

*MOTIVATIONAL INFLUENCES ON PERFORMANCE
MAINTAINED BY FOOD REINFORCEMENT*

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In Study 1, we examined the independent effects of reinforcer consumption during sessions and meal consumption prior to sessions on performance maintained by food reinforcement. Nine individuals with developmental disabilities participated. On alternate days, a preferred edible item was delivered during (a) seven sessions conducted before lunch (repeated-reinforcement condition) versus (b) one session each conducted before and after lunch (pre- and postmeal conditions). Results for 7 of 9 participants showed decreased response rates across sessions in the repeated-reinforcement condition; results for 3 of 9 participants showed decreased rates during postmeal relative to premeal conditions. Two participants who did not show a decrement in responding during either comparison participated in Study 2, in which reinforcer consumption during sessions, combined with meal consumption prior to sessions, also had no effect on their performance. In Study 3, we determined whether (a) choice of reinforcers, (b) increased break time between sessions, (c) varied reinforcers, or (d) intermittent reinforcement schedules mitigated the satiation effects observed for the 7 participants in Study 1. Pre-session choice of reinforcers resulted in maintained performance for 2 of 6 participants exposed to this condition. Varied reinforcement resulted in maintained performance for only 1 of 5 participants exposed to this condition. Neither the increased break between sessions nor the intermittent reinforcement schedule was effective in maintaining performance for the participants who were exposed to these conditions.

DESCRIPTORS: motivating operations, establishing operations, abolishing operations, meal effects, satiation, stimulus variation, choice, intermittent reinforcement

Michael (1982, 1993) described environmental events that alter the reinforcing effects of consequences and the frequency of behavior that produced those consequences in the past as *establishing operations* (EOs). Laraway, Snyckerski, Michael, and Poling (2003) subsequently proposed a revision of the term to *motivating operation* (MO) to emphasize the bidirectionality of antecedent variables in decreasing as well as increasing the reinforcing effects of consequences. Laraway et al. also suggested the term *abolishing operation* (AO) to describe

events that decrease the reinforcing effects of consequences. Thus, MOs subsume both EOs and AOs. MOs for behavior maintained by positive reinforcement often have been conceptualized along a continuum in which the reinforcing effects of a stimulus are presumably strongest in the presence of an EO that has resulted in deprivation from that stimulus, but progressively weaken through repeated exposure to the stimulus (AO). Events other than deprivation per se also may influence the effectiveness of reinforcers. For example, extreme heat, salty foods, or vigorous exercise may function as EOs for seeking a glass of water. Conversely, the reinforcing effectiveness of a glass of water might be expected to diminish if water had been consumed recently or in large quantities.

The influence of MOs might be observed with many stimuli that are used as positive reinforcers; our interest in the present study is limited to edible items because they are

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commonly used to establish and maintain performance in training and treatment programs. Vollmer and Iwata (1991) demonstrated EO and AO influences on performance with reinforcers consisting of food, praise, and music. Relevant to the current discussion, they observed that response rates during a reinforcement condition were higher when access to an edible reinforcer was unavailable for 30 min preceding the sessions (EO) than when participants had consumed lunch and had free access to the reinforcer during the pre-session period (AO). These results suggested that food functioned as a more effective reinforcer following periods of deprivation; however, it was unclear if the AO effect observed for these participants was a function of consumption of the meal prior to session, access to the reinforcer prior to session, or both. More recently, Gottschalk, Libby, and Graff (2000) regulated access to foods for 48 hr prior to their presentation during preference assessments and observed that preference for a food item increased following periods of deprivation and decreased following periods of satiation.

Although these studies showed that operant performance maintained by food (Vollmer & Iwata, 1991) and preference for food (Gottschalk et al., 2000) varied as a function of free and restricted access to reinforcers, in neither case did the pre-session exposure condition resemble those found more commonly in the natural environment (i.e., scheduled meals). Zhou, Iwata, and Shore (2002) evaluated the effects of meals on postmeal rates of responding. Response rates were higher prior to meals than after meals for 4 of 9 participants, suggesting an AO effect. However, food consumption during meals had little influence on postmeal responding for the remaining participants. These mixed findings pose questions about the influence of meals on the effectiveness of edible items as reinforcers. In the present study, we examined the independent effects of reinforcer consumption during sessions and meal consumption

prior to sessions on operant performance maintained by food. Once conditions had been identified in which performance decreased, we determined whether several strategies might prolong the effectiveness of edible items as reinforcers.

A number of studies have evaluated the effects of participants' choices of reinforcers on performance during subsequent training sessions, and these investigations have yielded mixed results. No differences have been observed across choice and no-choice conditions when these options were presented sequentially (Geckeler, Libby, Graff, & Ahearn, 2000; Lerman et al., 1997; Smith, Iwata, & Shore, 1995). By contrast, higher response rates have been observed under choice conditions when choice and no-choice conditions were presented concurrently (DeLeon et al., 2001; Fisher, Thompson, Piazza, Crosland, & Gotjen, 1997; Geckeler et al.; Graff & Libby, 1999).

