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A COMPARISON OF RESPONDING MAINTAINED UNDER SECOND-ORDER SCHEDULES OF INTRAMUSCULAR COCAINE INJECTION OR FOOD PRESENTATION IN SQUIRREL MONKEYS

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Key pressing by squirrel monkeys was maintained under second-order schedules of either intramuscular cocaine injection or food presentation. Under one schedule, each completion of a 10-response fixed-ratio unit produced a brief visual stimulus; the first fixed-ratio unit completed after 30 minutes elapsed produced the stimulus paired with either cocaine injection or food presentation. Generally, short pauses followed by high rates of responding were maintained within the fixed-ratio units, and responding was positively accelerated over the 30-minute interval. Under another schedule, each completion of a 3-minute fixed-interval unit produced the brief stimulus; completion of the 10th fixed-interval unit produced the stimulus paired with either cocaine injection or food presentation. Rates of responding increased within the fixed-interval units, and to a greater extent over the entire 10 fixed-interval units. Patterns of responding depended more on the schedule of reinforcement than on whether cocaine or food maintained responding. Omitting the brief stimuli following all but the last fixed-ratio or fixed-interval units decreased average rates and altered the patterns of responding. Substituting a visual stimulus that was never paired with cocaine or food following all but the last fixed-ratio or fixed-interval units decreased response rates to a lesser extent and did not substantially alter patterns of responding. When the duration of the paired stimulus was varied from .3 to 30.0 seconds, the highest response rates occurred at intermediate durations (1.0 to 10.0 seconds). The manner in which the stimulus changes affected performances depended more on the schedule of reinforcement than on whether cocaine injection or food presentation maintained responding.

Key words: Cocaine, intramuscular injections, second-order schedules, nonpaired stimuli, tandem schedules, self-administration, key pressing, squirrel monkeys

Under second-order schedules, responding maintained under one schedule requirement (the unit schedule) is treated as though it is a unitary response that is reinforced according to another schedule. Under some second-order schedules, a stimulus is briefly presented at the completion of each unit schedule and is paired with the reinforcer. The brief stimulus often modulates both rates and patterns of responding within the unit schedules (reviewed by Gollub, 1977, and by Kelleher, 1966a).

As with other schedules, responding under second-order schedules depends more on the schedule of maintaining events than on the particular events used to maintain responding. For example, Goldberg and Tang (1977) studied squirrel monkeys under second-order schedules of food presentation or intravenous morphine injection. Each 30th key press produced a brief visual stimulus (fixed ratio or FR 30) and the first FR 30 unit completed after 60 min had elapsed produced the visual stimulus accompanied by food presentation or morphine injection. This schedule can be designated FI 60-min (FR 30:S) (cf. Kelleher, 1966a). Responding within the FR 30 units was characteristic of FR schedules; a brief pause was followed by a sequence of 30 responses emitted at a high rate. Additionally, responding increased over the 60-min interval. Under this schedule, responding maintained by food presentation was similar to

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that maintained by morphine injection in all important aspects. Other reports indicate that responding maintained under a second-order schedule of electric-shock presentation is similar to that maintained under comparable schedules of food presentation (Byrd, 1972).

Although performances maintained by different events under second-order schedules can be quite similar, recent reports suggest that, using cocaine as the maintaining event, rates of responding can be higher than under comparable schedules of food presentation (Spealman & Goldberg, 1978; Kelleher & Goldberg, 1977). Higher rates of cocaine-maintained responding under second-order schedules may reflect some unique aspect of stimuli paired with cocaine; however, since they are found when there are repeated injections within experimental sessions, they may depend on the presence of cocaine. For example, the effectiveness of brief stimuli in maintaining responding can be enhanced in the presence of some drugs (Hill, 1970; see also Robbins, 1975, 1978). Alternatively, the higher rates may be due to the rate-modifying effects of cocaine on schedule-controlled responding (Barrett, 1976; Gonzalez & Goldberg, 1977; Spealman, Goldberg, Kelleher, Goldberg, & Charlton, 1977; Spealman & Kelleher, 1979).

In the present study, responding maintained under second-order schedules of cocaine injection was compared to that maintained under comparable schedules of food presentation over a range of stimulus conditions including paired, nonpaired, and different durations of brief stimuli. It was of interest to determine if the changes in brief stimuli affected food- and cocaine-maintained behavior similarly; differences might indicate a reason for the higher rates of responding often maintained by cocaine. Under all conditions, cocaine injections (as well as food presentations) were confined to the end of the daily experimental session to preclude any rate-modifying effects on schedule-controlled behavior or on the effectiveness of the brief stimuli. Since the behavioral effects of cocaine are relatively short (Gonzalez & Goldberg, 1977; Spealman et al., 1977), once-daily sessions allowed the present comparison without a confounding by current pharmacological effects of cocaine. Both second-order schedules with FR units and second-order schedules with FI units were studied. The use of more than one schedule when comparing behaviors maintained by different events is particularly useful as potential effects of the different events under comparable schedules can be contrasted to the effects of the different schedules with the same maintaining event.

With injections at the end of the session, it is also possible to use routes of administration that might otherwise interfere or disrupt subsequent responding. Responding of rhesus monkeys has been maintained under an FI 60-min (FR 10:S) schedule with intramuscular injections (Goldberg, Morse, & Goldberg, 1976). The present study extended the use of intramuscular injections to the squirrel monkey and to second-order schedules with FI units. Additionally, the study provides information not presently available on brief stimulus functions under second-order schedules of intramuscular cocaine injection.

METHODS

Subjects

Eight squirrel monkeys (*Saimiri sciureus*) were used in the experiments; all had experience under various schedules of food presentation or electric shock delivery. They were housed individually with unrestricted access to water and fed at least an hour after the experimental sessions. Handling of the monkeys generally was as described by Kelleher, Gill, Riddle, and Cook (1963). Body weights of the individual monkeys are given in Table 1.

