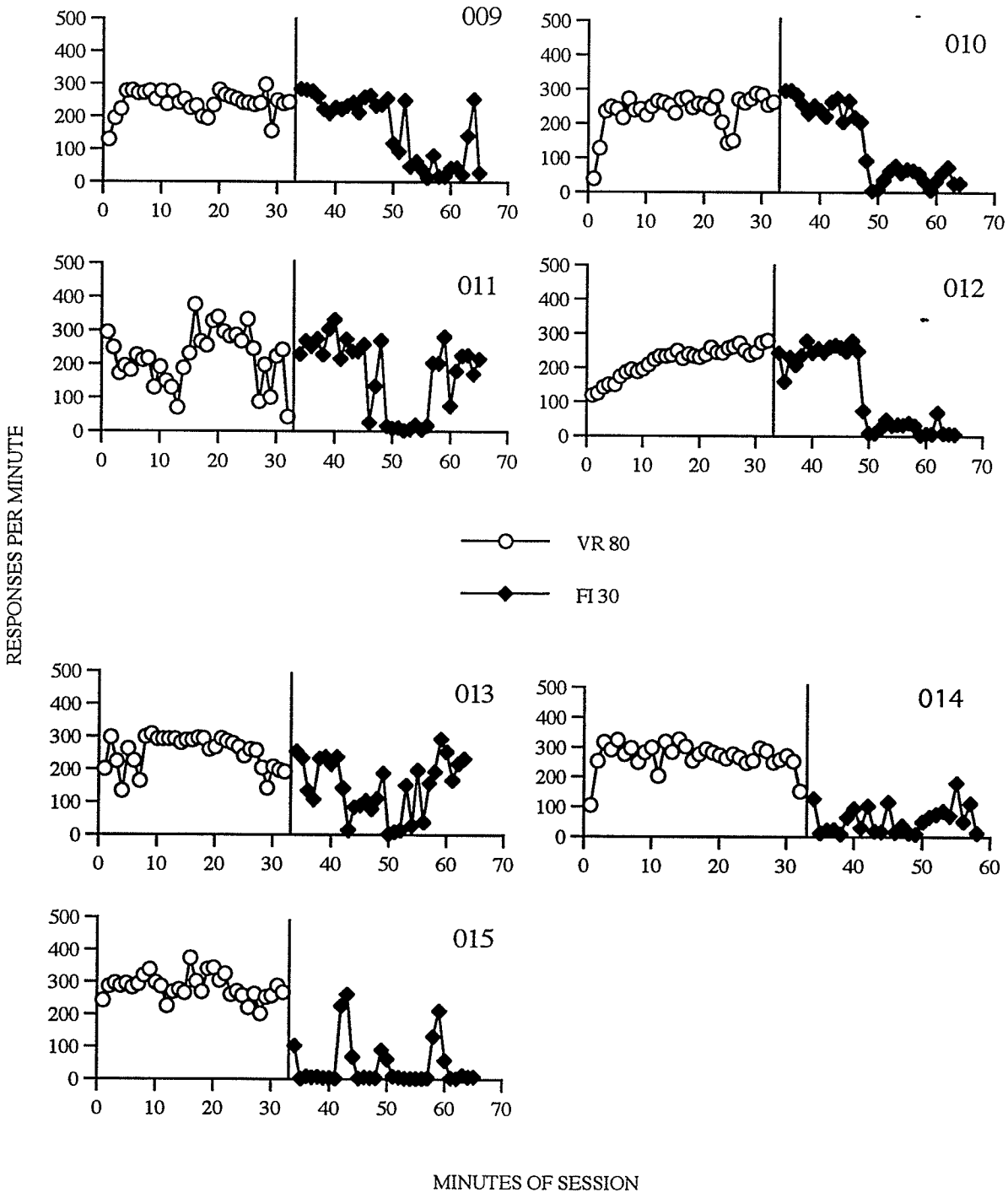
Appendix D

Individual Subject Graphs (Experiment 1)

SIVR Graphs

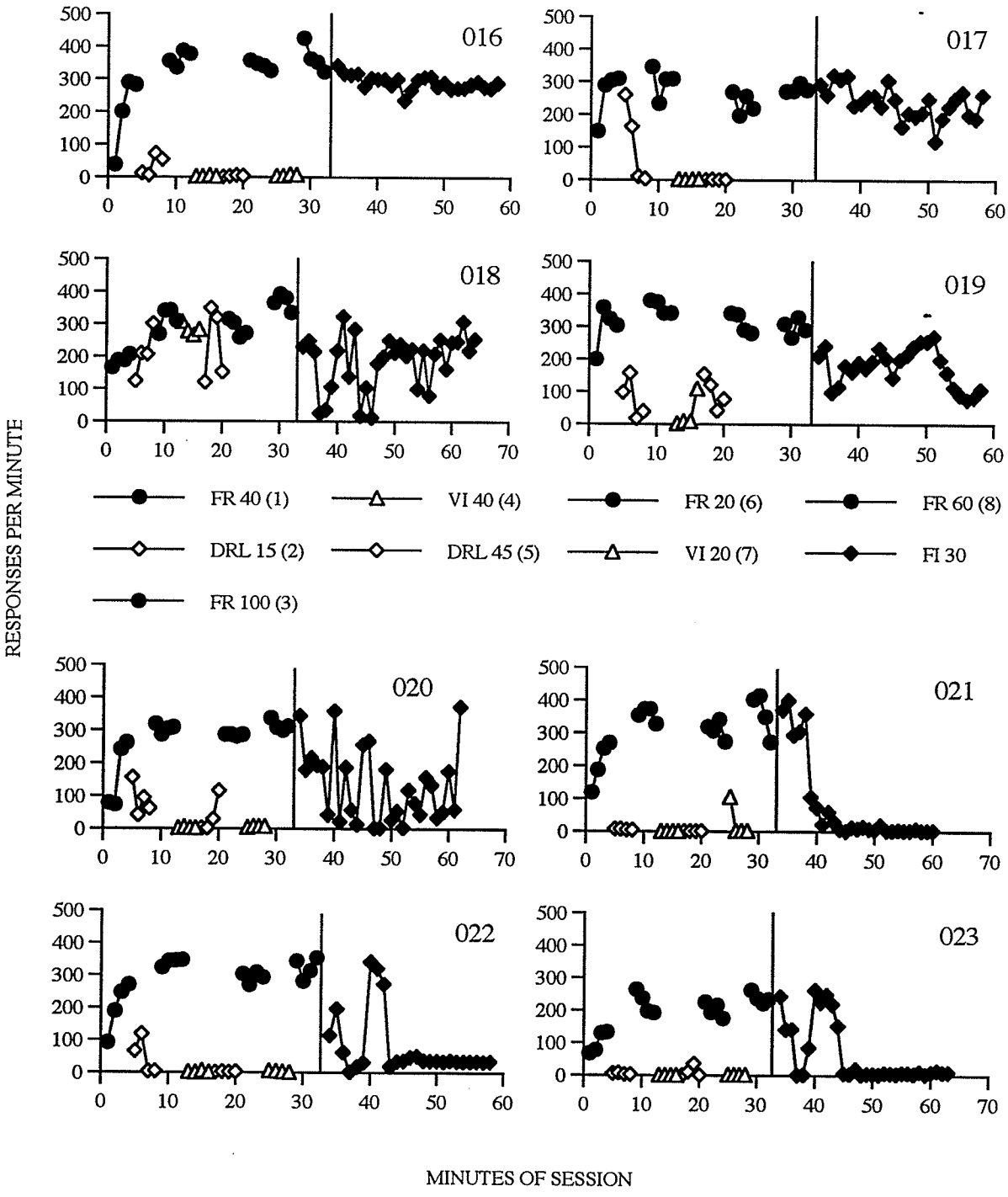


Appendix D (continued)



Appendix D (continued)