Another strategy for recovering rates of responding would be to allow a period of time to elapse between the consumption of food and food-reinforcement sessions, such that the reinforcing effects of food might be reestablished through a period of deprivation preceding sessions. As noted previously, Gottschalk et al. (2000) found that selection responses during preference assessments increased for food items to which access had been restricted prior to sessions, but the implications of these results are limited because (a) the study did not investigate the effects of deprivation on performance (other than selection during preference assessments), and (b) the 48-hr deprivation period would be impractical for reinforcement sessions conducted several times per day. Thus, further empirical evaluation of increased break time between sessions as a response-maintenance strategy seems warranted.

Egel (1980, 1981) presented data indicating that varying the stimuli that are delivered as reinforcers may facilitate response maintenance. Egel (1980) first showed that children with

autism responded faster and for a longer time when varied edible reinforcers were delivered following bar pressing relative to a condition in which the same edible reinforcer was delivered. Egel (1981) later found that children with autism made more correct responses on discrimination tasks under varied versus constant reinforcer conditions. These results suggest that varied reinforcer presentation may facilitate performance during a single session; however, the effectiveness of such a procedure in mitigating AO effects across repeated reinforcement sessions remains unknown.

To review, one purpose of the present study was to identify the independent effects of reinforcer consumption during sessions and meal consumption prior to sessions on performance. In addition, once conditions had been identified in which performance decreased, the effects of several procedures (participants' pre-session choice of reinforcers, increased break between reinforcement sessions, varied presentation of reinforcers, and intermittent schedules of reinforcement) in mitigating AO effects were evaluated.

GENERAL METHOD

Participants and Setting

Nine men who attended an adult vocational program for individuals with developmental disabilities participated. All participants were ambulatory, followed instructions, and communicated vocally or via manual signs. Lance (37 years old) had been diagnosed with moderate mental retardation and a seizure disorder. Jerry (31 years old) had been diagnosed with cerebral palsy, moderate mental retardation, and a seizure disorder. Mark (37 years old) had been diagnosed with Klinefelter's syndrome and moderate mental retardation. Mitch (34 years old) had been diagnosed with severe mental retardation. Carter (36 years old) had been diagnosed with moderate mental retardation and a seizure disorder. Donald (43 years old) had been diagnosed with autism and mild

mental retardation. Robert (23 years old) had a brain shunt and had been diagnosed with mild mental retardation. Doug (26 years old) had been diagnosed with moderate mental retardation and a seizure disorder. Greg (32 years old) had been diagnosed with mild mental retardation.

Sessions were conducted in individual cubicles located in the workshop that were separated from adjacent work stations by office dividers. All cubicles contained tables, chairs, and other session materials as needed (see below). Sessions lasted 5 min and were conducted two to seven times daily, 3 to 5 days per week.

Response Measurement and Interobserver Agreement

During preference assessments conducted in the first phase, observers recorded approach responses to items presented by an experimenter. An approach response was defined as the participant reaching for or pointing to either of the stimuli presented during a trial. An index of preference was calculated by dividing the number of trials on which a stimulus was approached by the number of trials it was presented and multiplying by 100%.

The target response for all experimental sessions was pressing a switch on a flat panel with sufficient force to illuminate a small light in the center of the panel. The dependent measure was the number of responses per minute. Data also were collected on reinforcer delivery (the experimenter placing an edible item on a plate next to the panel) and reinforcer consumption (the participant placing the edible item in his mouth) to serve as measures of procedural integrity. All data were collected on laptop computers.

Interobserver agreement was assessed by having a second observer simultaneously but independently record data during a mean of 40% (range, 31% to 53%) of the sessions across participants. Agreement percentages for data from the preference assessments were calculated by comparing observers' records on a trial-by-trial basis. The number of trials on which both

observers scored approach responses to the same item was divided by the total number of trials and multiplied by 100%. Agreement percentages for all other data were calculated by partitioning session time into 10-s intervals and comparing observers' records on an interval-by-interval basis. The smaller number of responses in each interval was divided by the larger number of responses; these fractions were then averaged across intervals and multiplied by 100%. Mean percentage agreement for selections during the preference assessments was 99% (range, 97% to 100%) across participants. Mean percentage agreement for switch pressing was 95% (range, 92% to 96%) across participants. Mean percentage agreement for reinforcer delivery was 94% (range, 92% to 97%) across participants.

Procedural integrity percentages for reinforcer delivery were calculated by comparing the number of switch-pressing responses and reinforcer deliveries per session and dividing the smaller of these values by the larger and multiplying by 100%. Mean procedural integrity for reinforcer delivery was 99% (range, 96% to 100%) across participants. All participants consumed all reinforcers delivered by the experimenter during 100% of the sessions. Binary data (i.e., yes or no) were recorded on participants' consumption of the lunchtime meal (meals were prepared by staff at the residential facilities for all participants) during the study and indicated that all participants consumed all meals throughout the experiment.