Apparatus

During experimental sessions, monkeys were restrained at the waist in a chair similar to that described by Hake and Azrin (1963). Three pairs of colored lamps mounted behind the clear Lucite front panel served as visual stimuli. A response key (BRS/LVE rat lever #121-05, Beltsville, Maryland) protruded through the front panel in front of the monkey about 8 cm above the waist. Each depression of the key with a force exceeding 20 g (0.19 *N*) produced an audible click of a relay mounted behind the front panel and was recorded as a response. Also mounted on the front panel was a recessed receptacle into which 300-mg banana-flavored pellets (P. J. Noyes Co., Lancaster, New Hampshire) could be delivered. Below the monkey was a small stock which

Table 1

Session Numbers for Experiments on Stimulus Duration and Body Weights[a] for all Subjects

	FR 10 (FI 3-min)				*FR 30-min (FR 10)*			
	Cocaine		*Food*		*Cocaine*		*Food*	
Stimulus Durations	*MS-10 (750-800 g)*	*MS-23 (850-950 g)*	*MS-1 (600-700 g)*	*MS-2 (650-700 g)*	*MS-13 (650-800 g)*	*MS-19 (900-1050 g)*	*MS-6 (650-730 g)*	*MS 8 (800-900 g)*
0.3	96-105	182-204	137-161	47-61	242-256	485-494	241-251	135-147
1.0	49- 69	161-181 220-242	44- 64	26-36	277-287	464-473	210-225	104-118
3.0	33- 48	205-219	107-136	62-79	257-266	495-518	252-267	148-162
10.0	70- 84	120-139 424-437	65- 90	27-46	231-241	474-484	226-240	119-134
30.0	85- 95	140-160 438-445	91-106	80-94	267-276	519-528	268-277	163-172

[a]These weights are ranges (rounded to the nearest 10 g) for the approximately two years during which the experiments were conducted.

restrained its tail. The chairs were enclosed in ventilated, sound-attenuating chambers with white masking noise continuously present. Events were scheduled and data were recorded with electromechanical switching equipment located in an adjoining room.

Procedure

Responding was maintained under two second-order schedules of either cocaine injection or food presentation. Under one schedule, each 10th response in the presence of a white light produced a 1-sec change to amber light (FR 10:S). Completion of the first FR 10 unit after a 30-min interval had elapsed [FI 30-min (FR 10:S)] produced a 3-min change in illumination to amber light, during which either cocaine was injected (MS-13, MS-19) or food was presented (MS-6, MS-8). Under the other schedule, the first response after 3-min had elapsed in the presence of white light produced the 1-sec stimulus change to amber light (FI 3-min: S). Completion of the tenth fixed interval unit [FR 10 (FI 3-min:S)] produced a 5-min change to amber light during which either cocaine was injected (MS-10, MS-23) or food was presented (MS-1, MS-2).

Following completion of the last unit schedule requirement under either schedule of cocaine injection, there was an immediate change to amber light, the chamber door was manually opened (the latency from the onset of the stimulus to the opening of the door was approximately equal to the duration of the prior stimulus changes: one-sec, except where specified), the monkey's leg was firmly grasped, and cocaine was injected into the calf muscle. The total time taken for the injection was 10 sec or less. The chamber door was closed for the remainder of the 3- or 5-min stimulus period, after which the monkey was returned to its home cage.

Following completion of the last unit schedule requirement under either schedule of food presentation, there was an immediate change to amber light and 10 300-mg pellets were automatically presented at 1-sec intervals (starting after a latency equal to the duration of the brief stimulus). The chamber remained closed for the duration of the 3- or 5-min period, after which the monkey was returned to his home cage.

With some subjects, experiments on the dose of cocaine or the amount of food were conducted before or between the present experiments, which were conducted at 3.0 g/presentation of food and, for the most part, at 3.0 mg/injection of cocaine (total dose expressed as the hydrochloride salt which was dissolved in .5 ml of .9% NaCl solution). Effects of paired, nonpaired, and no brief stimuli (see below) were assessed with MS-13 at 1.0 mg cocaine, and experiments on stimulus duration with MS-23 at 5.6 mg cocaine, doses that maintained response rates at levels comparable to those at 3.0 mg.

Establishment of responding under FI 30-min (FR 10:S). After several sessions in which responding had no consequences, MS-13 and MS-19 were exposed to short FI schedules of cocaine injection. The first (MS-19) or tenth (MS-13) response after a 3-min (MS-19) or 6-min (MS-13) interval elapsed produced a change from white to amber light, during

which cocaine was injected. The durations of the FI and stimulus change were varied during the initial five sessions. After these initial sessions, the amber light that accompanied cocaine injection was briefly presented (for 1 sec) following completion of each FR unit during the experimental session, and cocaine injection accompanied the first FR completed after the elapse of the FI. With MS-13, after the initial five sessions, the final parameters of the second-order schedule were immediately imposed; with MS-19, they were approached gradually over two weeks. Under the final schedule conditions, completion of each FR 10 unit produced a 1-sec amber light, and the first FR unit completed after a 30-min FI had elapsed was followed by a 3-min amber light and cocaine injection (see above).

With no preliminary training, MS-6 and MS-8 were exposed to an FI 30-min (FR 10:S) schedule of food presentation. All aspects of this schedule were identical to the FI 30-min (FR 10:S) schedule of cocaine injection except that delivery of 10 food pellets replaced injection of cocaine.

Establishment of responding under FR 10 (FI 3-min:S). Responding was established with all four monkeys under the FR 10 (FI 3-min:S) schedule of food presentation (see above). After stable performance was obtained, cocaine was injected along with food presentation for two monkeys (MS-10 and MS-23), and subsequently the number of food pellets was decreased to zero.

Brief stimulus changes. Effects of the brief stimuli on responding were assessed first by removing all brief stimuli except those that accompanied the cocaine injection or the food presentation. Under this condition, all aspects of the schedule remained the same except that the white light remained on during the 1-sec period following completion of all but the last unit schedule; completion of the last unit schedule produced the amber light followed, in 1 sec, by injection of cocaine or presentation of food. All monkeys except one (MS-10) were returned to the second-order schedule with paired brief stimuli. Effects of brief stimuli were then further assessed by presenting a nonpaired brief stimulus (green light) following completion of all but the last unit; completion of the last unit produced the amber light followed, in 1 sec, by cocaine injection or food presentation. Each condition was studied for at least 10 consecutive sessions and until performances showed no systematic day-to-day trends.

