

*WITHIN-SESSION CHANGES IN RESPONDING DURING  
AUTOSHAPING AND AUTOMAINTEANCE PROCEDURES*

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Four pigeons were exposed to autoshaping procedures in which an 8-second light on a response key was followed by food. Pecks on the key had no scheduled consequences. Subjects were also exposed to negative automaintenance procedures in which a peck on the illuminated key canceled the following food. The intertrial interval varied from an average of 7 seconds to an average of 232 seconds in different conditions. Rate of responding usually changed within sessions during autoshaping. Responding also changed within sessions for the 1 subject that responded during negative automaintenance. The within-session patterns of responding were flatter, peaked later, and were more symmetrical around the middle of the sessions at lower rates of food presentation, regardless of whether subjects responded on autoshaping, negative automaintenance, or previously reported variable-interval schedules. These results imply that similar variables produce within-session changes in responding during both classical (Pavlovian) and operant conditioning procedures.

*Key words:* within-session changes in responding, autoshaping, classical conditioning, operant conditioning, variable-interval schedule, key peck, pigeons

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Response rates often increase to a peak and then decrease within sessions when subjects respond on operant conditioning procedures (e.g., McSweeney & Hinson, 1992). These within-session changes in responding deserve study because they may be large and orderly (e.g., McSweeney & Hinson, 1992). They occur for a wide variety of species, procedures, responses, and reinforcers (e.g., McSweeney & Roll, 1993). As discussed elsewhere, they may also have a number of important theoretical and methodological implications (e.g., McSweeney & Roll, 1993).

The present experiment examined within-session changes in responding during autoshaping (Brown & Jenkins, 1968) and negative automaintenance (Williams & Williams, 1969) procedures. Examining responding during these procedures is important for three reasons. First, finding within-session changes would extend the generality of these changes to two new procedures. If within-session changes occur only under limited conditions, then they would reflect processes peculiar to those conditions. If they occur more generally, then they may reflect more important processes. Because autoshaping is often

considered to be a classical (i.e., Pavlovian) conditioning procedure (e.g., Swartzentruber & Rescorla, 1994), finding within-session changes during autoshaping would extend the generality of these changes to classical conditioning.

Second, examining responding during autoshaping will clarify the theoretical variables that produce within-session changes in responding. If within-session changes occur during autoshaping, then the presence of the response-reinforcer relation and the use of a free-operant procedure are not necessary to produce these variables. To give one example, within-session changes in operant responding might be attributed to sensitization and habituation (e.g., Groves & Thompson, 1970) to aspects of the procedure that are presented repeatedly (e.g., the reinforcers) or for a prolonged time (e.g., the experimental enclosure). If that is so, then within-session changes should be observed during classical conditioning procedures because they present reinforcers repeatedly and expose the subject to the experimental enclosure for a prolonged time. If within-session changes fail to occur during autoshaping, then theoretical explanations such as sensitization-habituation would be rendered less plausible relative to explanations that place more emphasis on the presence of a response-reinforcer relation or the use of a free-operant procedure.

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This material is based on work supported by the National Science Foundation under Grant IBN-9403719. The authors thank Cari B. Cannon for her comments on an earlier version of this manuscript.

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Third, finding within-session changes during autoshaping would have methodological and theoretical implications for research in classical conditioning. Methodologically, studies of autoshaping may allow session length to covary with their independent variables (e.g., Gibbon, Baldock, Locurto, Gold, & Terrace, 1977). If rate of responding changes systematically within the session, then rate of responding averaged over sessions of different lengths may be difficult to interpret. For example, suppose that response rates decline within sessions. In that case, shorter sessions will yield higher average rates of responding than longer sessions do. The effect of an independent variable on rate of responding may not be interpretable if sessions of different length are conducted for different values of that independent variable.

Theoretically, finding within-session changes in response rates during autoshaping would imply that influential theories of classical conditioning provide an incomplete understanding of significant factors. Such theories have identified many factors that alter conditioned responding (e.g., Rescorla & Wagner, 1972). None of these factors, however, has been interpreted as changing systematically during the session so that the amount of conditioned responding should change systematically within the session once asymptote is reached. It would be a challenge, then to see how current theories might be modified or elaborated to accommodate the within-session changes.