Preference Assessment

Preference for nine edible items was assessed using a paired-stimulus procedure (Fisher et al., 1992). As a control for potential extraexperimental influences, the edible items were not used as reinforcers in participants' other training programs and were not typically provided as part of participants' meals (e.g., it was observed that Lance typically brought potato chips as part of his lunch; thus, potato chips were not included in his initial preference

assessment). In addition, information from staff interviews was considered when selecting items to be included in the initial preference assessment to ensure that a participant's food allergies or dietary restrictions (if any) were not compromised (individuals with strict dietary restrictions were not selected for participation in the study). Thus, unless contraindicated by staff feedback, items included were common snack items (e.g., M&Ms[®], pretzels, potato chips). Participants consumed each edible item prior to the assessment to insure familiarity with all of the stimuli. Each edible item was paired at least twice with every other item in a random order. On each trial, two items were placed on separate plates approximately 0.3 m apart and 0.4 m in front of the participant. An approach response to one of the items produced access to that item; the other item was removed. Attempts to approach both items simultaneously were blocked, followed by a repetition of the trial. If neither item was approached within 5 s, the experimenter prompted the participant to approach and consume each item, and then repeated the trial. If the participant did not approach either item when the trial was repeated, the experimenter removed both items and initiated a new trial. On all but one occasion, preference assessments involved a total of 72 trials completed during a single session (Carter's preference assessment was conducted over 2 consecutive days and involved 144 trials). The item selected most frequently during the preference assessment was used as the reinforcer during Studies 1 and 2. The six most frequently selected items were used as reinforcers during Study 3.

Experimental Task and General Session Characteristics

The microswitch panel and various alternative activities (e.g., magazines, beads, crayons and paper) were available in a free-operant arrangement during all sessions. Participants were prompted to select alternative activities from among an array of items prior to the first baseline session, and the item selected was used

throughout the experiment. Prior to each session, the experimenter used a verbal-gestural-physical prompting sequence to ensure that the participant engaged in both the target response and the alternative activity and came into contact with the contingency in effect. All sessions were 5 min in length. During reinforcement sessions, an edible item was delivered on a fixed-ratio (FR) 1 schedule (except as otherwise noted) by placing it on a plate located directly behind the task apparatus. Prior to each reinforcement session, the experimenter used a verbal-gestural-physical prompting sequence so that the participant would consume the edible item after it was placed on the plate.

This experimental task was selected because it was a discrete response that could be easily observed by the experimenter and observers and because response effort and duration would remain relatively constant during and across sessions. As such, observed fluctuations in response rates could not be attributed to fatigue or varying task requirements. The FR 1 schedule was selected because continuous reinforcement is used commonly in training the acquisition of new responses. Finally, use of the microswitch task and the FR 1 schedule permitted a systematic replication of the methods described by Zhou et al. (2002).

The types of comparisons conducted in the various studies placed additional requirements on general session characteristics. First, because we were interested in the effects of reinforcer consumption across sessions, a subsequent session in a given run was not begun until the participant had consumed all edible items from a prior session. Second, if a participant was unable to complete a series of sessions on a given day, data for that day were discarded (this occurred rarely).

STUDY 1

METHOD

Procedure

Baseline. These sessions were conducted prior to any manipulation to establish a baseline rate

of responding in the absence of reinforcement. Because edible items were unavailable and no programmed consequences followed completion of the task, there were no temporal restrictions placed on when baseline sessions were conducted (i.e., baseline could be conducted before and after lunch).

Repeated reinforcement. Seven successive sessions were conducted, with 5-min breaks between sessions. The run of sessions was set at seven because it represented the typical number of sessions that could be completed (with breaks between) before lunch for all participants. The first session was conducted at the same time as the premeal session (described below) on alternate days, and all sessions were completed before lunch.

Premeal and postmeal sessions. One reinforcement session (premeal) was conducted at the same time each morning at least 90 min after breakfast and before the participant ate lunch. The premeal session served as the baseline against which responding during the postmeal session was compared. On the same day that a premeal session was conducted, a postmeal session was conducted within 15 min of the completion of the participant's lunch.

Experimental Design

Demonstration of a basic reinforcement effect was shown in a nonconcurrent multiple baseline design across participants. During the reinforcement phase, the effects of reinforcer consumption during repeated-reinforcement sessions and of meal consumption prior to sessions were examined in a multielement experimental design. Repeated-reinforcement (Condition A) and premeal-postmeal (Condition B) conditions were conducted on alternate days to isolate the effects of the two types of food consumption. The effects of repeated-reinforcement sessions were assessed by comparing the response rate during the first of the run of consecutive sessions with that of the last for each day on which Condition A sessions were conducted. Similarly, the effects of meals were assessed by comparing the response rate