FV Graphs



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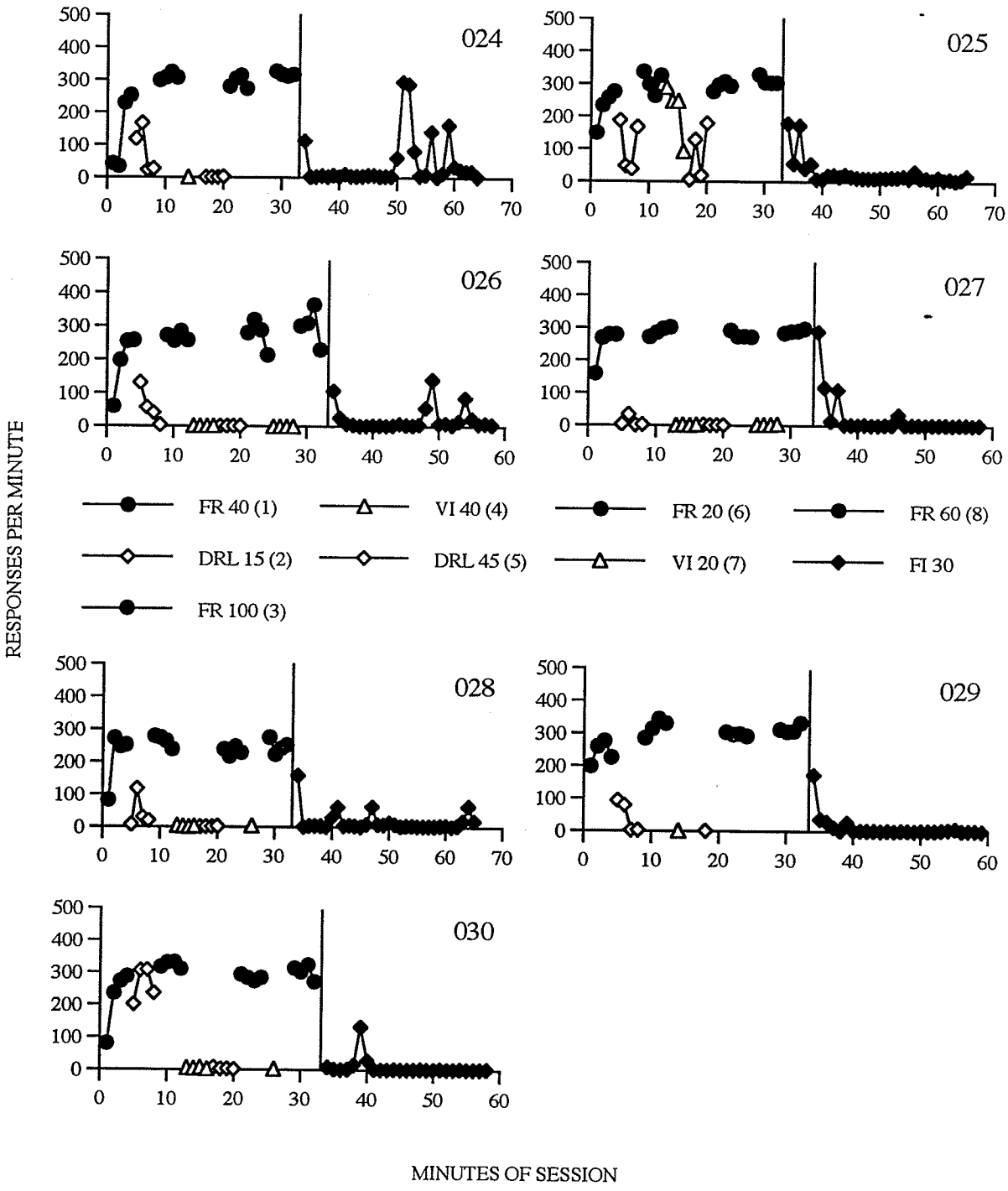
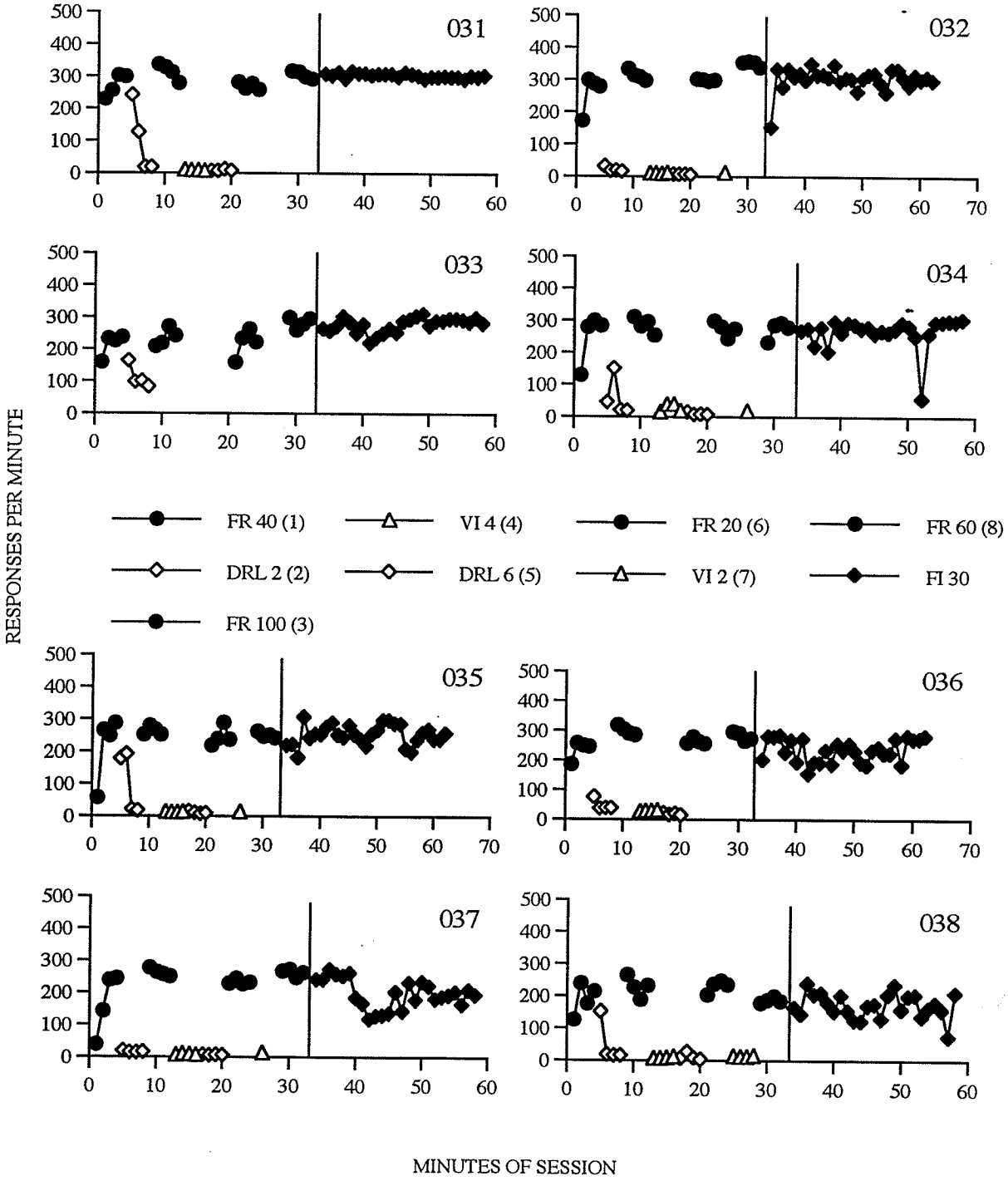
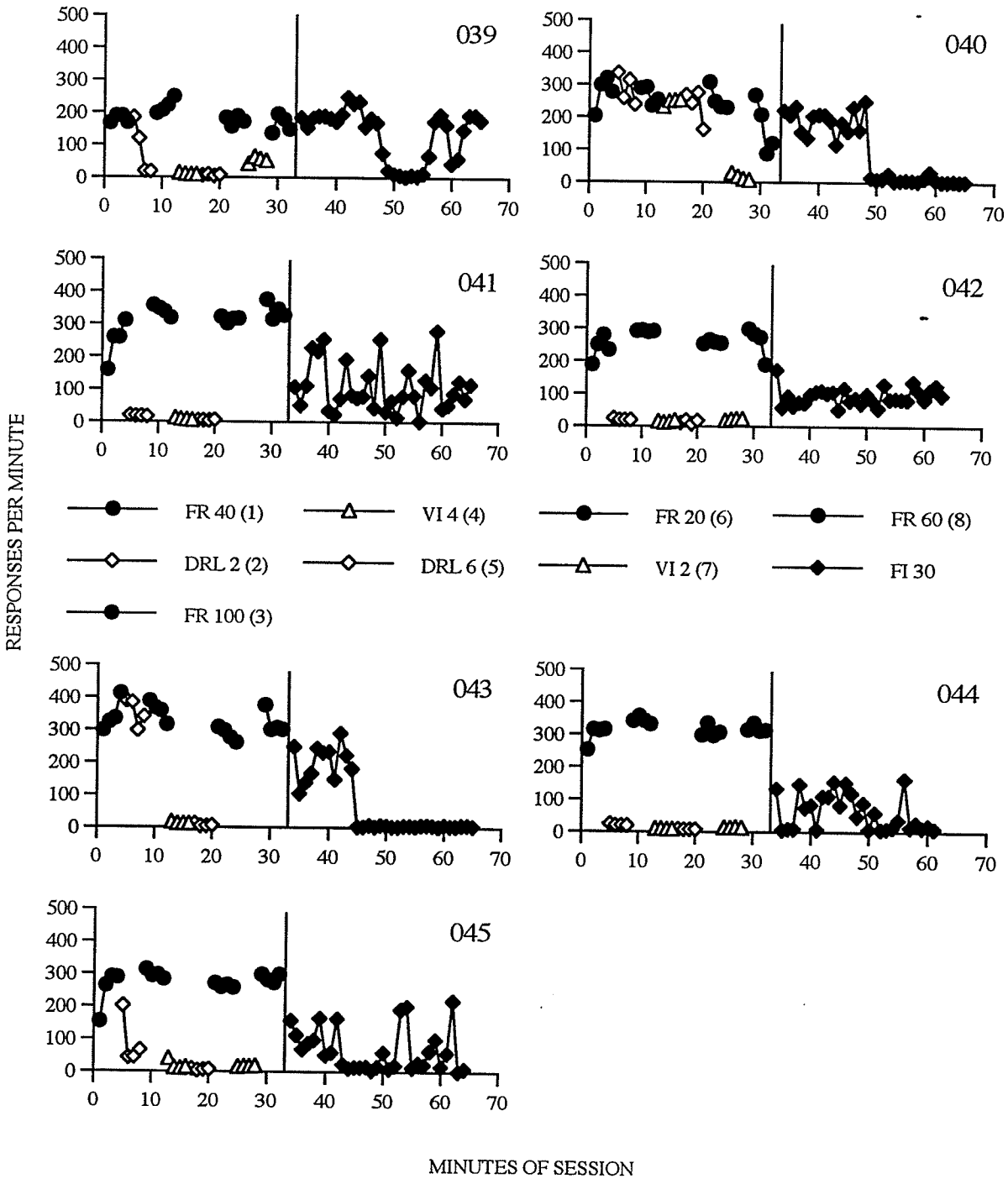


Appendix D (continued)

NFV Graphs



Appendix D (continued)



Appendix E

Raw Data for Chi-Square Analyses

Table E1

Number of Subjects per Group Categorized as Sensitive or Insensitive during the FI Test Phase (Experiment 1)

	SIVR	FV	NFV
Insensitive (>59.9 responses/min)	13	8	15
Sensitive (0-59.9 responses/min)	2	7	0

Table E2

Number of Subjects per Group Categorized as Sensitive or Insensitive during Minutes 23-35 of FI Responding (Experiment 1)

	SIVR	FV	NFV
Insensitive (>19.9 responses/min)	15	7	13
Sensitive (0-19.9 responses/min)	0	8	2

Appendix E (continued)

Table E3

Number of Subjects per Group Categorized as Sensitive or Insensitive during the FI Test Phase (Experiment 2)

	SIVR	FR	DRL	BOTH
Insensitive (>59.9 responses/min)	20	38	24	36
Sensitive (0-59.9 responses/min)	1	5	19	7

Table E4

Number of Subjects per Group Categorized as Sensitive or Insensitive during Minutes 23-25 of FI Responding (Experiment 2)

	SIVR	FR	DRL	BOTH
Insensitive (>19.9 responses/min)	20	37	26	34
Sensitive (0-19.9 responses/min)	1	6	17	9

Appendix E (continued)

Table E5

Number of Subjects in Functional and Nonfunctional Groups Responding at Functional Rates (Experiment 2)

	Functional	Nonfunctional
Nonfunctional (>6.9 responses/min)	49	63
Functional (0-6.9 responses/min)	15	2

Appendix F

Manipulation Check for Point Density Match

Table F1

Point Densities per Minute by Schedule Component in Experiment 2

	Condition			
	FR-F		FR-N	
	High-rate	Low-rate	High-rate	Low-rate
	4.3 (FR 50)	0.9 (DRL 30 s)	4.8 (FR 50)	22.5 (DRL 1 s)
	2.1 (FR 125)	0.8 (VI 50 s)	2.3 (FR 125)	9.8 (VI 4 s)
	10.8 (FR 25)	0.5 (DRL 60 s)	11.2 (FR 25)	7.6 (DRL 5 s)
	2.7 (FR 100)	1.2 (VI 40 s)	2.8 (FR 100)	16.7 (VI 2 s)
Mean:	5.0	0.9	5.3	14.2
Range:	2.1-10.8	0.5-1.2	2.3-11.2	7.6-22.5
	Test: 3.5 (FI 15 s)		Test: 3.7 (FI 15 s)	
	DRL-F		DRL-N	
	High-rate	Low-rate	High-rate	Low-rate
	20.1 (FR 10)	6.4 (DRL 5 s)	18.5 (FR 10)	4.6 (5X DRL 1 s)
	11.1 (FR 25)	2.1 (VI 20 s)	10.8 (FR 25)	1.8 (5X VI 4 s)
	40.1 (FR 5)	1.4 (DRL 25 s)	38.6 (FR 5)	1.3 (5X DRL 5 s)
	14.9 (FR 20)	3.9 (VI 10 s)	14.2 (FR 20)	3.5 (5X VI 2 s)
Mean:	21.6	3.5	20.5	2.8
Range:	11.1-40.1	1.4-6.4	10.8-38.6	1.3-4.6
	Test: 3.3 (FI 15 s)		Test: 3.5 (FI 15 s)	

Appendix F (continued)

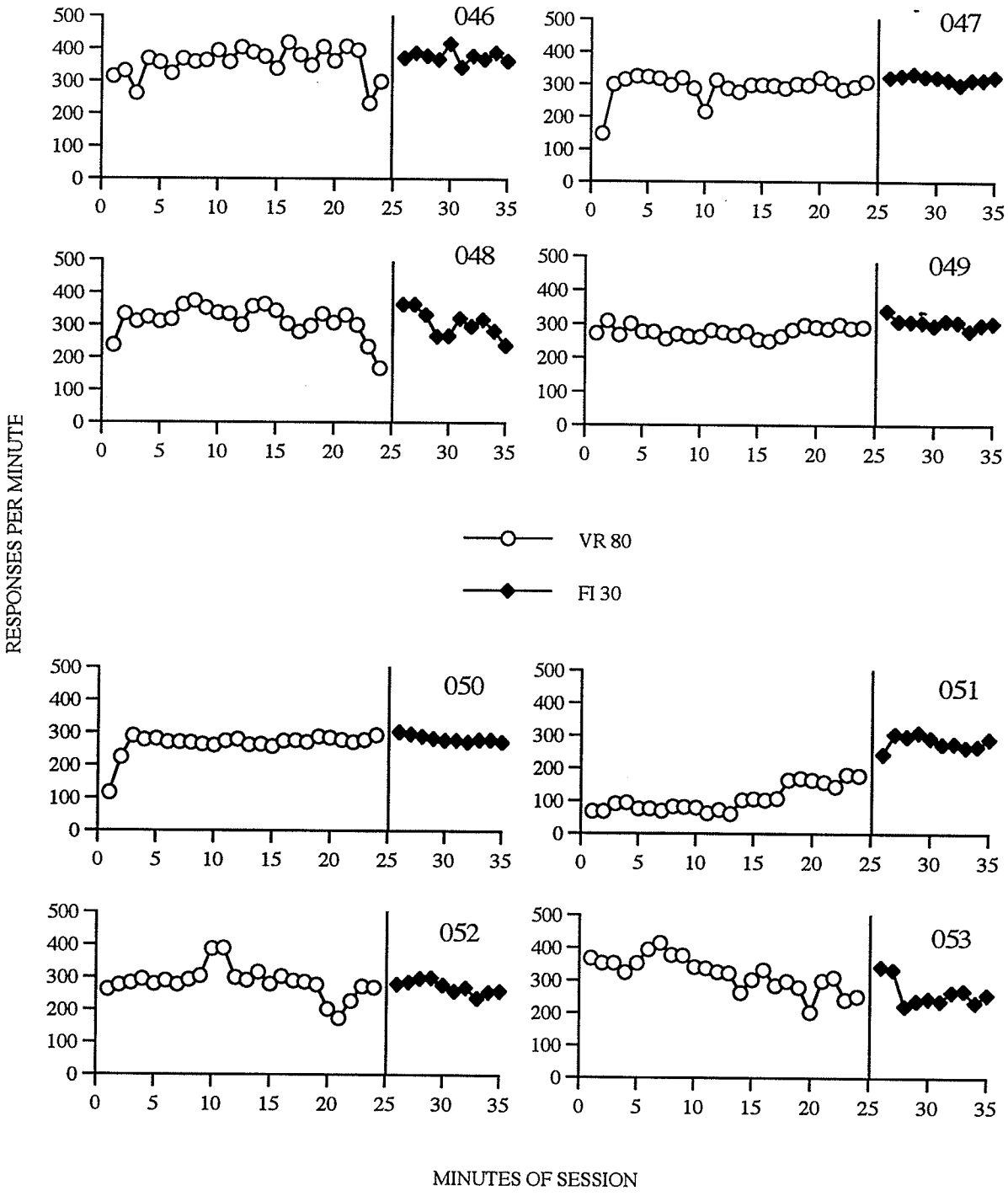
Table F1 (continued)