The results of some past studies suggest that within-session changes in responding do occur during classical conditioning (e.g., Bruner, 1965; Lubow, 1965; Lyon & Ozolins, 1970; Rubin & Brown, 1969; Siegel & Domjan, 1971; Tomie, 1976). However, the relation between these within-session changes and those reported during operant conditioning is unclear. To begin with, studies of classical conditioning usually involve only a few sessions. Therefore, the within-session changes during classical conditioning might be produced by factors related to acquisition rather than by the steady-state variables that produce the within-session changes in operant responding. More importantly, merely observing within-session changes during both operant and classical conditioning does not establish that these changes are produced by

the same variables. Instead, a functional analysis that studies responding at several levels of an independent variable is needed (e.g., Bitterman, 1960, 1965). One similarity might occur by chance. Similar functional changes are harder to dismiss as an artifact and therefore provide stronger evidence that the changes are produced by a common mechanism.

The present experiment studied autoshaped responding under steady-state conditions comparable to those used in past operant studies. Each autoshaping procedure was conducted for 30 sessions, and data from the last five sessions of exposure to each procedure were used for analysis, as is typical for operant procedures (McSweeney, 1992). Within-session changes in responding during autoshaping were also compared to the within-session changes in responding during previously conducted operant procedures that delivered the same programmed rates of food presentation. Within-session changes in operant responding are often flatter, more symmetrical around the middle of the session, and peak later for schedules that provide relatively lower rates of food (McSweeney, 1992; McSweeney, Roll, & Cannon, 1994). If similar changes in within-session patterns occur for autoshaping when the time between successive food presentations (inverse of rate of food presentation) is varied, then strong evidence would be provided that the same variables produce the within-session changes in responding for both operant and classical conditioning.

The present experiment also examined responding during negative automaintenance procedures (Williams & Williams, 1969). These procedures were conducted because autoshaping arranges an implicit operant contingency. During autoshaping, a light (conditioned stimulus, CS) appears on a response key and is followed by response-independent food presentation (unconditioned stimulus, US). Successive light-food presentations are separated by an intertrial interval (ITI). Because the light signals food, many authors have argued that the determinants of autoshaped behavior are primarily Pavlovian (e.g., Papini & Brewer, 1994). However, others have argued that operant factors may contribute because responding on the illuminated key may be quickly followed by food (e.g.,

Locurto, 1981; see also Dinsmoor, 1995). If so, then the within-session changes in responding during autoshaping might be an artifact of this implicit operant contingency. Such a contingency is not present during negative automaintenance. A peck on the illuminated key cancels the following food. Because pecks are never followed immediately by food, pecking seems unlikely to be due to reinforcement (operant conditioning) of pecking. Therefore, within-session changes in response rates that are observed during negative automaintenance cannot be a by-product of changes in operant responding.

### METHOD

*Subjects.* The subjects were 4 experimentally naive pigeons that were maintained at 85% of their free-feeding body weights by post-session feedings given after all subjects had completed their daily sessions. Subjects were housed individually and were maintained on a 12:12 hr light/dark cycle.

*Apparatus.* The apparatus for autoshaping was a three-key experimental enclosure (30 cm by 36 cm by 27 cm). The three response keys (2.5 cm diameter) were 21.5 cm above the floor and 7.5 cm apart. The left key was located 7 cm from the left wall; the right key was 7.5 cm from the right wall. A force of approximately 0.25 N was required to operate each key. An opening (4.5 cm by 5 cm) allowed access to a food hopper. It was 7.5 cm above the floor and 15 cm from the right wall. A houselight (4 cm diameter) was located 1.5 cm from the ceiling and 0.5 cm from the right wall.

The apparatus for negative automaintenance was a three-key experimental enclosure (30 cm by 35.5 cm by 27 cm). Response keys were 2.5-cm Plexiglas panels, located 7 cm apart and 3 cm from the ceiling. The left and right keys were mounted 6.5 cm from the side walls. An opening (5 cm by 4 cm), located directly below the center key and 8 cm above the floor, allowed access to the food hopper. A Plexiglas panel (4 cm diameter), 1 cm below the ceiling and 0.5 cm from the right side, served as a houselight. A treadle was also located on the floor directly below the left and right keys. The treadles will not be described because they were not used in this experiment.

Each apparatus was housed in a sound-attenuating chamber. A ventilating fan masked noises from outside the chambers. An IBM®-compatible computer, programmed using Med-State® notation, presented the experimental events and recorded the data. This computer was located in a different room from the experimental enclosures.