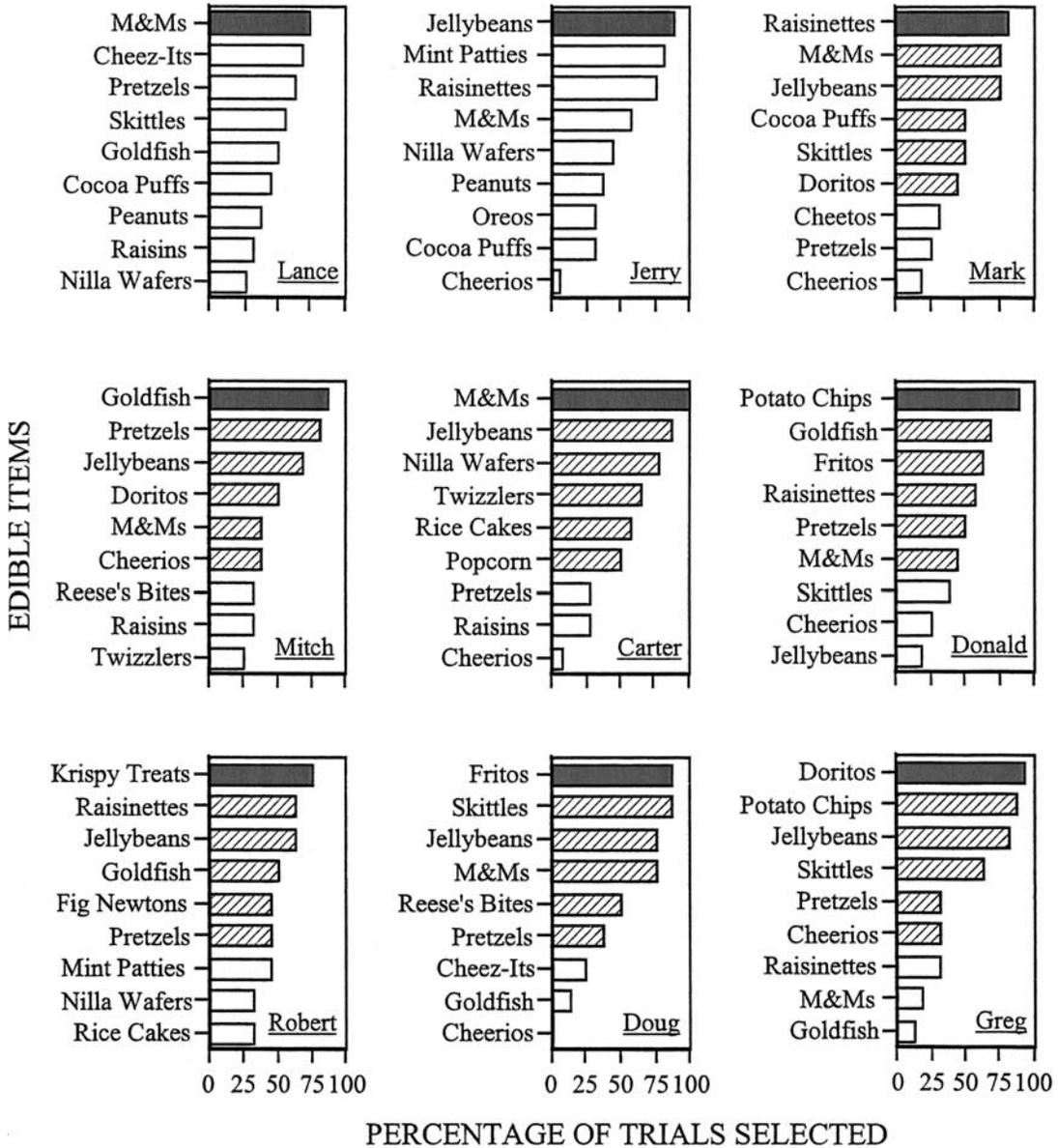


Figure 1. The percentage of trials on which participants selected each edible item presented during the preference assessment. Shaded bars indicate items used as reinforcers in Studies 1 and 2; striped bars indicate additional items used as reinforcers in Study 3. Open bars indicate unused items.

during the premeal session with that during the postmeal session for each day on which Condition B sessions were conducted.

RESULTS

Figure 1 shows results of the preference assessments, depicted as the percentage of trials

on which each edible item was selected. Lance and Jerry participated in Studies 1 and 2, during which only the most highly ranked edible item was used as a reinforcer. The remaining 7 individuals participated in Studies 1 and 3; during Study 3, the six most highly ranked edible items were used as reinforcers.