	Condition			
	BOTH-F		BOTH-N	
	High-rate	Low-rate	High-rate	Low-rate
	4.2 (FR 50)	6.0 (DRL 5 s)	4.9 (FR 50)	4.7 (5X DRL 1 s)
	2.2 (FR 125)	2.1 (VI 20 s)	2.4 (FR 125)	1.7 (5X VI 4 s)
	11.9 (FR 25)	1.3 (DRL 25 s)	11.9 (FR 25)	1.3 (5X DRL 5 s)
	3.1 (FR 100)	4.1 (DRL 10 s)	2.8 (FR 100)	3.4 (5X VI 2 s)
Mean:	5.4	3.4	5.5	2.8
Range:	2.2-11.9	1.3-6.0	2.4-11.9	1.3-4.7
	Test: 3.5 (FI 15 s)		Test: 3.6 (FI 15 s)	

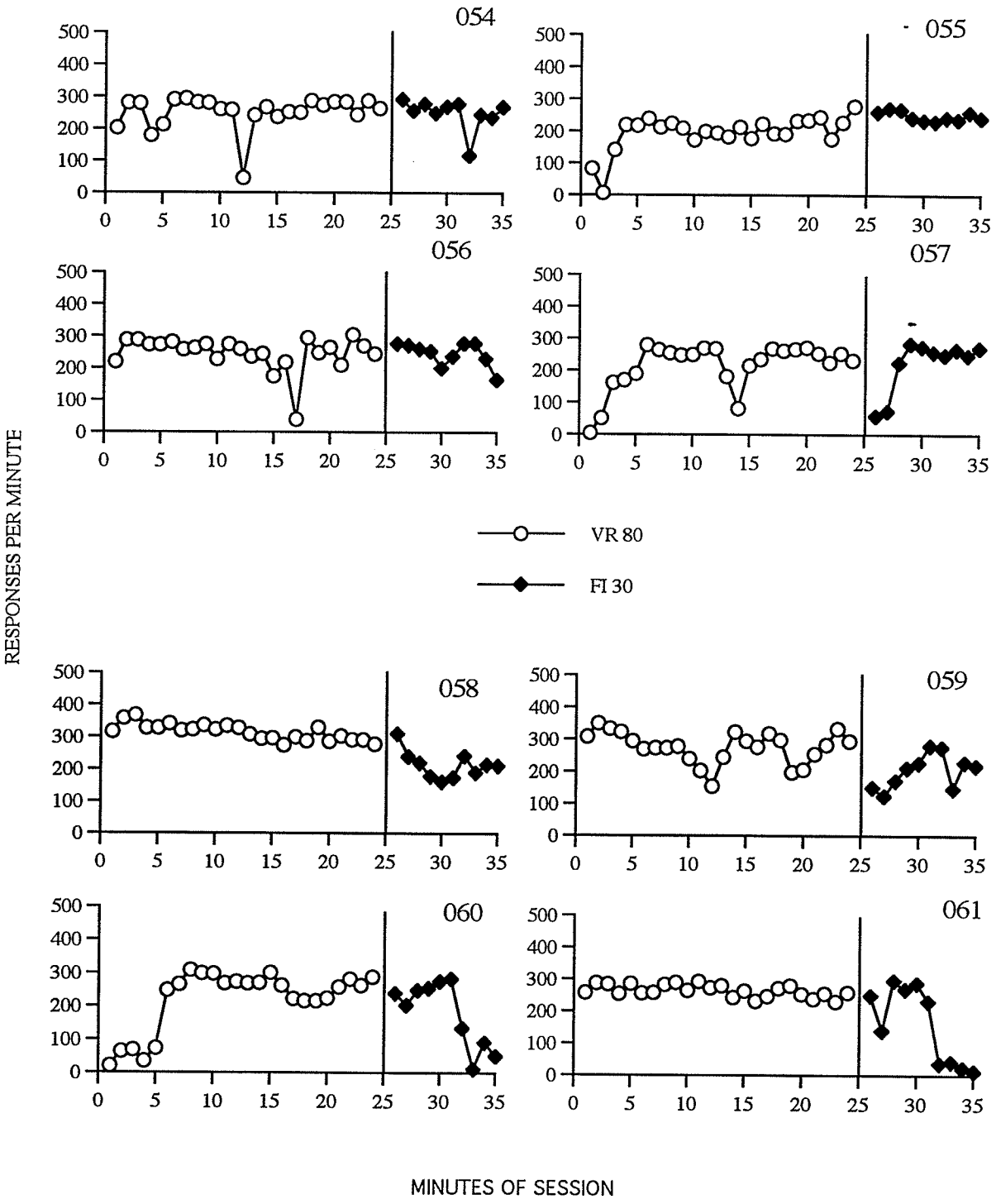
Appendix G

Individual Subject Graphs (Experiment 2)

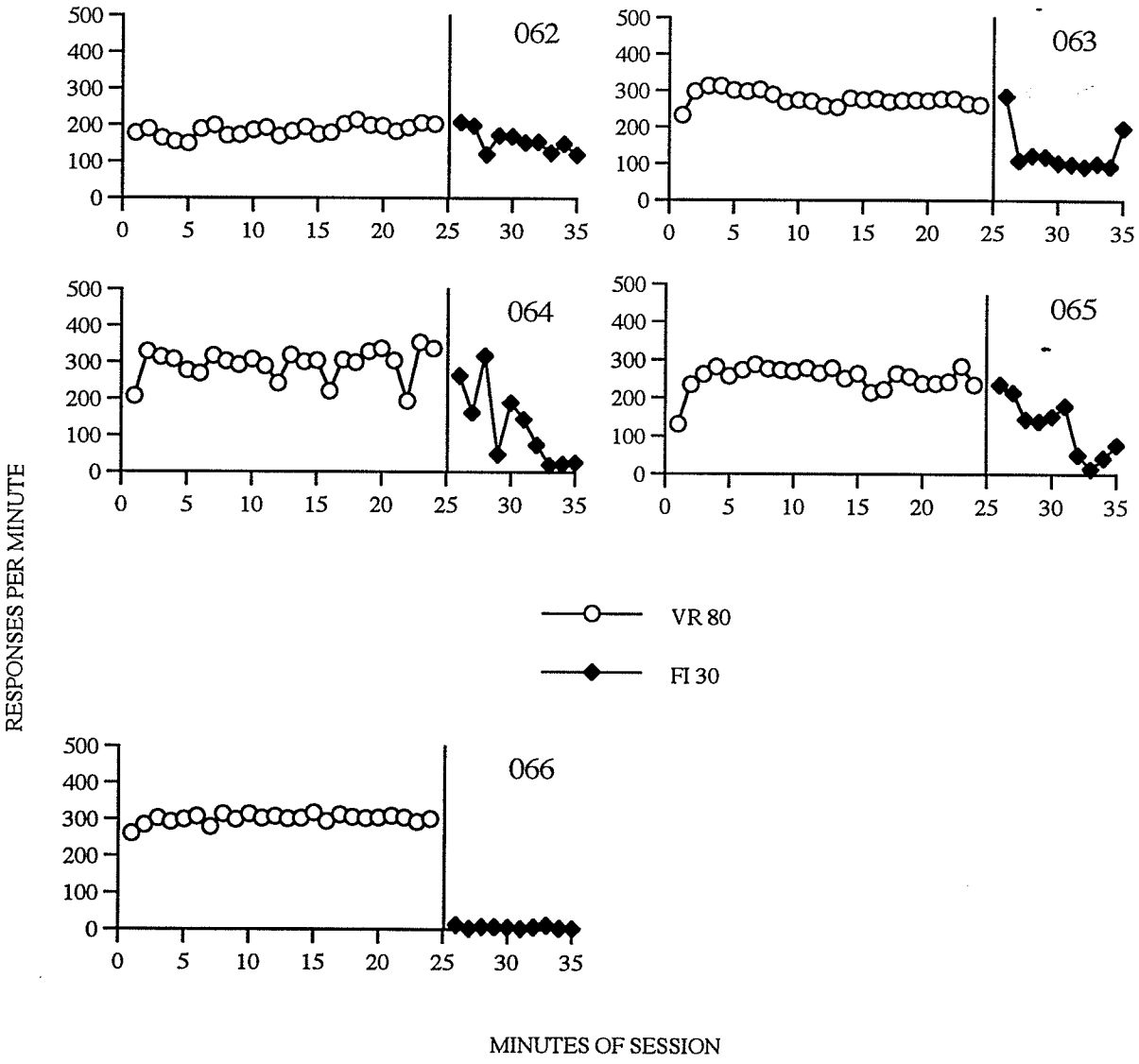
SIVR Graphs



Appendix G (continued)

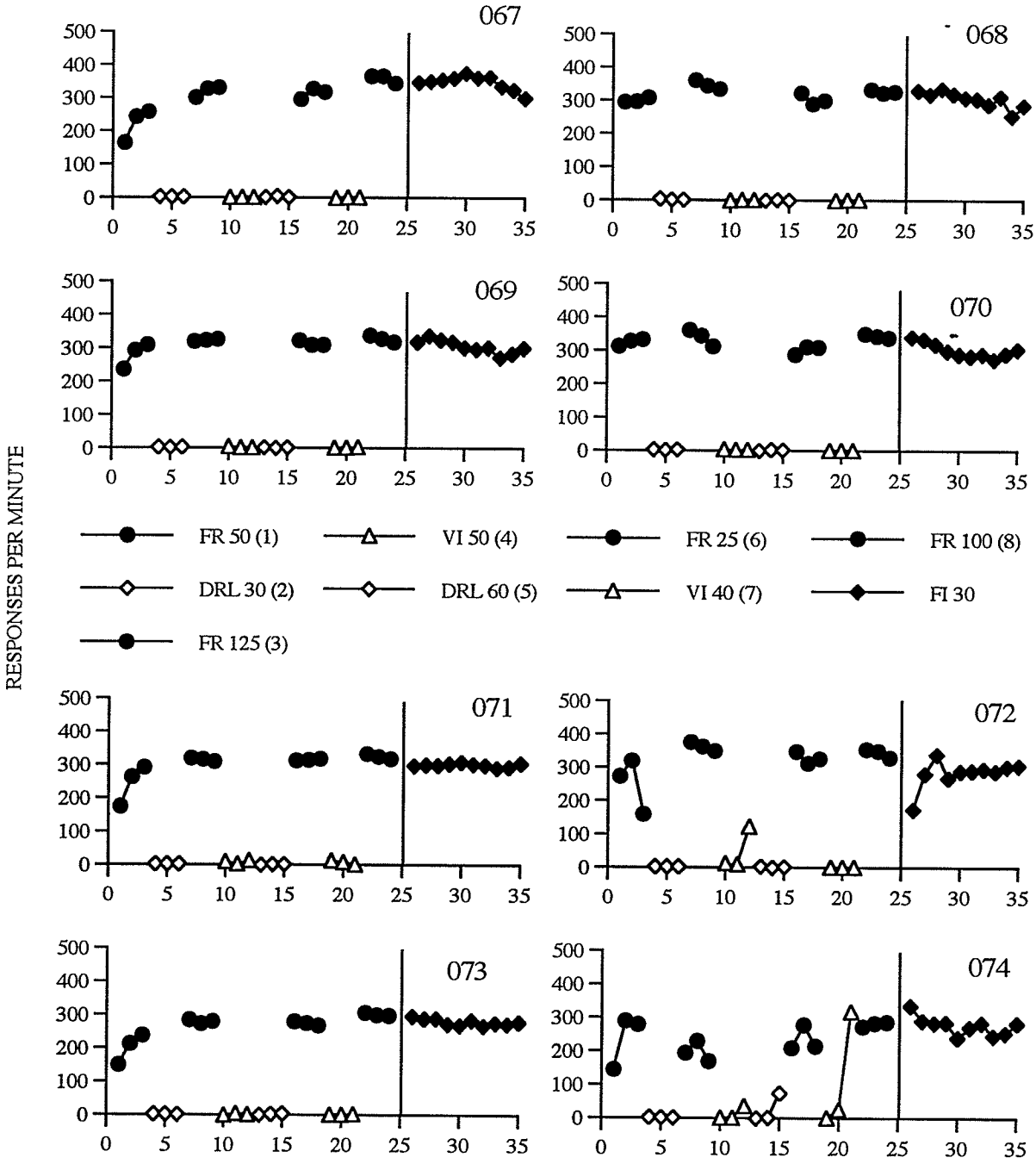


Appendix G (continued)