Stimulus duration. The duration of the paired stimulus (amber light) following completion of all but the last unit schedule was varied over a range from .3 to 30 sec. Injections of cocaine or presentations of food followed completion of the last unit schedule by a latency equal to the duration of the brief stimulus (i.e., .3 to 30 sec). As before, the amber light remained on for 3 or 5 min following the completion of the last unit schedule. Each condition was in effect for at least 10 sessions and until no systematic trends were seen. Different durations were studied in mixed sequences (Table 1).

RESULTS

Analysis of results. Average response rates under each schedule were calculated by dividing total responses in the presence of white light by the time elapsed in the presence of the white light. Responses and time in the presence of the amber or green lights were calculated separately. Additionally, responses in fourths of the FI units under the FR 10 (FI 3-min:S) schedules were cumulated over successive units. These data were used to indicate the extent of response patterning within the FI units. Responding in each session was also recorded with cumulative recorders (R. Gerbrands, Co., Arlington, Massachusetts).

Establishment of responding under FI 30-min (FR 10:S). Development of responding under the FI 30-min (FR 10:S) schedule of cocaine injection is shown in Figure 1 for MS-13; similar performances with slightly different procedures were obtained with MS-19. During the first session (Panel A), rate of responding was very low; following the injection there was a high rate that continued for about 1 min. During the second session (Panel B), response rate during the 6-min interval was higher than in the first session, and less responding occurred after the injection. During the fourth (Panel C) and fifth (Panel D) sessions, the length of the interval was increased to 9 and 12 min, respectively, and responding was still well maintained.

During the sixth session (Panel E), the second-order schedule with brief stimuli was imposed. After the first brief stimulus presenta-

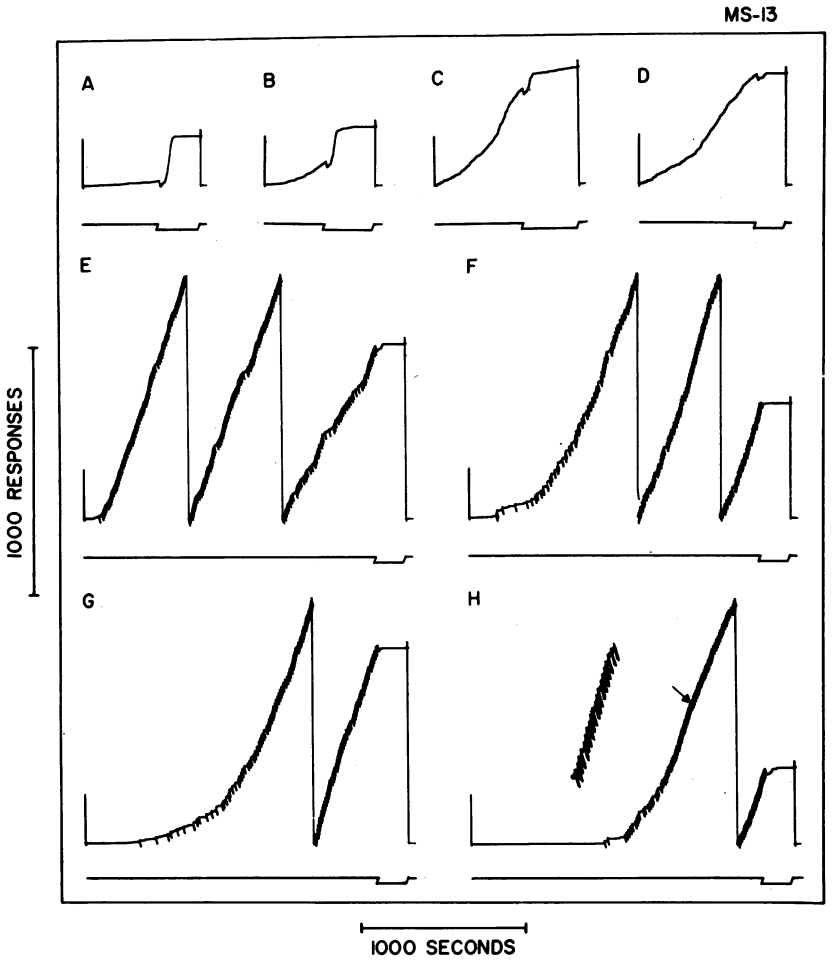

Fig. 1. Development of performance under FI 30-min (FR 10:S) with intramuscular cocaine injection (3.0 mg). Abscissae: time; ordinates: cumulative responses. Slashes on the cumulative record designate brief presentation of the stimuli eventually paired with the consequent event. A simultaneous offset of the cumulative response curve and the lower event line indicates the change in stimuli that accompanied the cocaine injection. A through D: 1st, 2nd, 4th, and 5th sessions, respectively—no brief stimuli. E through H: 6th, 14th, 31st and 294th sessions, respectively—with brief stimuli. Note the increase in response rate by the second session and the relatively stable performance over hundreds of sessions.

tion, there was a high rate of responding that was maintained throughout the remainder of the 30-min interval. In subsequent sessions, a lower rate early in the interval gradually developed (Panel F); by the 31st session (Panel G), the performance was relatively stable and characterized by a low rate early in the interval followed by a gradual transition to a high rate that was maintained until the end of the interval. Following most stimulus presentations there was a pause and, with the exception of the early portion of the interval, an abrupt transition to a high rate that was maintained until the next brief stimulus (see insert). The performance continued to be stable for many months (Panel H, 294th session).