*Procedure.* The subjects were first exposed to the autoshaping procedure. A trial began when the center key was illuminated with red light for 8 s. When the light terminated, the US (5-s access to mixed grain) was immediately presented. US presentation was followed by an ITI of variable duration, during which the keylight was off. Then a new trial began. The length of the ITI was determined by a variable-time (VT) 22-s, VT 112-s, VT 232-s, VT 7-s, or VT 52-s schedule in different conditions, presented in that order. Each condition was presented for 30 daily sessions conducted six or seven times per week. The VT schedules were constructed according to a 25-interval Fleshler and Hoffman (1962) series. Sessions were 60 min long, excluding the time for which the magazine was presented. Responses were recorded but had no scheduled effect. The houselight was illuminated throughout the session.

When all of the autoshaping procedures had been conducted, conditions were changed so that subjects responded on a negative automaintenance procedure. A red light was presented on the left key according to the same VT schedules used in the autoshaping procedures. The light terminated after 8 s and was followed by the US if the subject had not pecked the lighted key during that trial. A peck during the lighted-key period immediately darkened the keylight, canceled the following food, and started the ITI. All other procedural details were similar to those used for autoshaping.

### RESULTS

Figure 1 presents the rate of pecking the stimulus (responses per minute) during successive 5-min intervals for each subject at each ITI duration during the autoshaping procedures. Table 1 presents the rates of responding averaged over the session for the mean of all subjects responding at each ITI duration. Rates of responding were calculat-