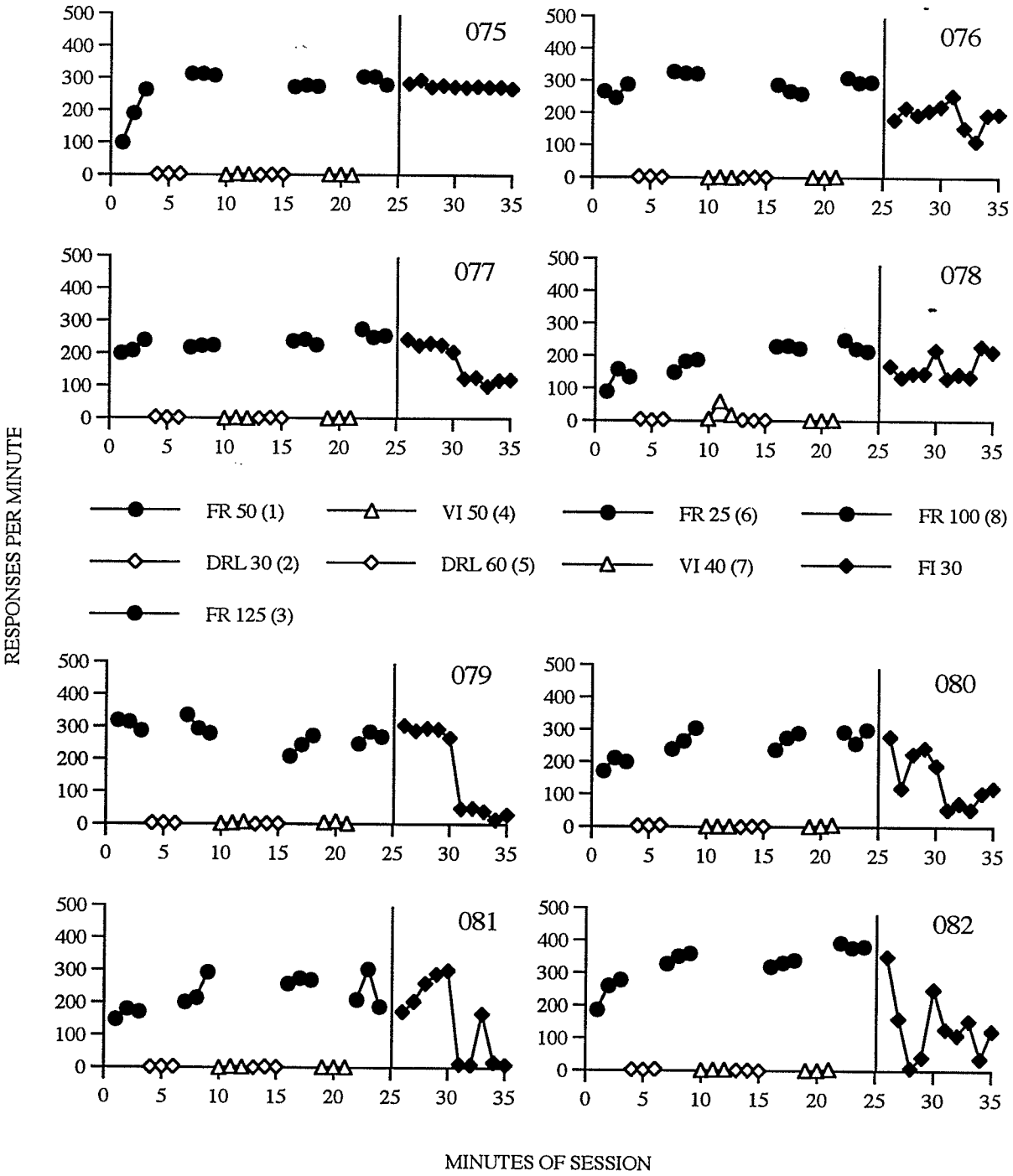


Appendix G (continued)

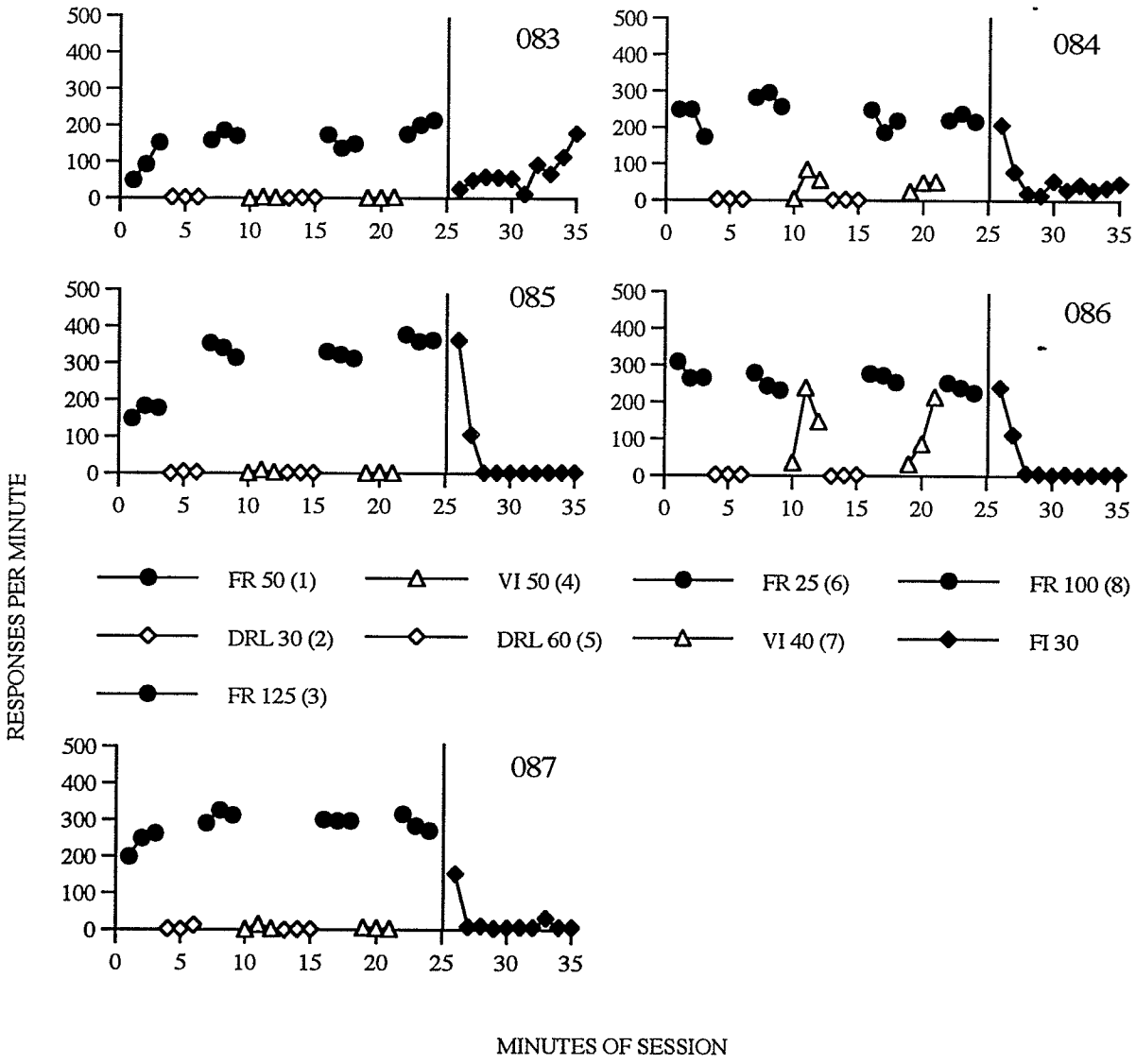
FR-F Graphs



Appendix G (continued)

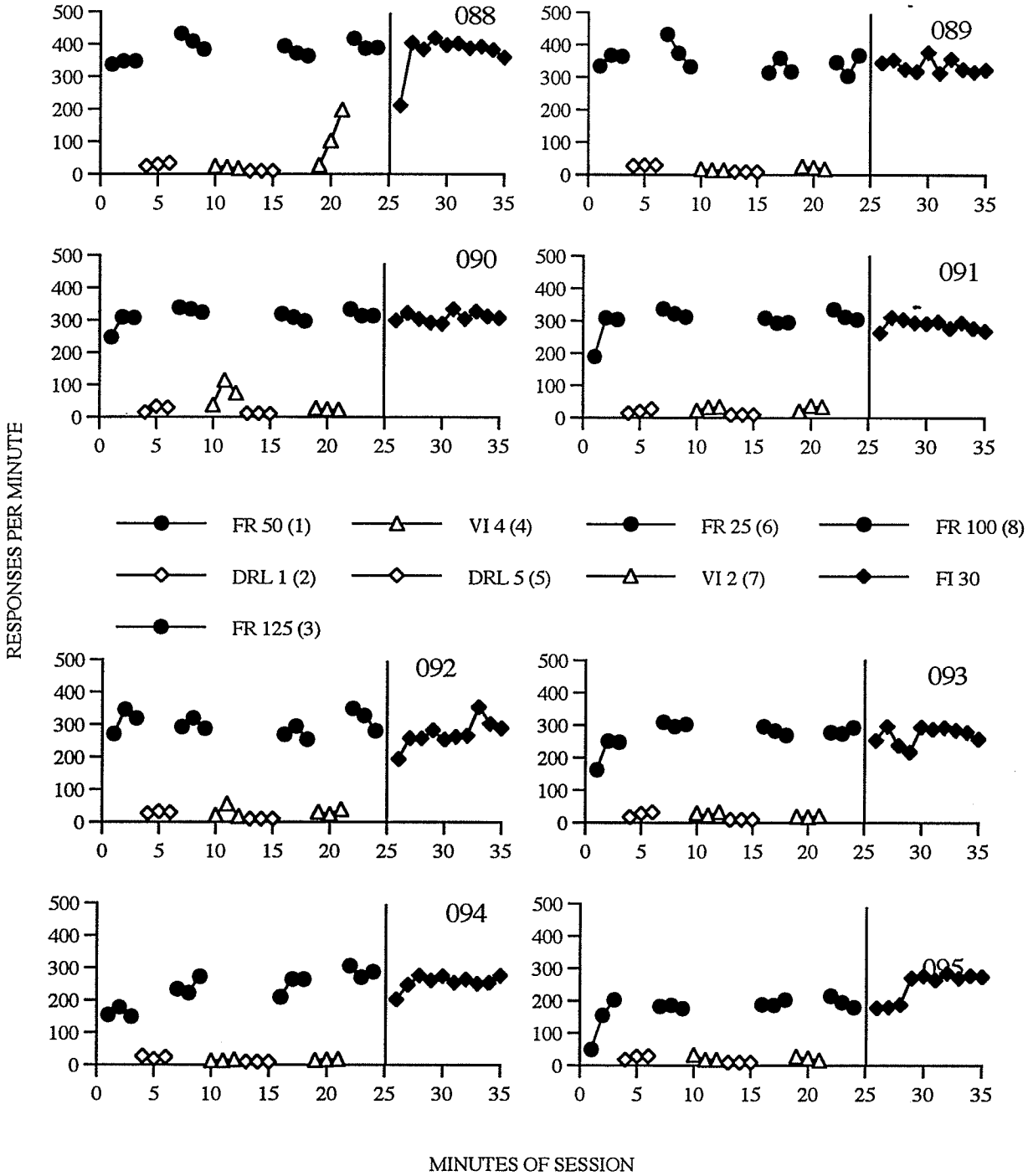


Appendix G (continued)