Patterns of responding under the FI 30-min (FR 10:S) schedule of food presentation were characterized by a low rate early in the 30-min interval, followed by gradual transition to a higher rate. Following a brief stimulus, there was a short pause and, except during the early portion of the interval, an abrupt transition to a high rate that was maintained until the next brief stimulus (Figure 2A, right). The characteristic FR pattern of responding was better seen in the performances of MS-8 than in those of the other three monkeys stud-

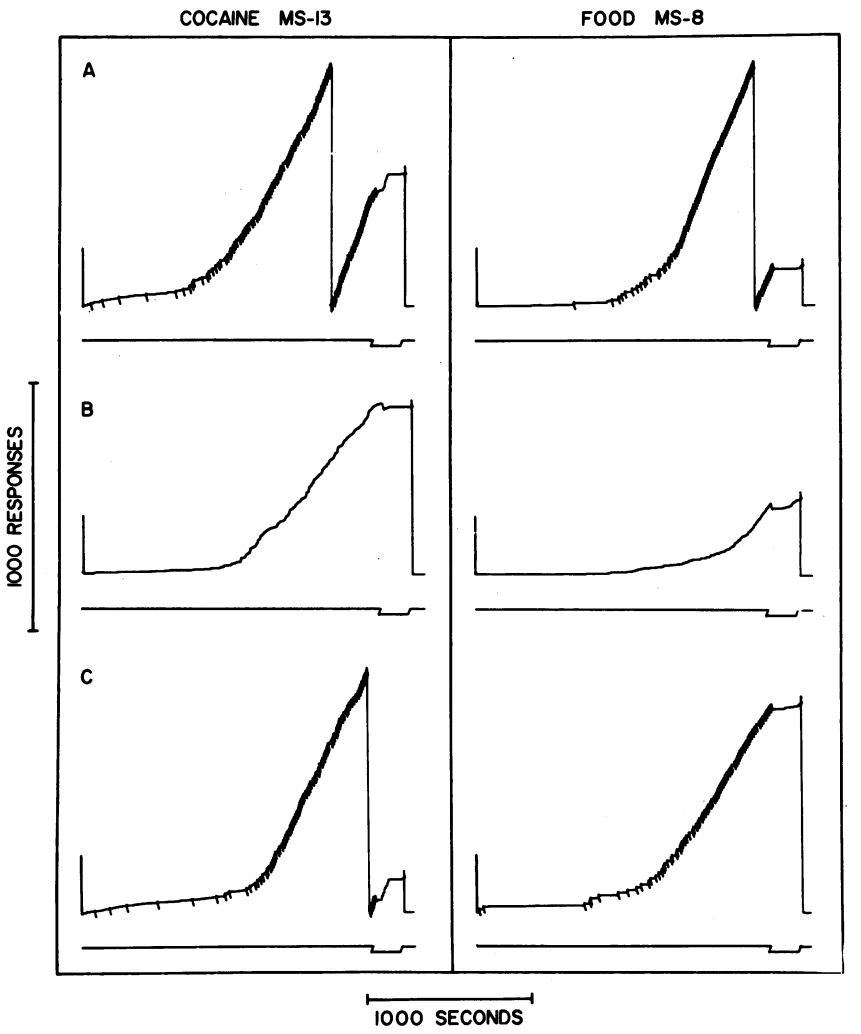

Fig. 2. Comparison of performances maintained by cocaine and food and effects of removing brief stimuli and of substituting nonpaired brief stimuli under FI 30-min (FR 10:S). Recording is as in Figure 1. A: paired brief stimuli—MS-13, .76, and MS-8, .63 resp/sec; B: no brief stimuli—MS13, .33, and MS-8, .15 resp/sec; C: nonpaired brief stimuli—MS-13, .53, and MS-8, .45 resp/sec. Note that the lowest response rates occurred with no brief stimuli and that nonpaired stimuli maintained rates between those maintained with paired stimuli and with no brief stimuli.

ied under the FI 30-min (FR 10:S) schedule with either cocaine or food. The performances maintained with food were generally similar to those maintained with cocaine with respect to overall rates and temporal patterns of responding (Figure 2A).

Establishment of responding under FR 10 (FI 3-min:S). Performances with food presentation for all four monkeys developed over about 20 sessions while response rate stabilized. Within the FI units, rates of responding were somewhat lower early in each interval and increased up to the stimulus presentation (Figure 3A, right). The addition of cocaine injections and the subsequent elimination of food presentation for MS-10 and MS-23 slightly decreased response rates and temporarily disrupted the patterns of responding. Stable performances with cocaine were qualitatively similar to those maintained by food presentation (Figure 3A). Although performances under schedules of cocaine injection had less within-unit patterning, they were not appreciably different from the earlier performances under schedules of food presentation.