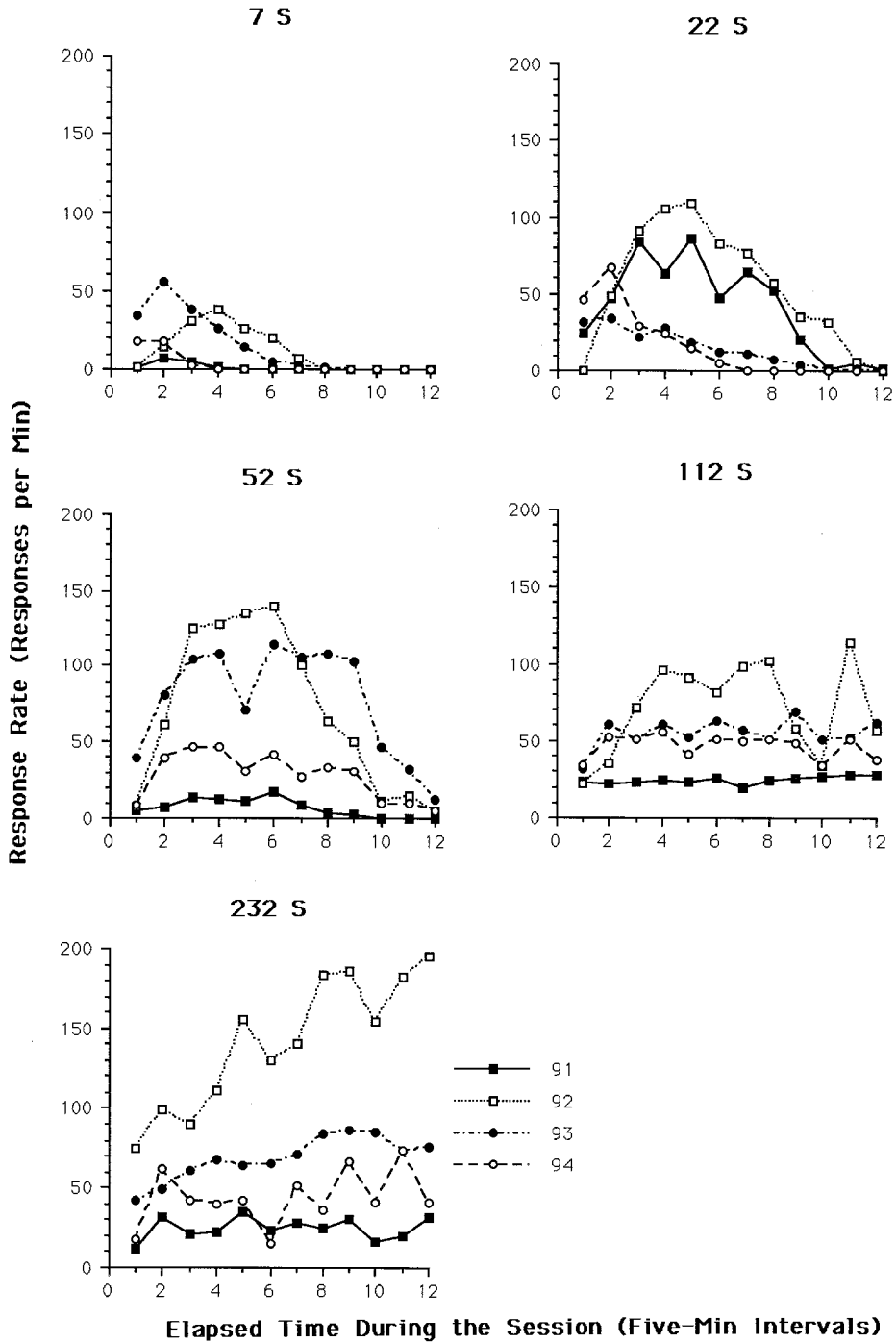


Fig. 1. Rate of responding during the stimulus (keylight) presentation (responses per minute) as a function of elapsed time (consecutive 5-min intervals) in the session for each subject responding on the autoshaping procedures at each ITI duration. Each panel presents the results for a particular ITI duration. Each function presents the results for an individual subject.

Table 1

Mean rate of responding averaged over the session (rate), the difference between the proportion of responses in the highest and the lowest 5-min interval (difference), the proportion of total-session responses during the first half of the session (proportion), and the ordinal number of the 5-min interval that contained the peak rate of responding (peak). Results are presented for the mean of all subjects responding during each autoshaping condition and for Subject 93 responding during each autoshaping and negative automaintenance condition.

	ITI duration				
	7 s	22 s	52 s	112 s	232 s
Rate (responses per minute)					
<i>M</i> autoshaping	7.7	31.1	45.4	49.4	69.9
93 autoshaping	14.8	14.2	77.2	55.1	68.8
93 automaintenance	2.9	63.5	37.6	34.3	32.9
Difference					
<i>M</i> autoshaping	.258	.151	.132	.057	.066
93 autoshaping	.316	.200	.109	.056	.054
93 automaintenance	.223	.160	.114	.086	.068
Proportion					
<i>M</i> autoshaping	.971	.749	.639	.482	.411
93 autoshaping	.981	.854	.561	.485	.424
93 automaintenance	.861	.531	.431	.524	.499
Peak					
<i>M</i> autoshaping	2	2	6	11	9
93 autoshaping	2	2	6	9	9
93 automaintenance	3	5	11	1	8

ed by dividing the number of responses on the illuminated key in a 5-min interval by the time for which the key was illuminated during that interval. Rates were presented instead of absolute number of responses because the stimuli were presented fewer times during a 5-min interval when the ITI was long than when it was short. These results and all of those that follow were averaged over the last five sessions for which an ITI was in effect.

Table 1 shows that the absolute rate of responding averaged over the session increased with increases in the length of the ITI. A one-way (ITI duration) within-subject analysis of variance applied to the rates of responding by individual subjects showed that this change was significant,  $F(4, 12) = 4.062$ ,  $p < .026$ . Finding increases in the rate of responding on a constant-duration stimulus with increases in ITI duration is consistent with the conclusion that the rate of responding (and the speed of acquisition) during classical conditioning procedures is determined by the ratio of the time between successive US presentations to CS duration (e.g., Balsam, 1984; but see Gibbon et al., 1977, for evidence that

stimulus duration can play a more important role than ITI duration).

Figure 1 shows that the rate of pecking often changed within experimental sessions. Although the form of the change varied somewhat from subject to subject, response rates usually increased and then decreased. Relatively constant responding or responding that did not change in a systematic manner occurred for Subject 91 during the 112-s and 232-s conditions and for Subject 94 during the 232-s condition.

Table 1 presents the mean rates at which Subject 93 responded, averaged over the session, during each autoshaping and negative automaintenance procedure. Figure 2 presents the proportion of total-session response rates during successive 5-min intervals for Subject 93 responding on each autoshaping and negative automaintenance procedure. Results are presented only for Subject 93 because it was the only subject that responded consistently during negative automaintenance. Rates of responding were calculated as in Figure 1. Proportions were calculated by dividing the rate of responding during the