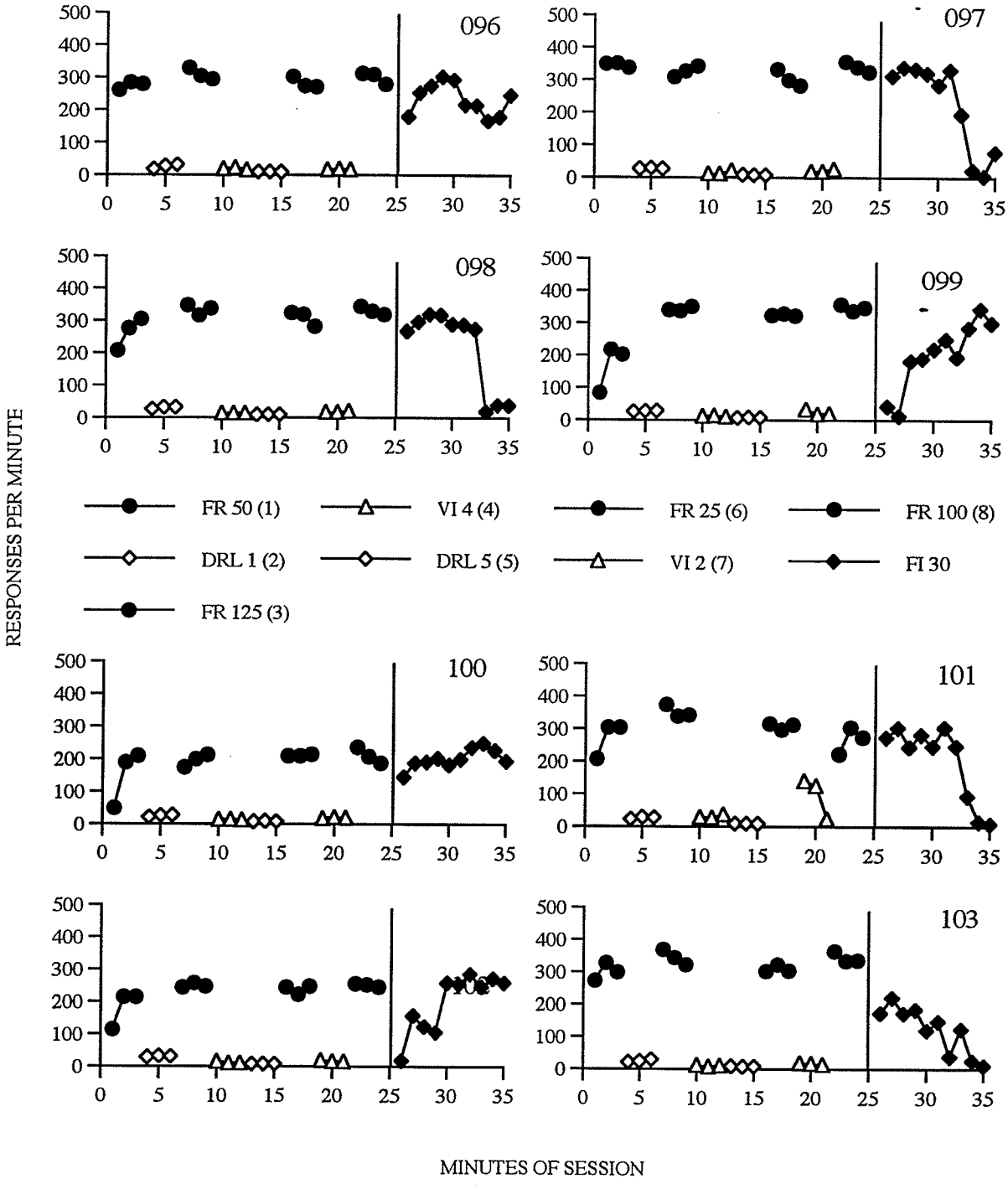


Appendix G (continued)

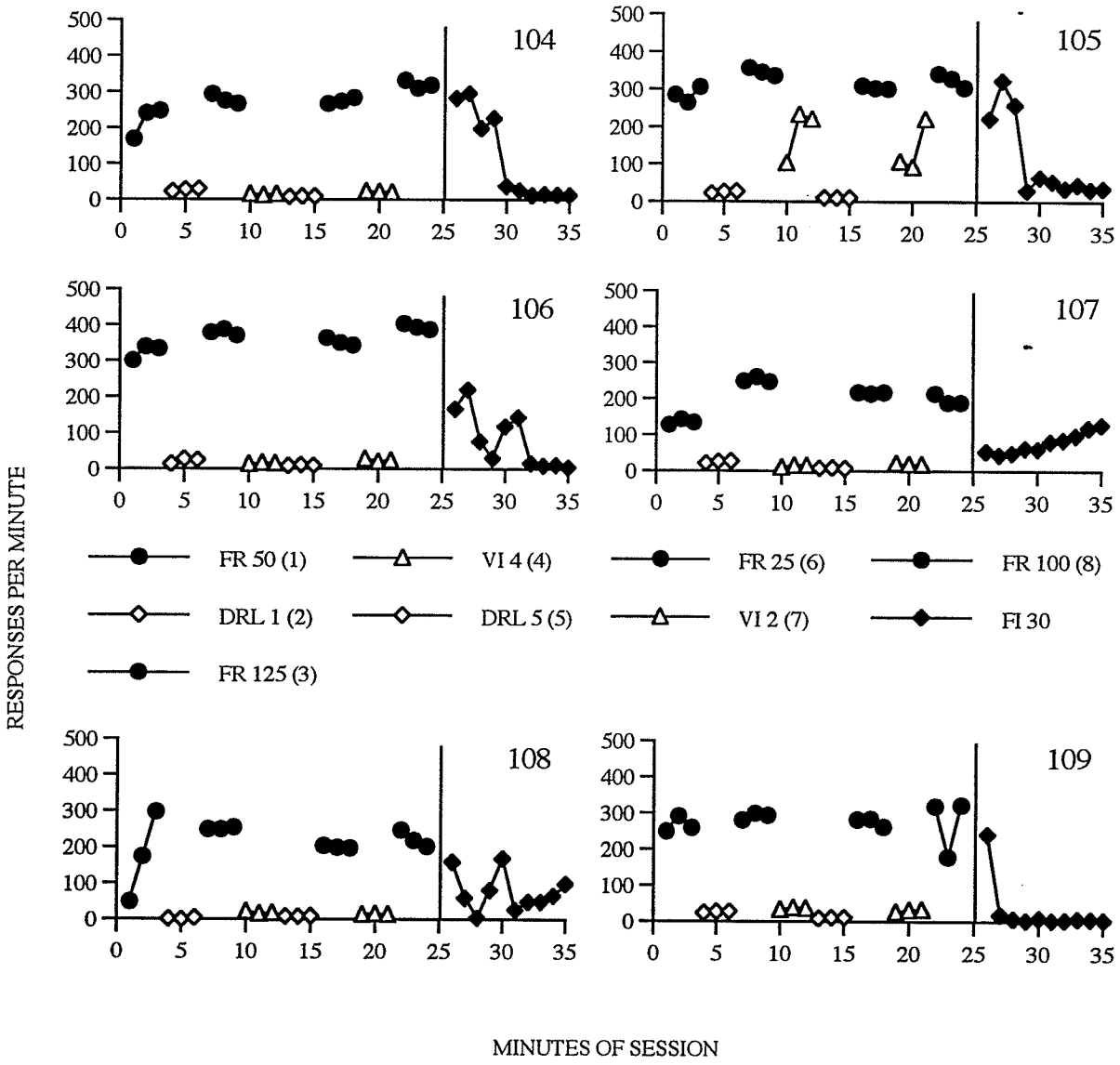
FR-N Graphs



Appendix G (continued)

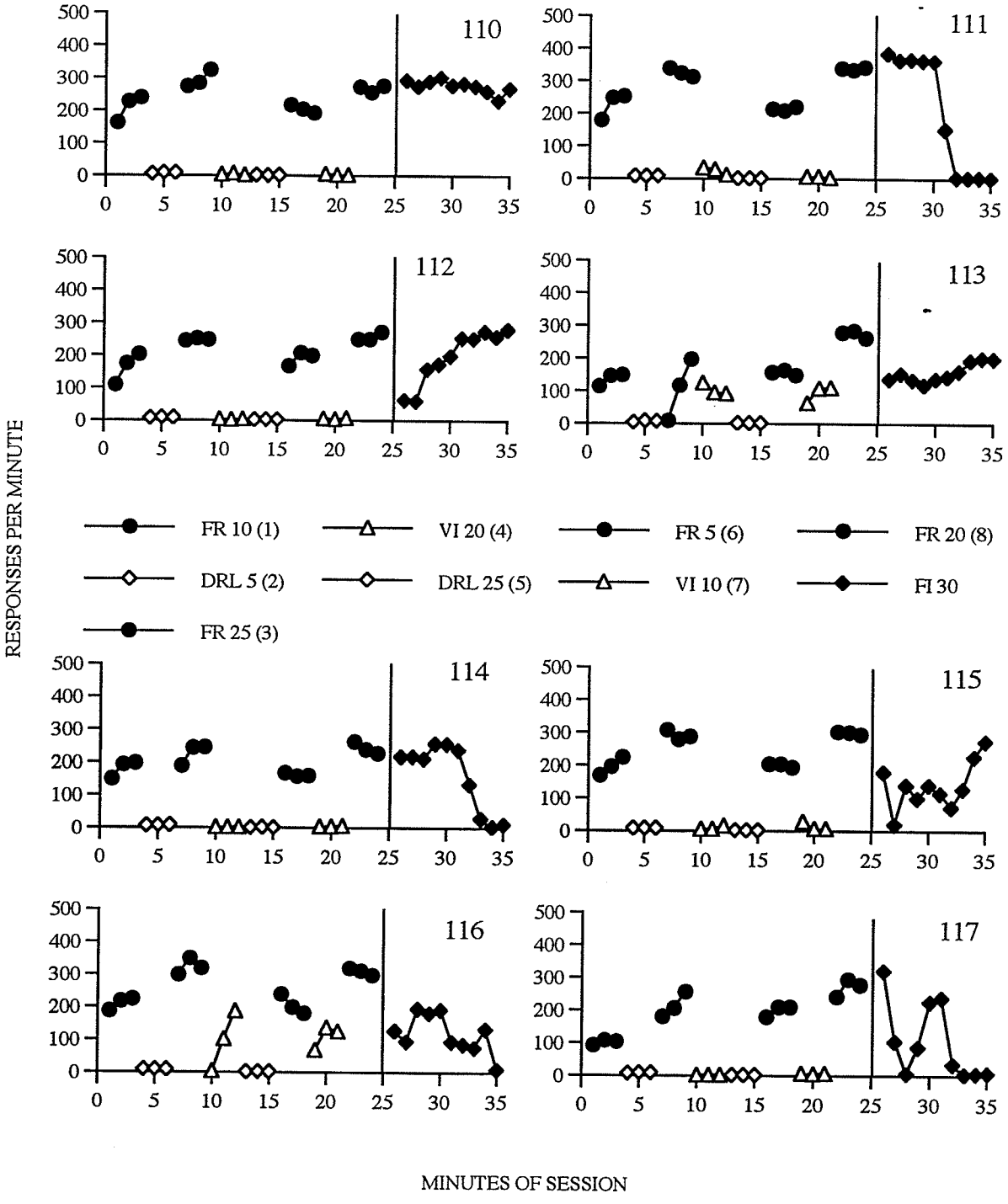


Appendix G (continued)