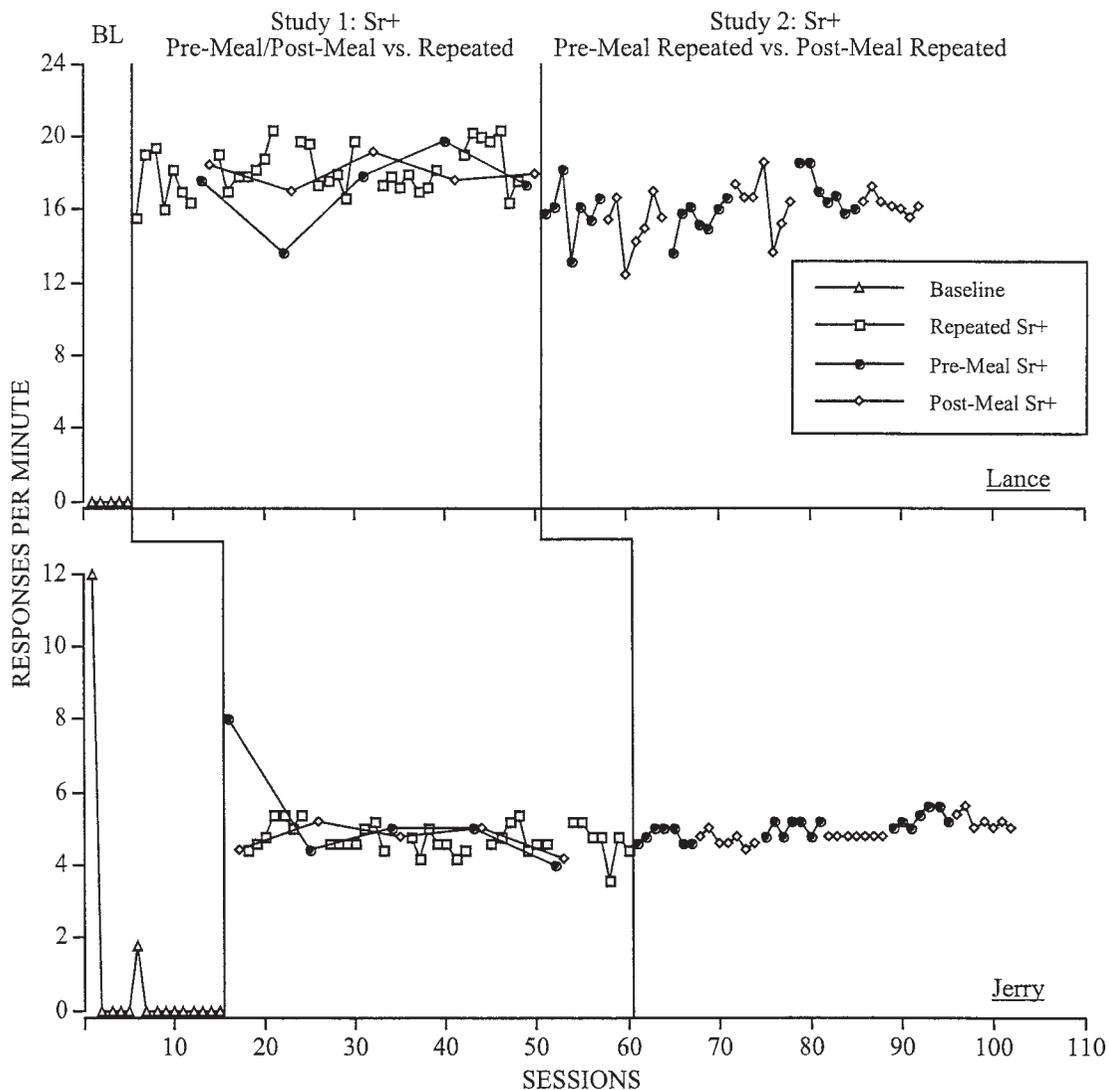


Figure 2. Number of responses per minute during Studies 1 and 2 for Lance and Jerry.

Items used as reinforcers in Studies 1 and 2 are represented by shaded bars; additional items used as reinforcers in Study 3 are represented by striped bars.

The left side of Figure 2 shows results of Study 1 for Lance and Jerry. Lance exhibited no switch presses during baseline and immediately began responding at high rates when M&Ms® were delivered during the reinforcement phase. On repeated-reinforcement days, response rates during the last session of each run were lower

than those during the first session (referred to hereafter as an AO effect) on only 1 of the 5 days. On pre- and postmeal reinforcement days, response rates during postmeal sessions were slightly lower than during premeal sessions for only 1 of the 5 days. Jerry's switch pressing did not occur during 13 of 15 baseline sessions and immediately increased when jellybeans were delivered during the reinforcement phase. On repeated-reinforcement days, his responding remained stable across sessions during all