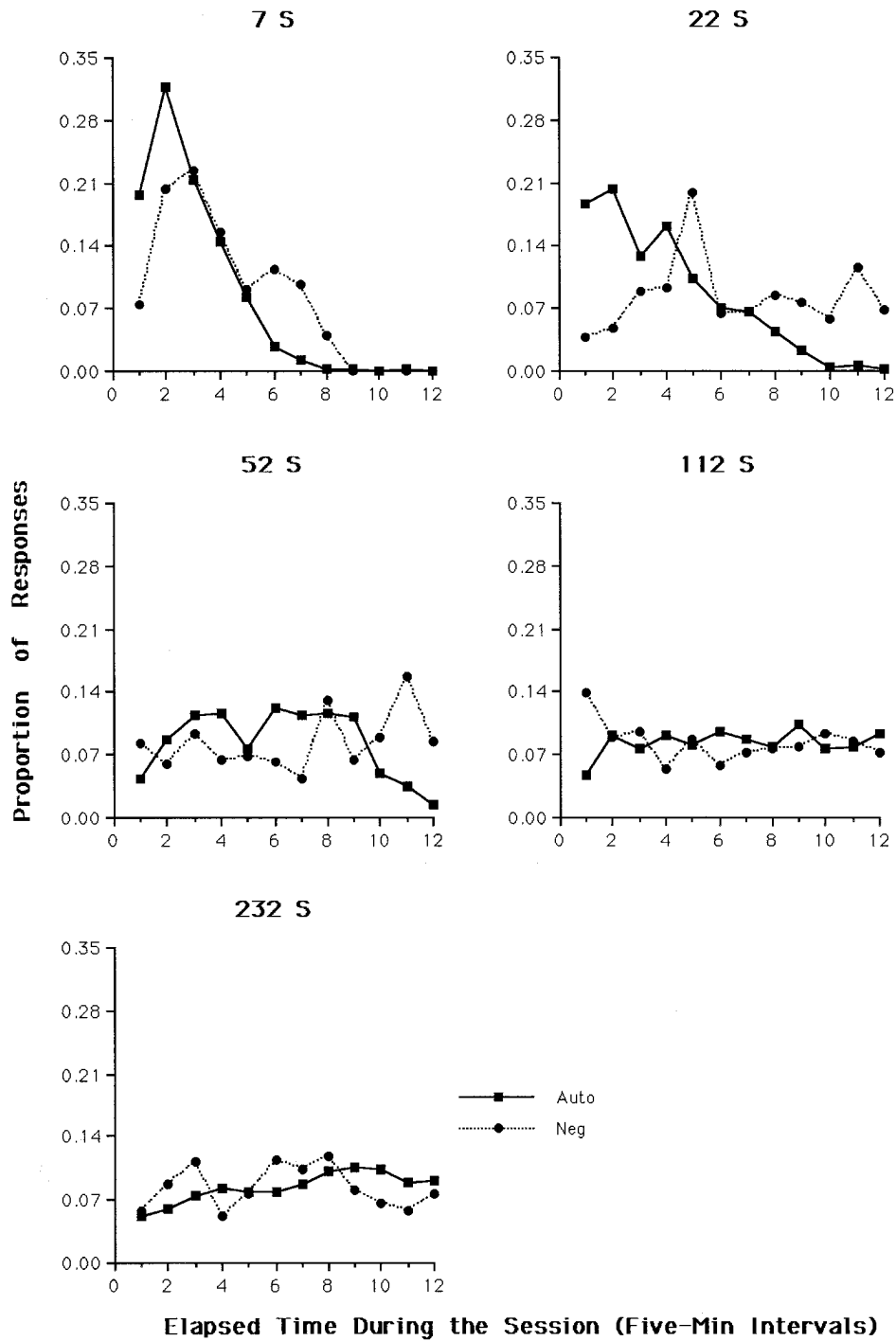


Fig. 2. Proportion of the total-session response rates for Subject 93 responding on the negative automaintenance (dotted line) and autoshaping (solid line) procedures plotted as functions of elapsed time in the session. Each panel presents the results for a particular ITI duration.

stimulus presentation in a 5-min interval by the rate of responding during the stimulus summed over the 12 intervals in the session. Proportions were presented so that differences in the absolute rates of responding would not obscure similarities in the within-session patterns of responding. It should be noted that the measures of response rates represent somewhat different variables for autoshaping and negative automaintenance, even though these rates were calculated in analogous ways. Because a response terminated the stimulus during negative automaintenance, response rate is the inverse of the latency to the first response. Response rate for autoshaping was influenced by the latency to the first response, but it was also influenced by the rate at which subjects responded after responding began.