The performances maintained under the two

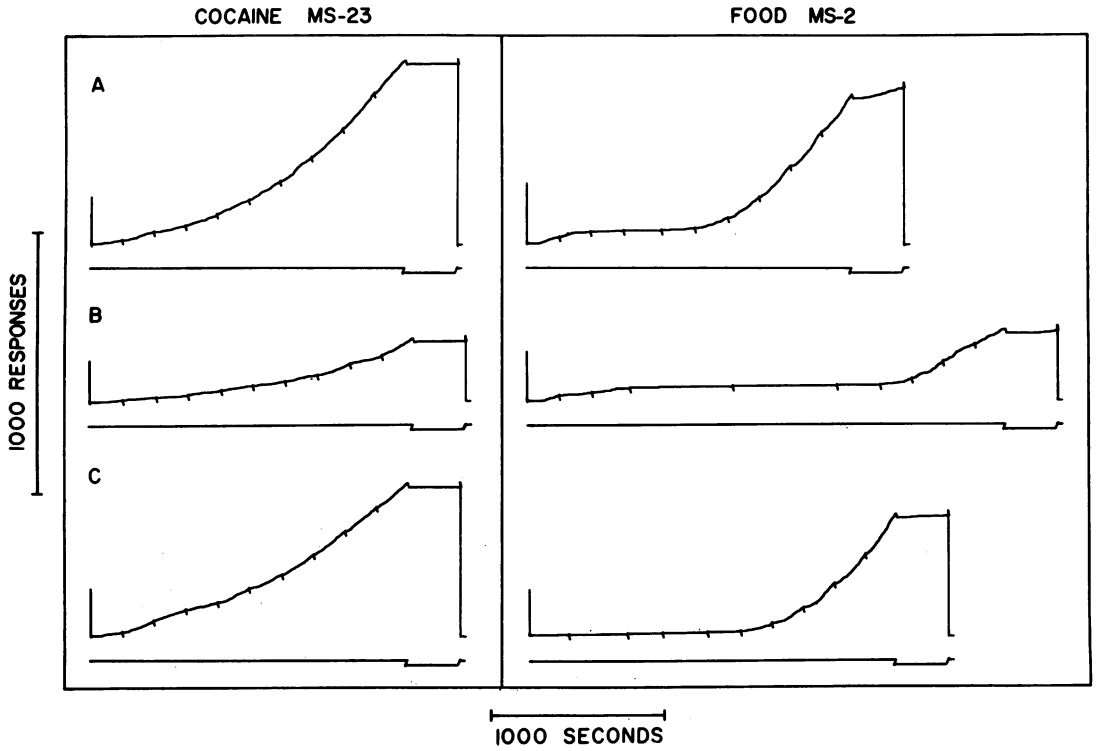

Fig. 3. Comparison of performances maintained by cocaine and food and effects of removing brief stimuli and of substituting nonpaired brief stimuli under FR 10 (FI 3-min:S). When no brief stimuli were presented, slashes indicate the completion of each successive FI requirement; otherwise, recording is as in Figure 1. A: paired brief stimuli—MS-23, .39, and MS-2, .31 resp/sec; B: no brief stimuli—MS-23, .13, and MS-2, .10 resp/sec; C: nonpaired brief stimuli—MS-23, .32, and MS-2, .22 resp/sec. Note that lowest response rates were maintained with no brief stimuli, intermediate rates with nonpaired stimuli, and highest rates with brief paired stimuli.

second-order schedules tended to depend more on the particular schedule than on whether cocaine or food was the maintaining event. Response rates under the FI 30-min (FR 10:S) schedule were approximately twice those under the FR 10 (FI 3-min:S) schedule (Figure 4). Additionally, the patterns of responding were distinctly different under the two second-order schedules and qualitatively similar under a given schedule with cocaine or food as maintaining events (compare Figures 2A and 3A).

Brief stimulus changes. The effects of removing the brief stimuli are shown in Figures 2 and 3. The top panels of each figure show representative performances maintained by cocaine (left panels) and food (right panels) with the paired stimuli. Removing the brief stimuli (Figures 2B and 3B) markedly decreased response rates for all monkeys, and there was less indication of orderly changes in rate within FI units (Figure 3). Additionally, without brief stimuli there was more within-session positive acceleration of responding under the FI 30-min (FR 10) schedule than under the FR 10 (FI 3-min) schedule, regardless of maintaining event. Mean response rates for all of the monkeys were decreased to about the same extent for responding maintained by cocaine or food (Figure 4, top panels). For all four monkeys, regardless of maintaining event, with the brief stimuli removed there was less of a change in rate across fourths of the FI units than was apparent with the paired brief stimulus (Figure 5).

Substituting nonpaired for paired brief stimuli also decreased rates of responding (Figures 2C, 3C, and 4, lower panels), but not so much as eliminating the stimuli entirely (compare upper and lower panels in Figure 4). The rates of responding maintained by food or cocaine were decreased to about the same extent under the FR 10 (FI 3-min:S) schedule and under the FI 30-min (FR 10:S) schedule (Figure 4). Some patterning within the FI units was

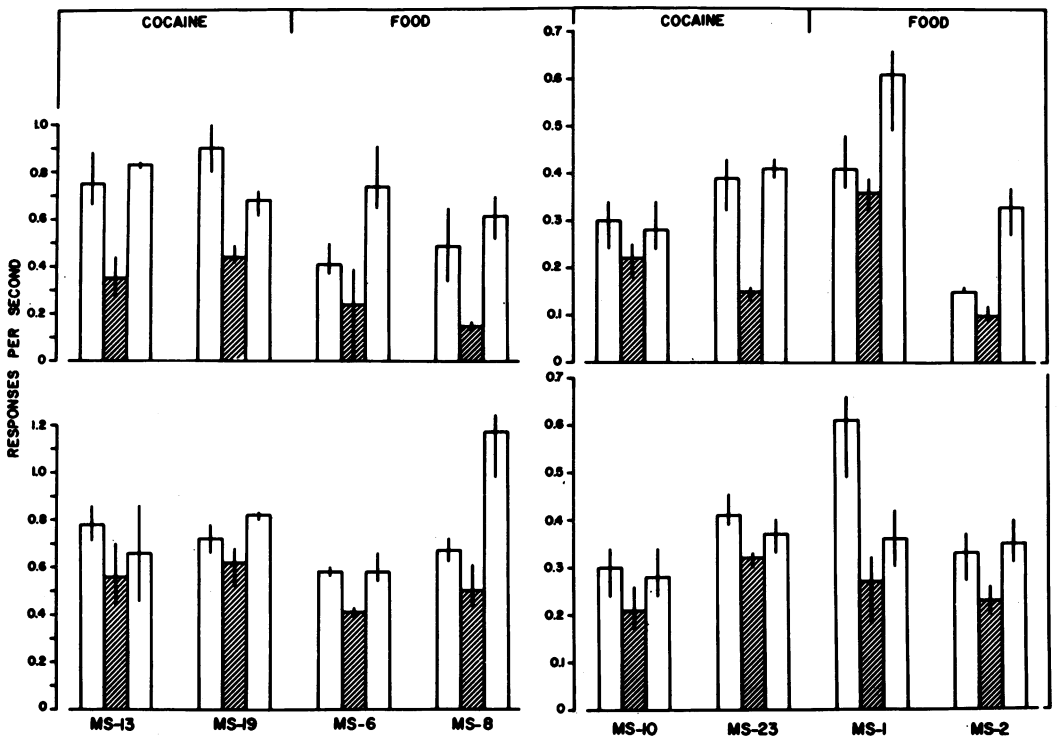

Fig. 4. Effects on mean rate of responding when the brief stimulus was omitted (upper panels, hatched bars) or when nonpaired brief stimuli were presented (lower panels, hatched bars). Left panels: FI 30-min (FR 10:S); right panels: FR 10 (FI 3-min:S). Open bars are stable performances from sessions with paired brief stimuli that preceded or followed each condition. Each bar represents the mean of the last three sessions under that condition; vertical lines indicate the range. Note the differences in coordinates. Rates under the FI 30-min (FR 10:S) schedule were approximately twice those under the FR 10 (FI 3-min:S) schedule. Response rates were decreased to the greatest extent by eliminating brief stimuli.

still obtained with the nonpaired stimuli (Figure 5); rates of responding increased over the fourths of the FI units to about the same extent as with paired stimuli (Figure 5).