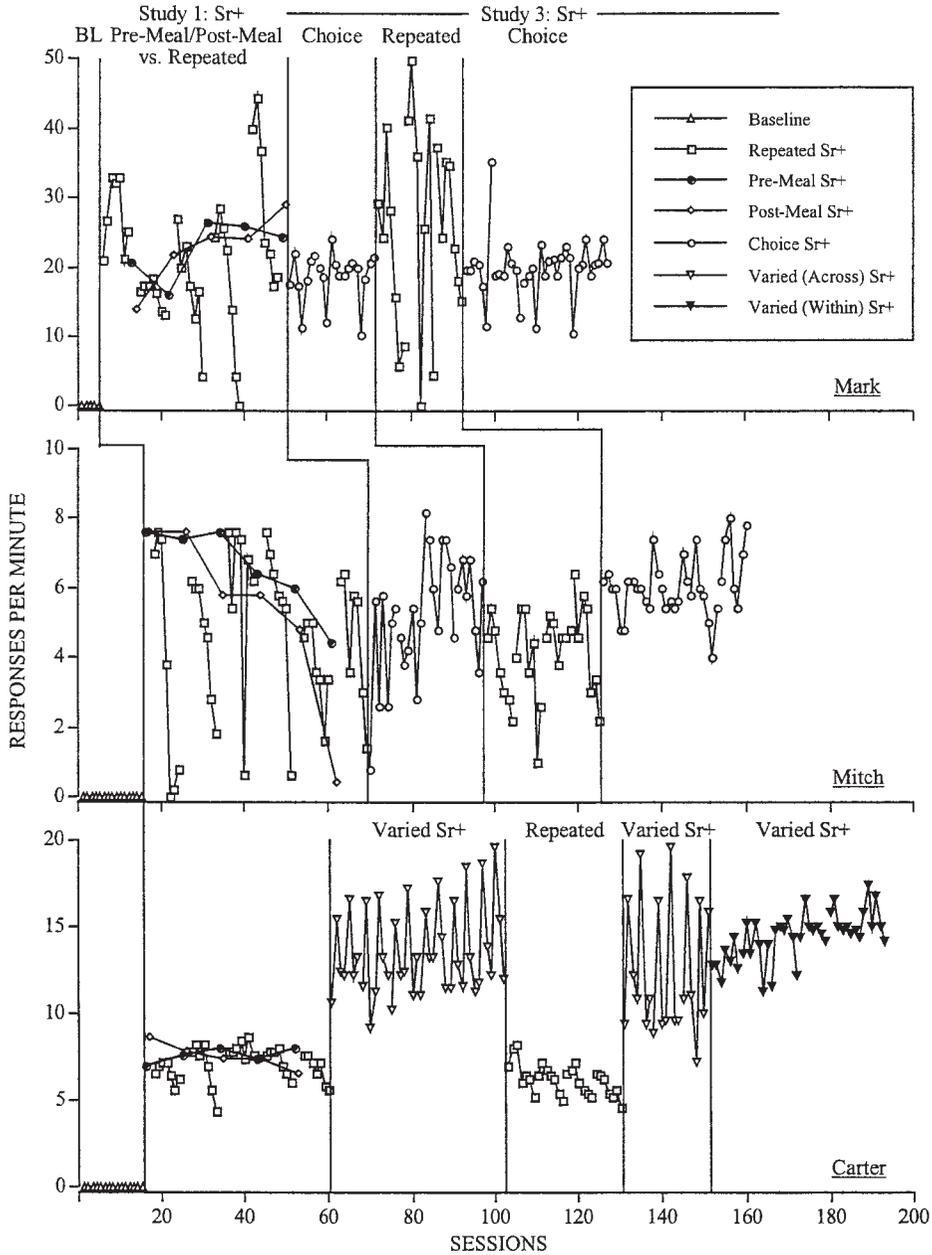


Figure 3. Number of responses per minute during Studies 1 and 3 for Mark, Mitch, and Carter.

5 days; the highest and lowest response rates differed by less than 1.5 across 35 repeated-reinforcement sessions. On pre- and postmeal reinforcement days, Jerry's responding was stable and only slightly lower during the postmeal sessions than during premeal sessions on 2 of the 5 days. Thus, neither Lance's nor

Jerry's data showed an AO effect resulting from either repeated consumption of a specific edible reinforcer across a series of seven reinforcement sessions or consumption of their lunch prior to reinforcement sessions.

The left side of Figure 3 shows results of Study 1 for Mark, Mitch, and Carter. None of

these participants exhibited switch presses during baseline, but all showed immediate increases in responding when a preferred edible item (Raisinettes® for Mark, Goldfish® crackers for Mitch, and jellybeans for Carter) was delivered during the reinforcement phase. On repeated-reinforcement days, Mark's switch pressing generally increased across the first few of a run of sessions but showed an AO effect on 4 of the 5 days. On pre- and postmeal reinforcement days, his response rates during postmeal sessions were slightly lower than during premeal sessions on 3 of the 5 days. On 2 of these 3 days, the difference between pre- and postmeal rates of responding was only 2 responses per minute. It should be noted that Mark often engaged in bursts of responding to produce several edible items before pausing to consume them, and then resumed with high rates of switch pressing (all other participants usually consumed edible items as they were earned). Even so, Mark's data showed an AO effect resulting from repeated reinforcer consumption but not from consumption of his lunch prior to reinforcement sessions. Mitch's performance during repeated-reinforcement sessions showed a reduction in response rates across sessions on all 6 days. On pre- and postmeal reinforcement days, his response rates during postmeal sessions were noticeably lower than during premeal sessions on the last 4 of 6 days. Thus, Mitch's data showed an AO effect resulting from both repeated reinforcer consumption and consumption of his lunch prior to reinforcement sessions. Carter's performance during repeated-reinforcement sessions showed a reduction in response rates across sessions on all 5 days. On pre- and postmeal reinforcement days, response rates during postmeal sessions were slightly lower than during premeal sessions on 2 of the 5 days, but the differences between pre- and postmeal responding were only 0.6 and 1.2 rpm, respectively. Carter's data showed an AO effect resulting from repeated reinforcer consumption

but not from the consumption of his lunch prior to reinforcement sessions.