Subject 93 usually responded faster during autoshaping than during the comparable negative automaintenance procedure (Table 1). The relatively high rate of responding during the 22-s ITI for negative automaintenance probably occurred because that was the first negative automaintenance condition conducted (i.e., a carryover effect).

The within-session changes in response rates reported in Figure 2 are variable. Several differences also appear between the results for autoshaping and negative automaintenance, particularly for short ITIs (7 or 22 s). For example, responding primarily decreased within the session during the 22-s autoshaping procedure. It increased and then decreased during the 22-s negative automaintenance procedure. However, the form of the within-session patterns of responding changed in the same way with changes in the ITI duration for both procedures. Table 1 summarizes these similarities for Subject 93: The within-session changes were flatter (smaller difference between highest and lowest proportion), more symmetrical around the middle of the session (proportion of total session responses closer to .50), and peaked later in the session (peak at higher numbered interval) at longer than at shorter ITI durations for both autoshaping and negative automaintenance. The only exception occurred for the 112-s ITI during negative automaintenance. Responding peaked during the first interval for this ITI instead of during a later interval.

Figure 3 presents the proportion of the to-

tal-session response rates for the mean of all subjects responding on the present autoshaping procedures and on VI schedules that presented similar programmed rates of food delivery in an earlier study (McSweeney, Weatherly, & Swindell, 1996). For example, responding during the 7-s ITI autoshaping procedure was compared to responding during a VI 15-s schedule because the 7-s average ITI plus the 8-s stimulus resulted in an average of 15 s between successive food presentations during this autoshaping condition. Proportions for autoshaping were calculated as in Figure 2. Proportions for the VI schedules were calculated by dividing the rate of responding during an interval by the sum of the rates of responding during the 12 intervals in the session. Again, proportions were presented so that differences in absolute rates of responding between the autoshaping procedures and the VI schedules would not obscure similarities in the within-session patterns of responding.

Figure 3 shows that the within-session changes in responding during the VI and autoshaping procedures differed, particularly when the programmed rate of food presentation was high. For example, responding increased and then decreased steeply during autoshaping for the 7-s ITI. Responding increased and then decreased more gradually during the VI 15-s schedule. Again, however, the form of the within-session patterns of responding for autoshaping and operant conditioning varied in similar ways with changes in the rate of food delivery. Within-session changes in operant responding are usually flatter, more symmetrical around the middle of the session, and peak later when subjects respond for lower rather than higher rates of operant reinforcement (McSweeney, 1992; McSweeney, Roll, & Cannon, 1994). Table 1 shows that was also true for the mean of all subjects responding on the autoshaping procedures. The within-session changes for the mean were flatter (smaller difference between the highest and lowest proportion), more symmetrical around the middle of the session (first-half proportion closer to .50), and peaked later (higher numbered interval) for longer than for shorter ITIs.

## DISCUSSION

The present results showed that within-session changes in responding are observed