Stimulus duration. Increases in stimulus duration first increased and then decreased response rates (Figures 6 and 7). The functions obtained for average response rate under the FI 30-min (FR 10:S) schedule, whether maintained by cocaine or food (Figure 8, upper four panels), were generally steeper than those for responding maintained by either event under the FR 10 (FI 3-min:S) schedule (Figure 8, lower four panels). Under the FI 30-min (FR 10:S) schedule, these changes in response rate occurred without appreciable changes in the overall patterns of responding (Figure 6). Under the FR 10 (FI 3-min:S) schedule, the rates of responding within FI units during the early parts of the session were greatest at intermediate stimulus durations. Additionally, as the stimulus duration increased there was some tendency for patterning within the FI units to become more pronounced (Figure 7).

Under the FI 30-min (FR 10:S) schedule of cocaine injection, response rates during the stimulus decreased with increased stimulus duration. Under the comparable schedule of food presentation, response rates changed considerably less across the range of stimulus durations studied (Figure 9). Under the FR 10 (FI 3-min:S) schedule with either event, response rates were generally highest at intermediate durations (1.0 to 3.0 sec).

DISCUSSION

In the present experiments, responding was established and maintained in squirrel monkeys under second-order schedules with a single daily intramuscular cocaine injection or a food presentation at the end of the experimental session. The performances maintained were generally similar to those previously reported

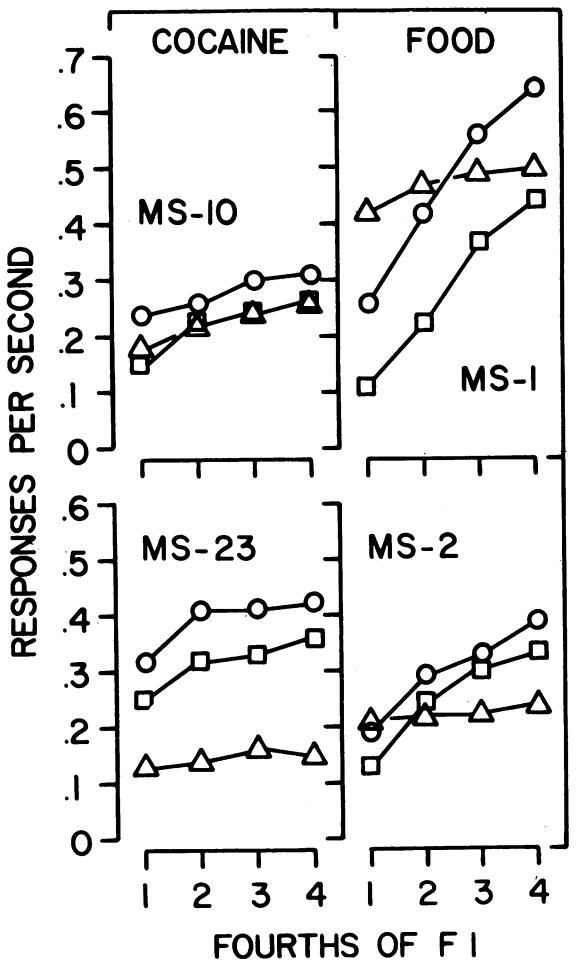

Fig. 5. Average rates of responding within successive fourths of the 3-min fixed-interval units. Circles: paired stimulus; triangles: no stimulus (tandem schedule); squares: nonpaired stimulus.

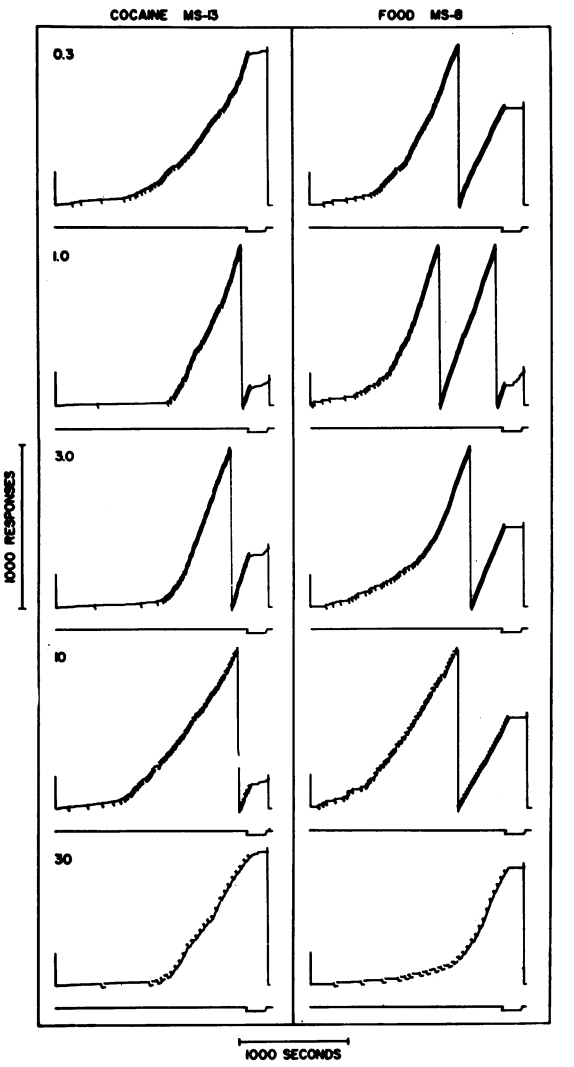

Fig. 6. Effects of stimulus duration under the FI 30-min (FR 10:S) schedules of cocaine injection or food presentation. Recording is as in Figure 1. Note that the highest rates occurred at intermediate durations.

under second-order schedules of food presentation in pigeons (Kelleher, 1966a, b) and squirrel monkeys (Goldberg, 1973; Kelleher & Goldberg, 1977), or of shock presentation (Byrd, 1972) when the maintaining events were presented repeatedly within experimental sessions. Moreover, the results of the present study comparing intramuscular cocaine injection and food presentation are consistent with previous studies comparing drug injection with food presentation in showing a high degree of similarity in performances at suitable parameter values (e.g., Goldberg & Tang, 1977; Goldberg et al., 1976; Kelleher & Goldberg, 1977).