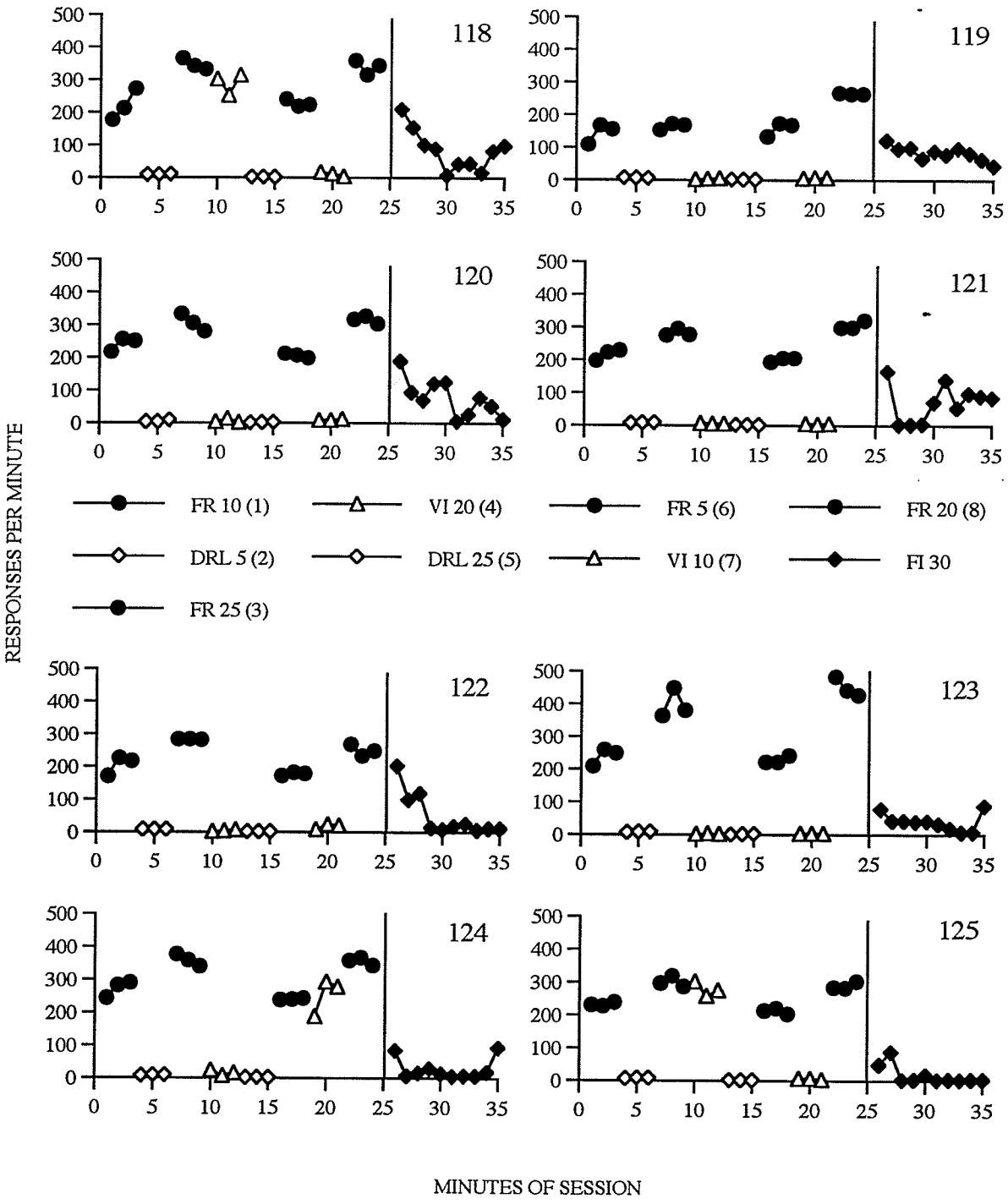


Appendix G (continued)

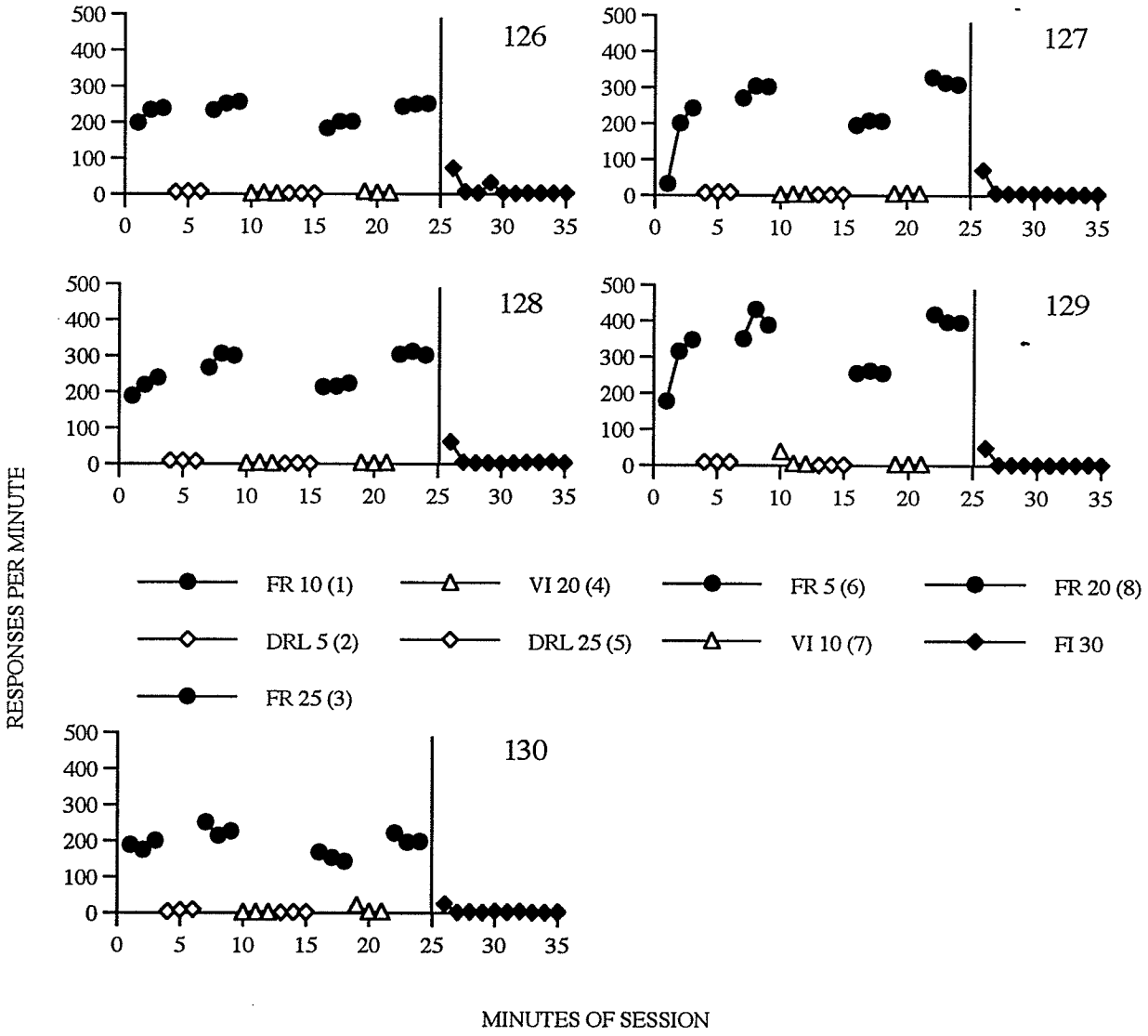
DRL-F Graphs



Appendix G (continued)

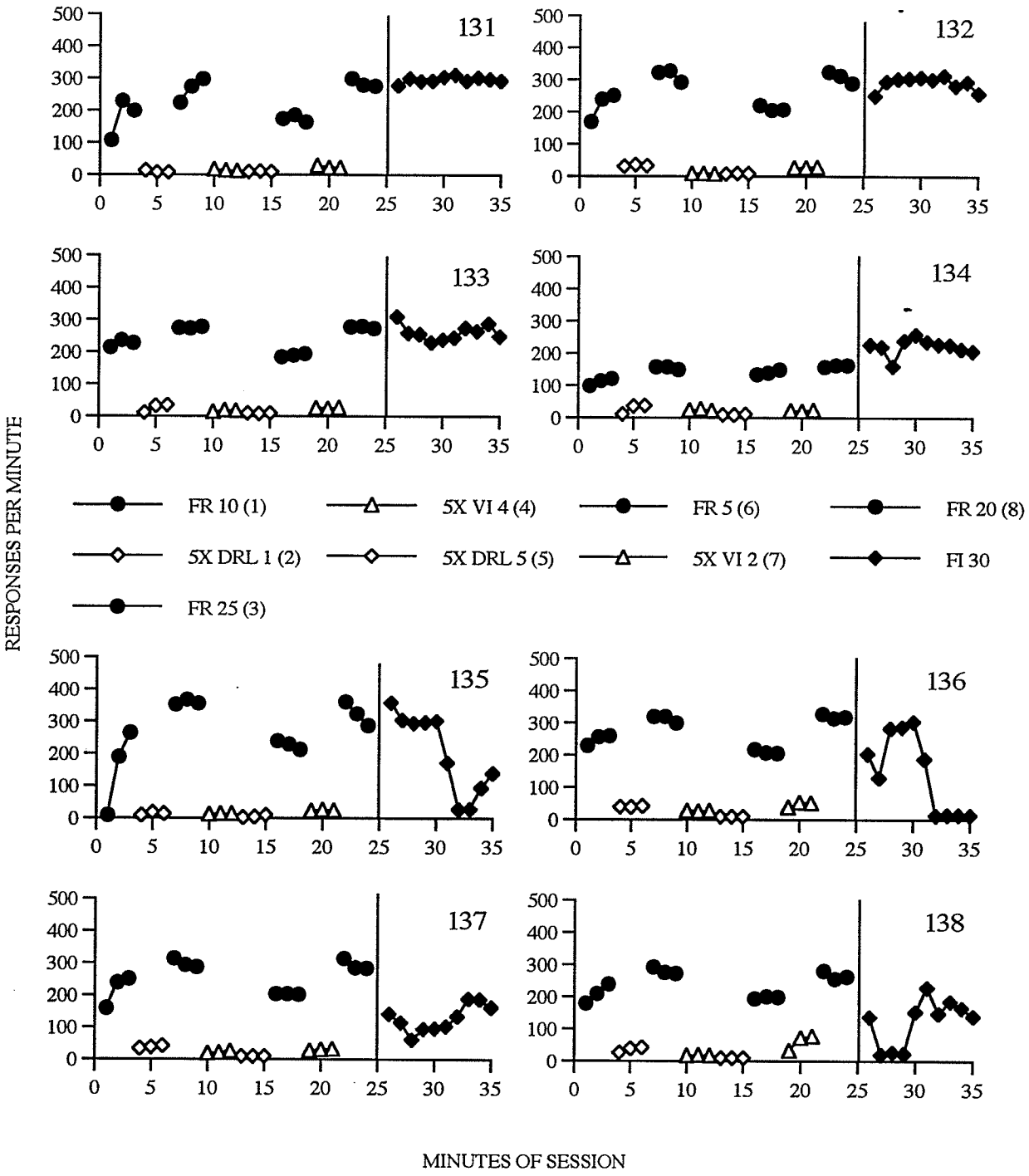


Appendix G (continued)