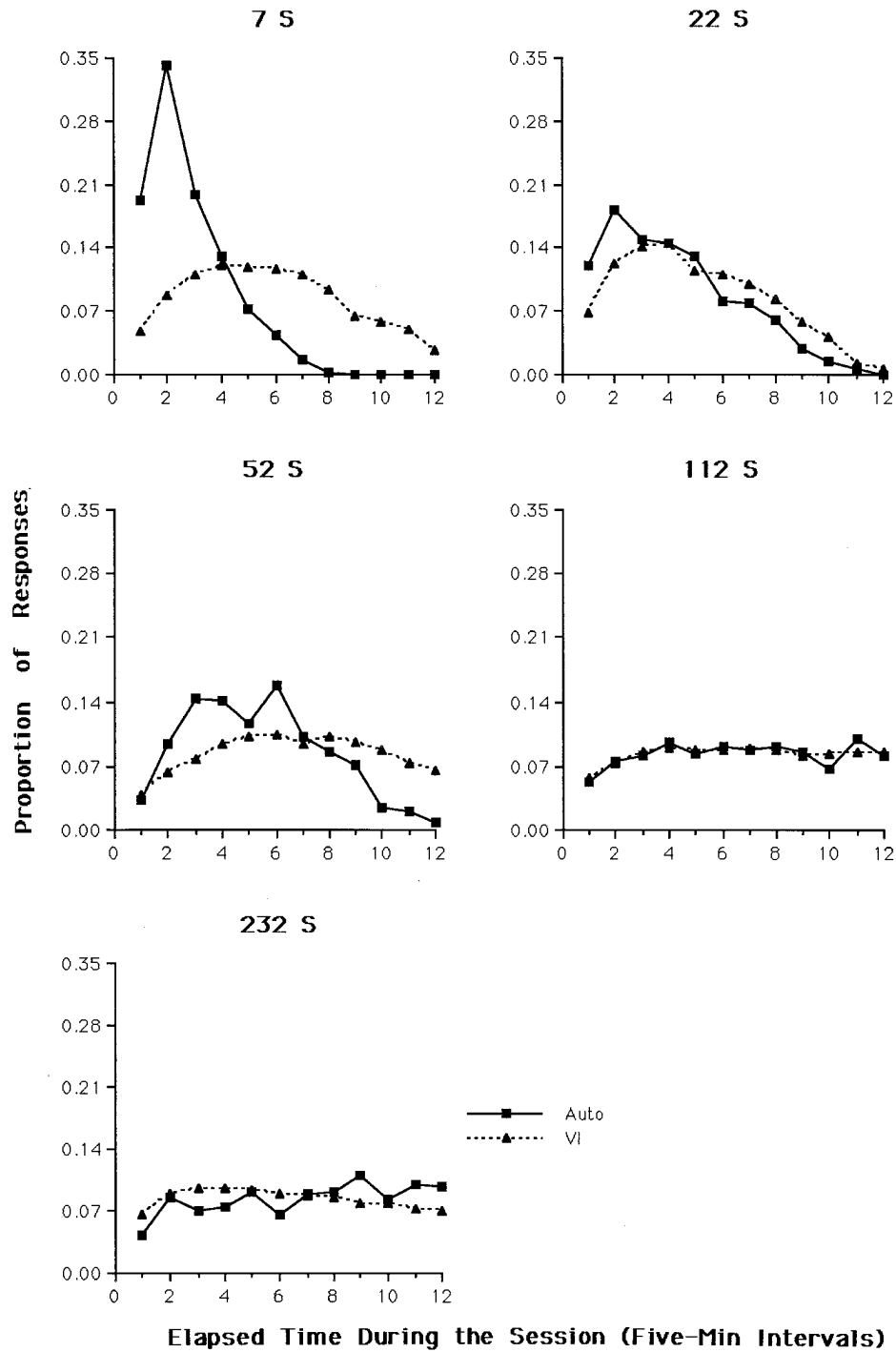


Fig. 3. Proportion of total-session response rates for the mean of all subjects responding on the autoshaping procedures of the present study (solid line) and on VI schedules (dotted line) that presented similar programmed rates of food delivery. The results for VI schedules were taken from McSweeney *et al.* (1996).



when subjects respond on autoshaping procedures (Figures 1, 2, and 3). Observing within-session changes during autoshaping extends the generality of these changes to a new procedure. Because within-session changes have been reported for a wide variety of operant procedures (e.g., McSweeney & Roll, 1993), as well as for consummatory responses (e.g., Rachlin & Krasnoff, 1983), responses that are evoked by stimuli (e.g., Thompson & Spencer, 1966), spontaneously occurring behaviors (e.g., activity, locomotion, exploration; e.g., Montgomery, 1953), and lever pressing before conditioning begins (e.g., Schoenfeld, Antonitis, & Bersh, 1950), within-session changes in responding may occur quite generally.

As argued earlier, observing within-session changes in responding during autoshaping has implications for theory and methodology in classical conditioning. For example, it implies that studies should not allow session length to covary with their independent variable. It also implies that theories of classical conditioning should be modified to accommodate within-session changes. For example, performance rules might be added to existing theories to predict these within-session changes, or parameters of existing models might be interpreted as changing systematically over the course of the session. Alternatively, more fundamental changes in the basic theories might be required. The exact nature of changes will depend on the results of future studies that more precisely specify the properties of within-session changes in classically conditioned responding.

The present results do not clearly indicate whether the within-session changes in classically conditioned responding are a by-product of the implicit operant contingency arranged by those procedures. As argued earlier, the negative automaintenance procedures were conducted to remove the operant contingency. Unfortunately, only 1 subject responded consistently during negative automaintenance. As a result, no general conclusions can be drawn about responding during those procedures.