The left side of Figure 4 shows results of Study 1 for Donald, Robert, Doug, and Greg. None of these participants engaged in switch pressing during baseline, but all showed immediate increases in responding when a preferred edible item (potato chips for Donald, small pieces of Rice Krispy Treats® for Robert, Fritos® for Doug, and Doritos® for Greg) was delivered during the reinforcement phase. All 4 participants also showed reductions in response rates across sessions on repeated-reinforcement days. Less consistent results were observed on days when pre- and postmeal reinforcement sessions were conducted. Donald's and Robert's response rates during postmeal sessions were slightly lower than during premeal sessions on only 1 of 5 days and 2 of 5 days, respectively. By contrast, Doug's and Greg's response rates during postmeal sessions were lower than during premeal sessions on 5 of 6 days (this effect was most pronounced for Greg).

In summary, three types of results were observed in Study 1. First, an AO effect due to repeated consumption of reinforcers was observed for 7 of 9 participants (Mark, Mitch, Carter, Donald, Robert, Doug, and Greg). Second, an AO effect due to consumption of lunch was observed for 3 of 9 participants (Mitch, Doug, and Greg). Finally, no AO effect due to either manipulation was observed for 2 of 9 participants (Lance and Jerry).

STUDY 2

METHOD

The purpose of this study was to evaluate the combined effects of consumption of (a) meals prior to sessions and (b) edible reinforcers during sessions on Lance's and Jerry's performance, because neither participant showed an AO effect in Study 1. Repeated-reinforcement sessions were conducted both before and after lunch.