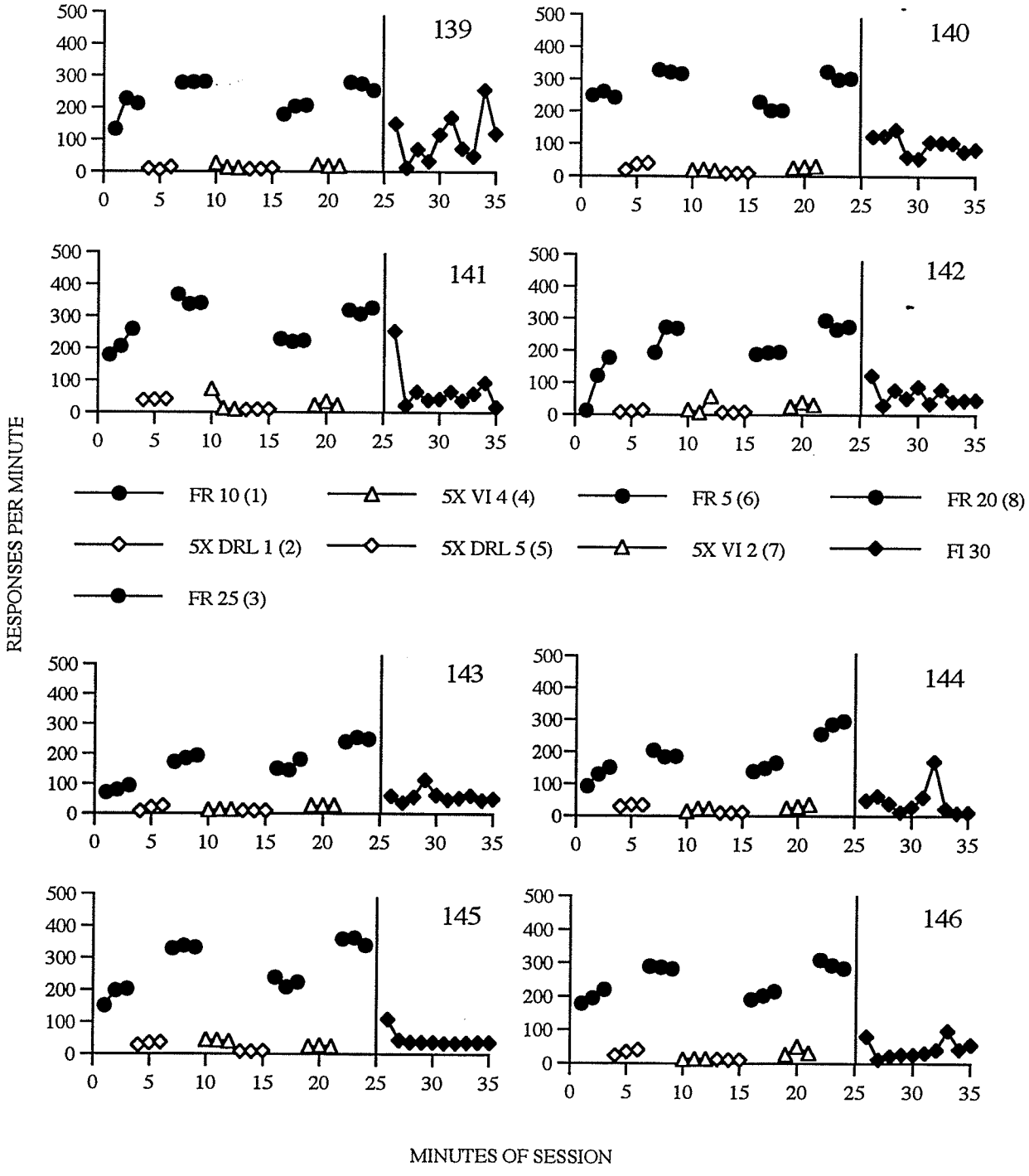


Appendix G (continued)

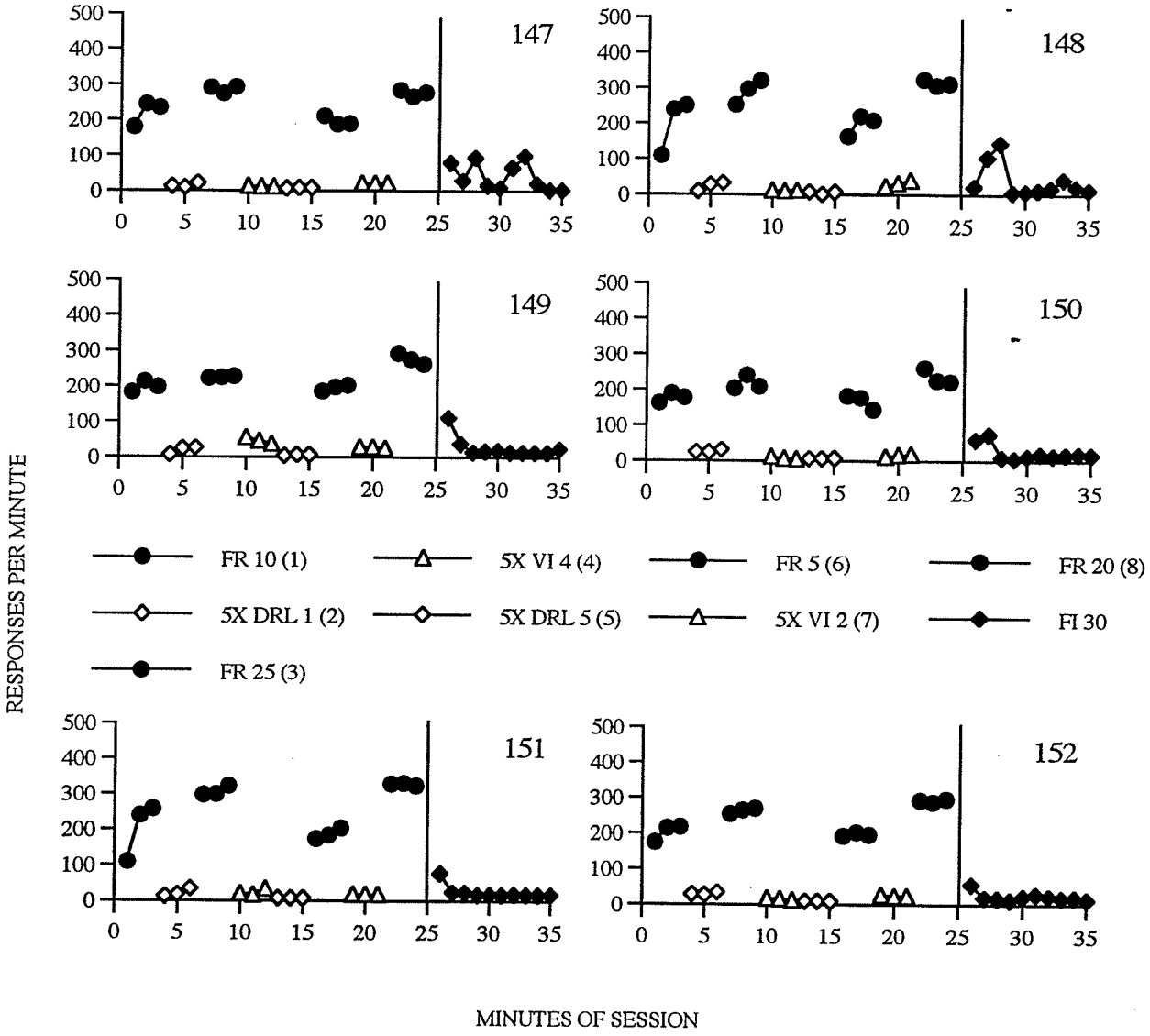
DRL-N Graphs



Appendix G (continued)

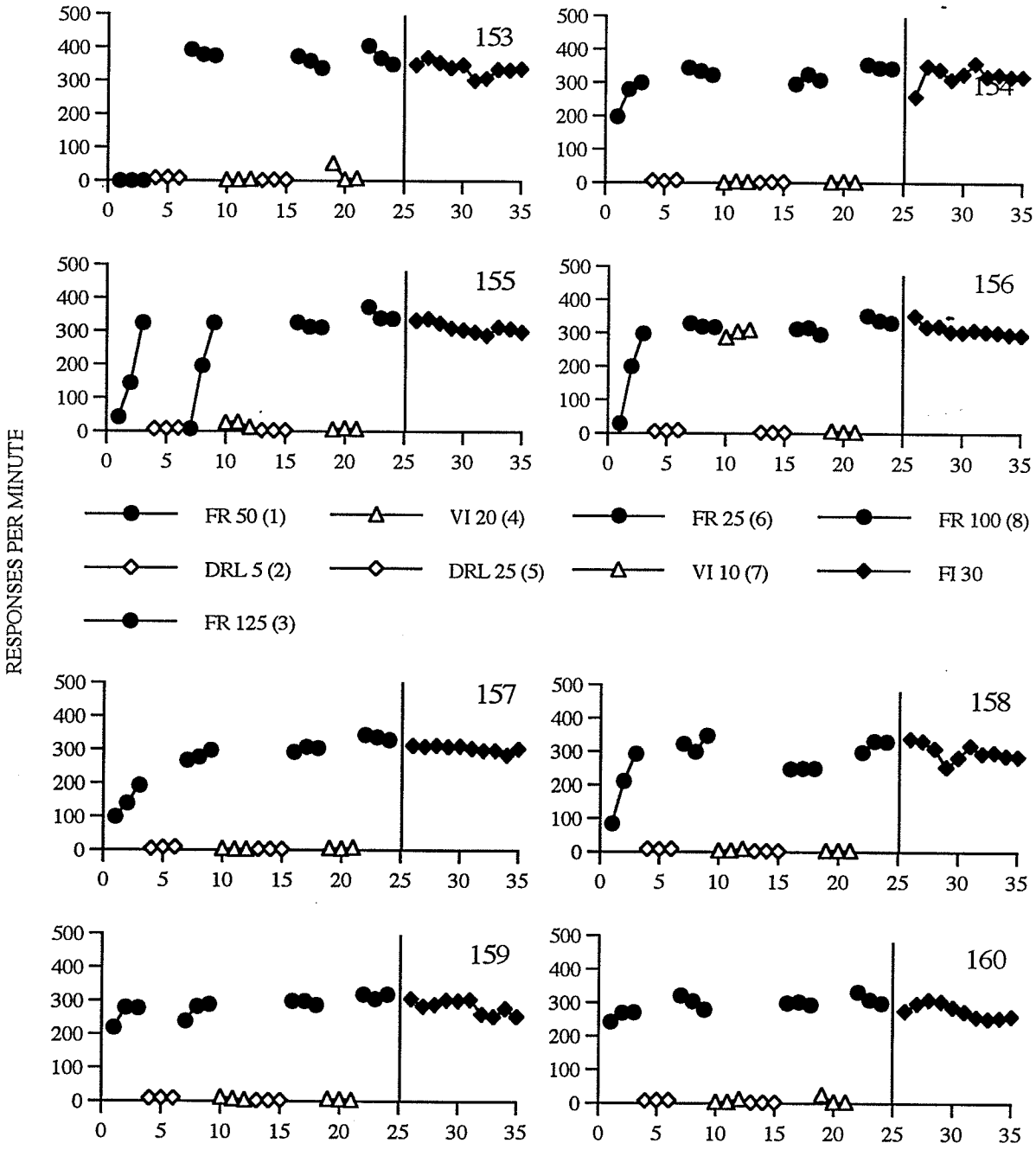


Appendix G (continued)

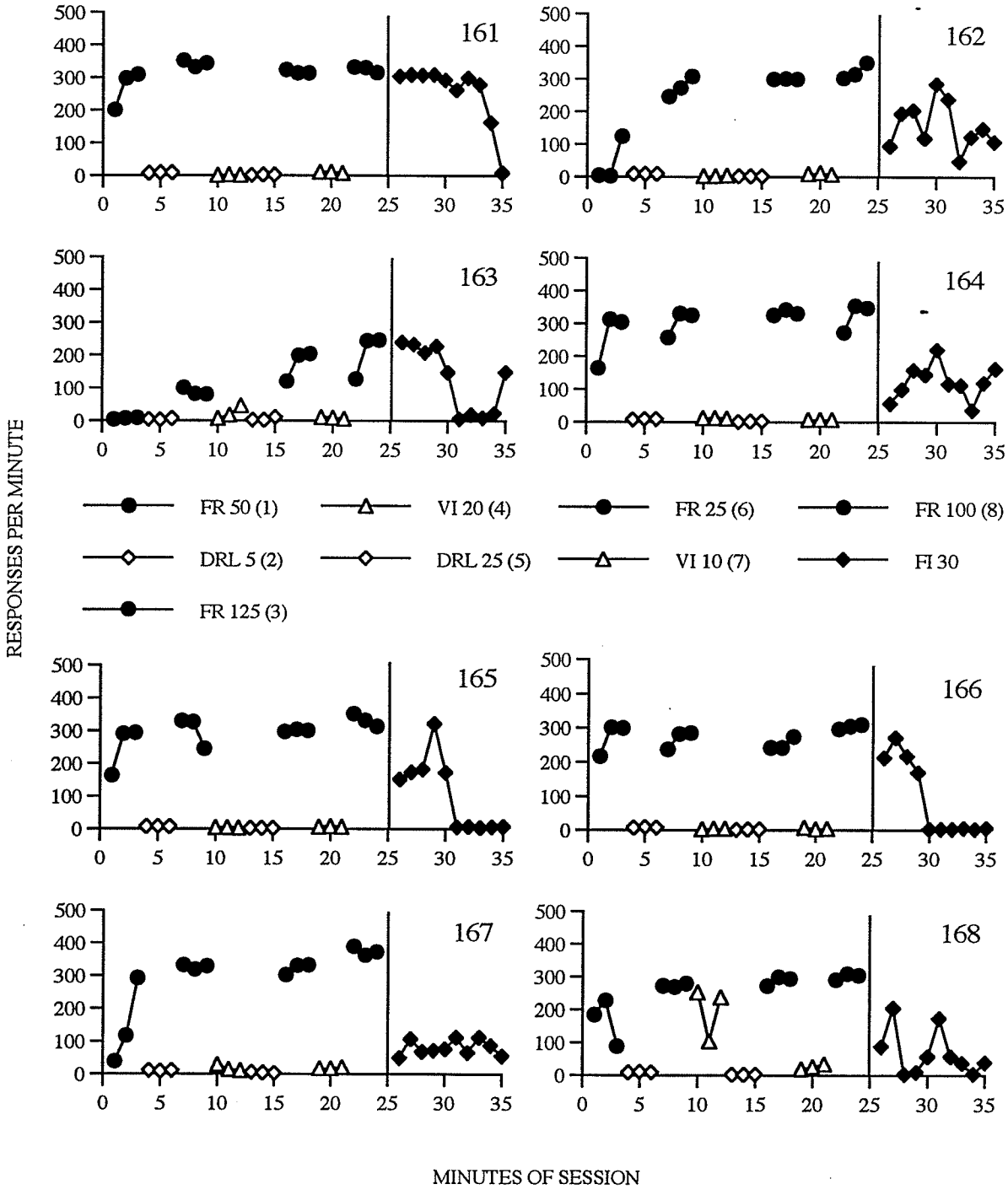


Appendix G (continued)