The 1 subject that did respond during negative automaintenance did, however, show large within-session changes in responding. These changes could not be attributed to a failure to detect the change in procedure

from the earlier autoshaping conditions. Subject 93 responded at a lower rate during negative automaintenance (average rate of 34.2 responses per minute) than during autoshaping (average rate of 46.0 responses per minute), as would be expected if the subject detected that its responses canceled food. Therefore, the within-session changes in responding reported for Subject 93 show that responding can change systematically within sessions, even when responses are not quickly followed by reinforcers.

Changing the programmed rate of food delivery changed the within-session pattern of responding in similar ways during autoshaping, negative automaintenance (for Subject 93), and operant procedures. The within-session patterns usually peaked later, were flatter, and were more symmetrical around the middle of the session when the time between successive food presentations was longer than when it was shorter. As argued earlier, observing these similarities suggests that similar factors produce the within-session changes in all cases. One similarity might be observed by chance, but finding functional similarities strongly supports a common explanation.

Future studies are needed to specify the exact nature of the variables that produce within-session changes in responding. The present results imply that such variables must be general enough to occur during many procedures. Many potential explanations meet this criterion, and a detailed discussion of these explanations is beyond the scope of this paper. However, past results question several possibilities. Past studies have shown that the early-session increases in responding are not produced by recovery from the handling routine (e.g., McSweeney & Johnson, 1994). Other studies have shown that the late-session decreases in responding are not produced by anticipation of factors that follow the session, such as postsession feedings or handling (e.g., McSweeney, Weatherly, & Swindell, 1995). They have also shown that factors related to the act of responding (e.g., muscular warmup followed by fatigue) contribute little to within-session changes in responding under typical procedures (e.g., McSweeney & Johnson, 1994; McSweeney, Weatherly, & Roll, 1995; McSweeney, Weatherly, Roll, & Swindell, 1995; Weatherly, McSweeney, & Swindell, 1995). They have questioned wheth-

er satiation for the reinforcer contributes to the late-session decreases in responding (e.g., McSweeney & Johnson, 1994; Roll, McSweeney, Johnson, & Weatherly, 1995). Finally, they have shown that some operational definitions of within-session changes in attention do not produce the within-session changes in response rates (e.g., McSweeney, Roll, & Weatherly, 1994; McSweeney, Weatherly, & Swindell, *in press*).

The explanation for the within-session changes that is most consistent with past results is sensitization and habituation (e.g., Groves & Thompson, 1970) to aspects of the experimental procedure that are presented repeatedly (e.g., reinforcers) or for a prolonged period (e.g., the experimental enclosure). As argued earlier, such an explanation is also compatible with the present results because food is presented repeatedly and the experimental enclosure is presented for a prolonged time during autoshaping and negative automaintenance.

The within-session patterns of responding differed somewhat when subjects responded on autoshaping, negative automaintenance, and VI schedules, especially when food was provided at a high rate. These quantitative differences may be attributed to a number of factors. One possibility is that trials procedures (e.g., autoshaping) produce different within-session patterns of responding than do free-operant procedures (e.g., VI schedules). This seems unlikely because the within-session patterns also differed for the two trials procedures (autoshaping and negative automaintenance). Signaling the availability of reinforcers on VI schedules (converting them to a trials procedure) also fails to change the within-session pattern of responding (Weatherly *et al.*, 1995).

A more likely explanation is that subjects obtained different rates of food presentations from the three procedures, even though the programmed rates were similar. The mean obtained rates of food presentation during autoshaping were 236.1, 119.8, 59.7, 29.4, and 14.1 per hour for the 7-s, 22-s, 52-s, 112-s, and 232-s ITI durations, respectively. The mean obtained rates of food presentations were 200.4, 18.6, 7.2, 0.4, and 1.2 per hour for the same ITI durations for Subject 93 during the negative automaintenance procedures. The mean obtained rates of food pre-

sentations were 171.3, 88.5, 54.0, 27.9, and 14.1 per hour for the VI 15-s, VI 30-s, VI 60-s, VI 120-s, and VI 240-s schedules, respectively. Because lower rates of food presentation often yield flatter within-session changes in responding (e.g., McSweeney, 1992; the present experiment), these differences in obtained rates of food presentation may have produced flatter within-session changes for the VI schedules and negative automaintenance than for autoshaping. In support of this argument, the differences in the obtained rates of food presentation were largest at the highest programmed rates of food presentation. The largest differences in the within-session patterns of responding were also observed at the highest rates of food. Further experiments are needed to test this explanation.

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Received November 1, 1995  
Final acceptance February 19, 1996