Omitting brief stimuli from second-order schedules decreases cocaine-maintained responding under second-order schedules with FR units (Goldberg, 1971, 1976) and under second-order schedules with FI units (Kelleher & Goldberg, 1977). In the experiment by Kelleher and Goldberg, removing the brief stimuli markedly decreased cocaine-maintained as well as food-maintained responding. Similar effects on responding maintained by either cocaine or food were obtained in the present study under second-order schedules with FI units and under schedules with FR units.

Differences between performances under second-order schedules of food presentation with paired and nonpaired brief stimuli have been

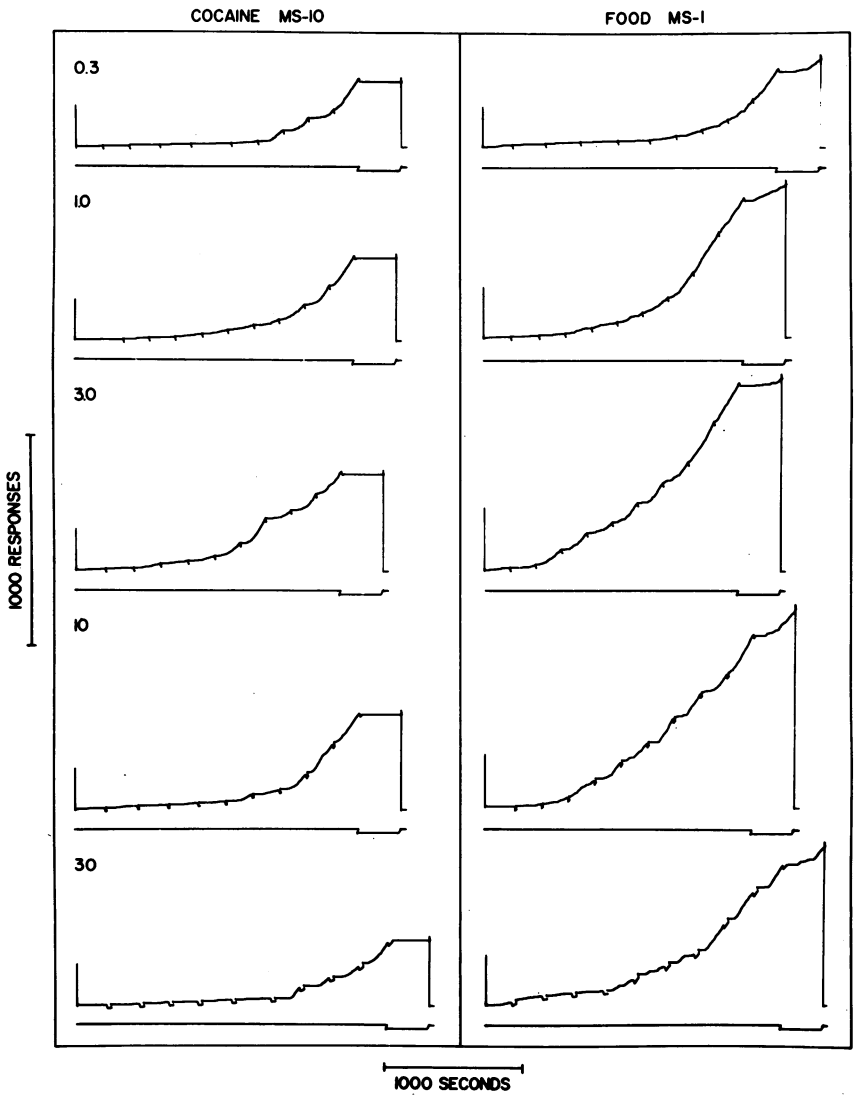

Fig. 7. Effects of stimulus duration under the FR 10 (FI 3-min:S) schedules of cocaine injection or food presentation. Recording is as in Figure 1. Note that the highest response rates occurred at the intermediate durations and that at those durations response rates during the initial units were relatively higher than at longer and shorter durations.

extensively investigated (reviewed by Gollub, 1977). While many investigators have found lower response rates and disrupted temporal patterns of responding with nonpaired stimuli (e.g., Kelleher, 1966b), others have found no differences in performance with paired and nonpaired brief stimuli (e.g., Stubbs, 1971). Stubbs suggested that the effects of the brief stimuli are primarily discriminative, either stimulus has the same temporal relationship to reinforcement and both maintain similar patterns of responding. In the present study, both paired and nonpaired stimuli were discriminative in that there was patterning within the units. The highest rates, however, were maintained with the paired brief stimuli; nonpaired stimuli maintained rates that were between those obtained with paired stimuli and those obtained when the brief stimuli were omitted. That the nonpaired stimuli maintained some responding may be due to the history of scheduled presentations of a similar, paired brief stimulus. A history of paired-stimulus presentations can influence the sub-