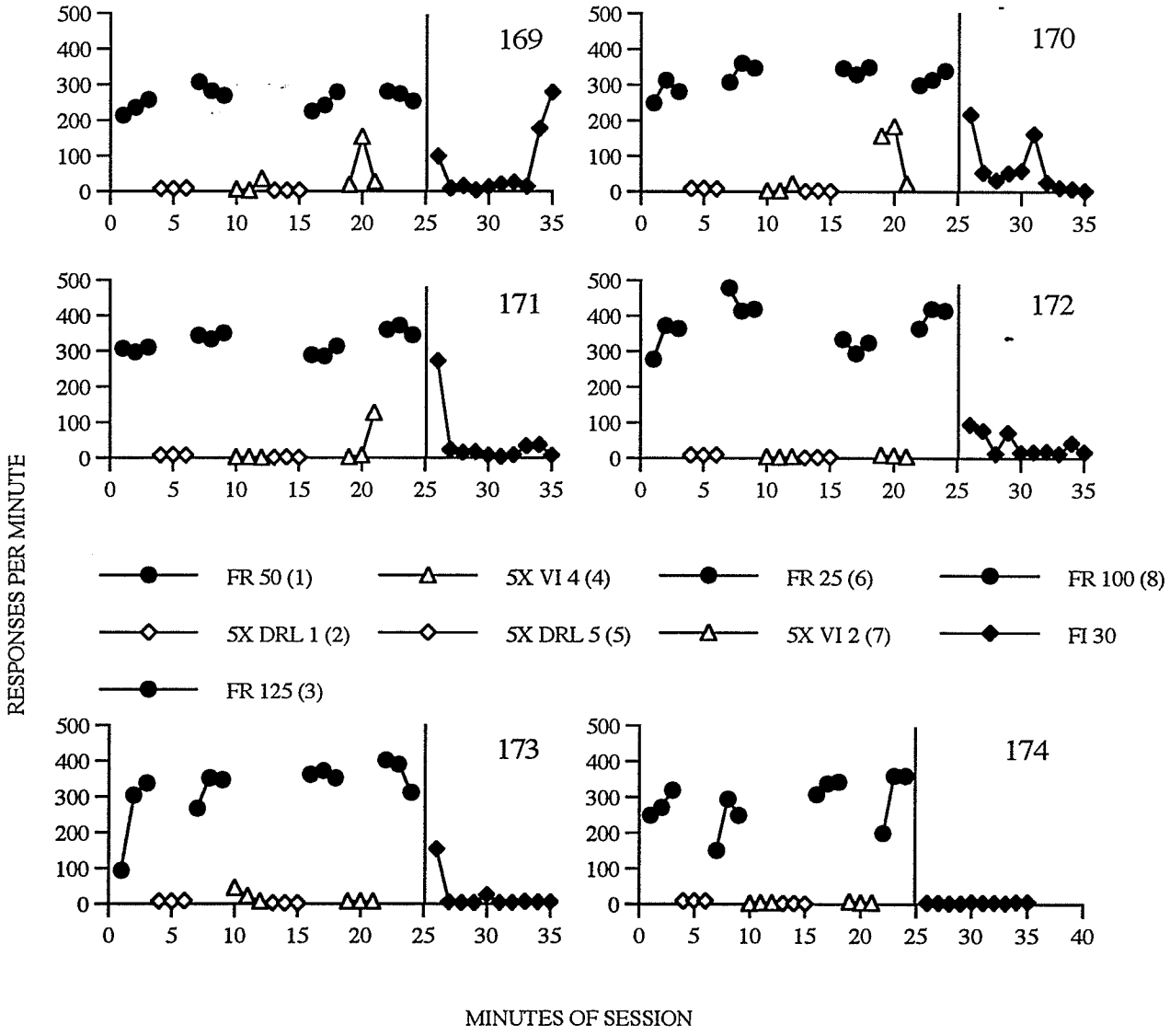
BOTH-F Graphs



Appendix G (continued)

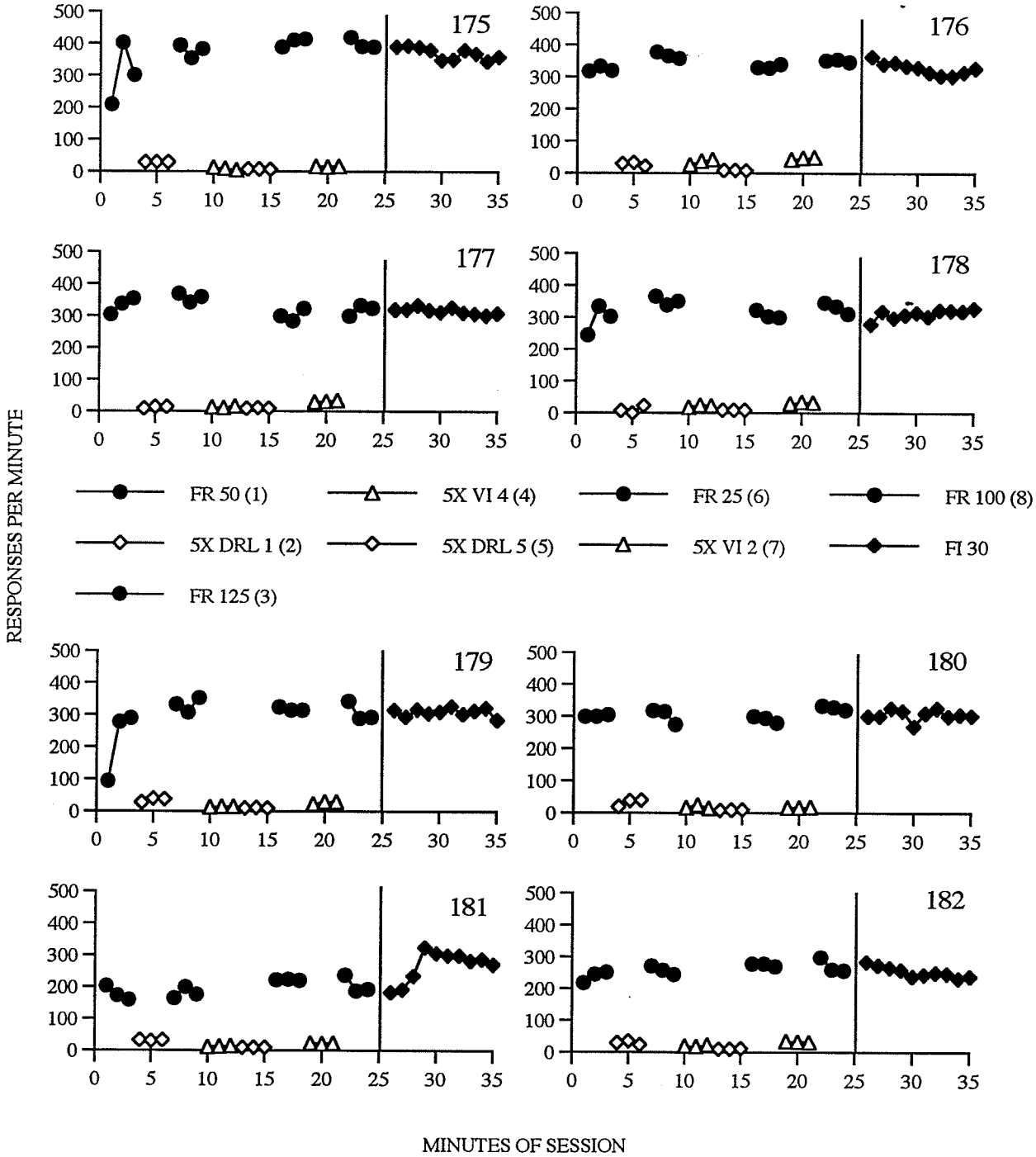


Appendix G (continued)

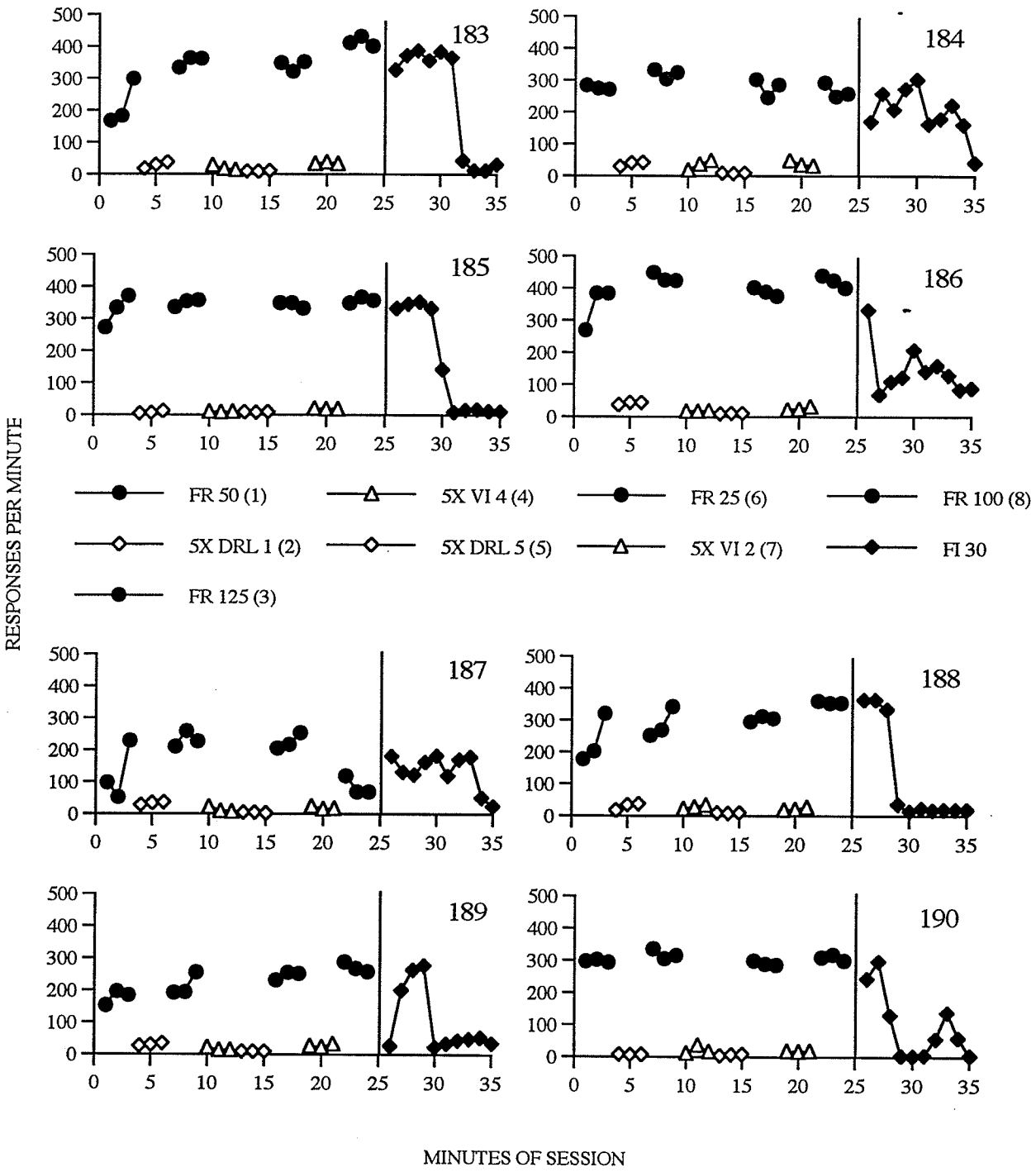


Appendix G (continued)

BOTH-N Graphs



Appendix G (continued)



Appendix G (continued)