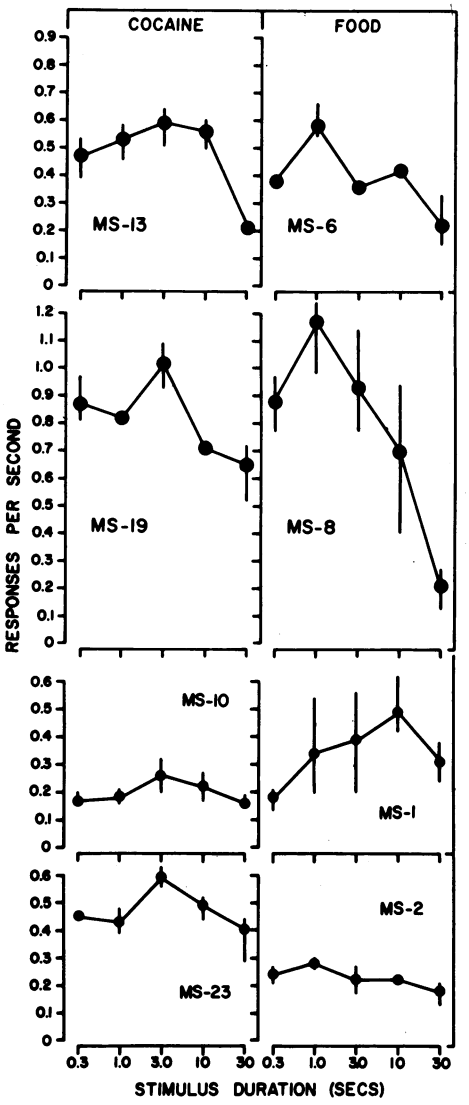

Fig. 8. Response rates during the units as a function of stimulus duration. Each point is the mean of the last three sessions under the condition; vertical bars represent the range of those sessions. For MS-23, points at 1.0, 10.0, and 30.0 are means of the last three sessions of each of two determinations. The means and ranges (in parentheses) for the first and second determinations are 1.0: .40 (.39 to .41), .47 (.45 to .48); 10.0: .49 (.44 to .52), .50 (.49 to .51); 30.0: .40 (.34 to .44), .37 (.29 to .44), respectively. Note that the functions are generally steeper under the FI 30-min (FR 10:S) schedule (upper four panels) than under the FR 10 (FI 3-min:S) schedule (lower four panels).

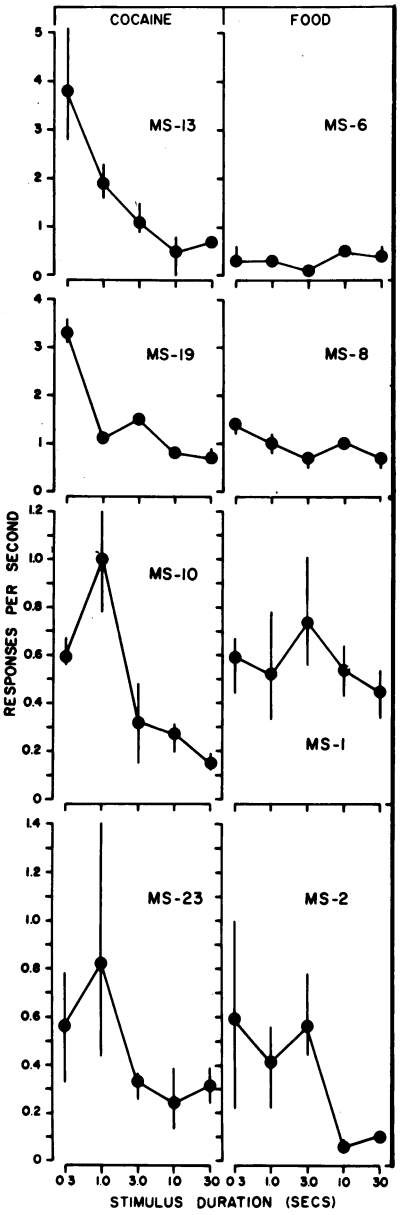

Fig. 9. Response rates during the stimuli as a function of stimulus duration. Details are as in Figure 8. The means and ranges for the first and second determinations for MS-23 are 1.0: .82 (.56 to 1.00), .82 (.44 to 1.44); 10.0: .33 (.26 to .39), .16 (.13 to .18); 30.0: .31 (.28 to .32), .32 (.24 to .39), respectively. Note that under the FI 30-min (FR 10:S) schedule (upper four panels) the functions differ for cocaine and food presentation whereas under the FR 10 (FI 3-min:S) schedule (lower four panels) the functions are more similar.

sequent effects of nonpaired stimuli (Marr & Zeiler, 1974). In the context of these experiments, it is most important to note that the effects of nonpaired stimuli were generally similar for cocaine- or food-maintained responding.

Increasing the duration of the stimulus following each unit of second-order schedules has

been reported to decrease response rates (Byrd, 1972; Cohen, Hughes, & Stubbs, 1973). A view that the effects of changes in stimulus duration are due primarily to delay in presentation of the maintaining event could explain those findings and the descending portions of the functions in Figure 8 (cf. Dews, 1960; Ferster, 1953; Skinner, 1938; Stretch, Gerber, & Lane, 1976). In the present study, however, rates of both cocaine- and food-maintained responding were highest at intermediate stimulus durations, suggesting other factors influencing performance. Possibly very brief stimuli are less effective in maintaining responding. Longer stimuli might maintain more responding; however, the cocaine injection or food presentation is increasingly delayed. Experiments in which the delay to cocaine injection or food presentation is varied independently of the duration of the other stimuli might bear on this possibility.

The present similarities between responding maintained by cocaine or by food presented at the end of the session are in contrast to other reports of higher rates of responding with cocaine than with food when presented repeatedly within sessions (reviewed by Spealman & Goldberg, 1978). There are a number of ways in which repeated cocaine injections within sessions can complicate a direct comparison of responding maintained by cocaine and that maintained by other events. Cocaine increases rates of schedule-controlled responding under a variety of circumstances, including when it is administered as a consequence of responding (Spealman & Kelleher, 1979). It has also been suggested that, in the presence of drugs with effects similar to those of cocaine, the effectiveness of brief stimuli in maintaining responding can be enhanced (e.g., Hill, 1970).

The present study compared brief stimulus effects under second-order schedules of cocaine injection with their effects under comparable schedules of food presentation. A single presentation of either event at the end of the session precluded complications from other pharmacological effects of cocaine injections. Under these conditions, there was little difference between cocaine- and food-maintained responding in the effects of brief stimulus changes on responding within a particular schedule condition. In contrast, across schedules and regardless of maintaining events, there were marked differences in the way changes in brief stimuli changed performances. Removing brief stimuli decreased response rates under both schedules, however, patterns of responding under the two schedules were distinctly different; under the FI 30-min (FR 10) schedule there was more patterning of responding over the session. With nonpaired stimuli, the patterns of responding resembled the patterns of responding maintained with paired stimuli and were also different under the two schedules. Finally, effects of stimulus duration were different across the two schedules; the functions for response rate and stimulus duration were steeper under the FI 30-min (FR 10:S) schedule. Thus, with the influence of cocaine injections on subsequent responding precluded, performances maintained under second-order schedules with cocaine or food are not only similar but also depend in a similar manner on the particular schedule under which cocaine or food is presented.

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