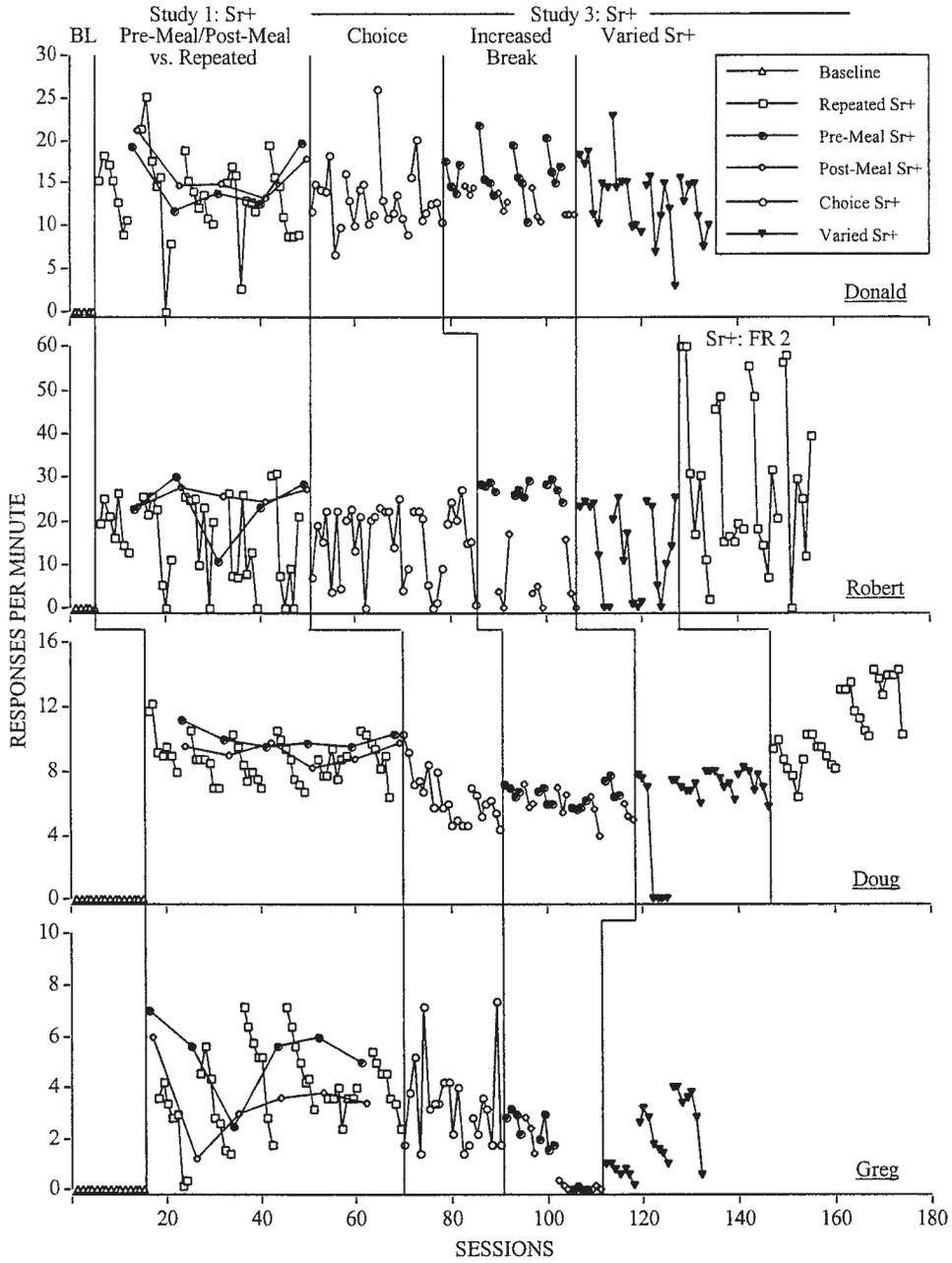


Figure 4. Number of responses per minute during Studies 1 and 3 for Donald, Robert, Doug, and Greg.

Procedure

Premeal repeated reinforcement. Seven successive repeated-reinforcement sessions were conducted as in Study 1. The first of these sessions occurred at the same time each morning,

a minimum of 90 min after the completion of breakfast and prior to each participant's lunch.

Postmeal repeated reinforcement. Seven successive repeated-reinforcement sessions were conducted, the first of which was conducted within

15 min of the completion of each participant's lunch.

Experimental Design

The combined effects of consumption of meals prior to sessions and edible reinforcers during sessions were compared to those of premeal access to specific reinforcers alone in a multielement design. Premeal repeated reinforcement (Condition A) and postmeal repeated reinforcement (Condition B) were conducted on alternate days to isolate the effects of meals on repeated-reinforcement sessions.

RESULTS

The right side of Figure 2 shows results of Study 2 for Lance and Jerry. Both participants' performance was very similar to that observed in Study 1 in that their response rates during repeated-reinforcement sessions conducted after lunch showed no systematic decrease relative to their performance during repeated-reinforcement sessions conducted before lunch. More specifically, their response rates during the last session of a given run were lower than those during the first on only 1 of 3 days (3rd day before lunch for Lance; 3rd day after lunch for Jerry). These results indicate that consumption of lunch, when combined with repeated access to specific edible reinforcers, had no deleterious effect on their performance.

STUDY 3

Participants from Study 1 who showed an AO effect due to repeated consumption of reinforcers (Mark, Mitch, Carter, Donald, Robert, Doug, and Greg) participated in this study, whose purpose was to evaluate several methods for mitigating AO effects. Four methods were evaluated: (a) allowing the participant to choose the edible reinforcer immediately prior to a session, (b) lengthening the amount of time between sessions, (c) varying the edible items used as reinforcers

within and across sessions, and (d) delivering edible items on an intermittent reinforcement schedule.

METHOD

Procedure

In all of the conditions described below, seven repeated-reinforcement sessions were conducted daily before lunch with 5-min breaks between sessions (as in Study 1), except as otherwise noted.

Choice of reinforcers. Prior to each session, the six most highly ranked items from the preference assessment were presented to the participant in a multiple-stimulus array (DeLeon & Iwata, 1996). The first item selected was used as the reinforcer during the subsequent session.

Increased break between sessions. The run of seven repeated-reinforcement sessions was interrupted such that four sessions occurred before lunch and the remaining three occurred after lunch. In addition, postmeal sessions were conducted after a minimum of 60 min had elapsed following the completion of lunch, and break periods between sessions were increased from 5 to 10 min.

Varied reinforcers across sessions (Carter only). The six most highly ranked items from the preference assessment were used as reinforcers during these sessions. Three pairs of preferred items were rotated across sessions (e.g., items ranked first and fourth were used as reinforcers during Sessions 1, 4, and 7; items ranked second and fifth were used as reinforcers during Sessions 2 and 5; and items ranked third and sixth were used as reinforcers during Sessions 3 and 6). Reinforcers were varied both within and across sessions: Edible items (from a pair) were alternated across reinforcer deliveries within a session, and pairs were alternated across sessions.

Varied reinforcers within sessions. All six of the most highly ranked edible items were delivered during each session and were rotated across reinforcer deliveries. Thus, reinforcers were varied within sessions during this condition.

Intermittent reinforcement. The most highly preferred edible item was used as a reinforcer during these sessions and was delivered according to an FR 2 schedule.

Experimental Design

The effects of four independent variables (choice of reinforcers, increased breaks between sessions, varied reinforcers, and intermittent reinforcement) were assessed using reversal designs. Response rates during the repeated-reinforcement conditions of Study 1 served as the baseline against which response rates during the conditions of Study 3 were compared. Effects of an independent variable, if observed, were replicated by conducting a reversal to repeated-reinforcement conditions (i.e., single reinforcer, no choice, and 5-min break between sessions), followed by another phase during which the independent variable was in effect.

RESULTS

The right side of Figure 3 shows results of Study 3 for Mark, Mitch, and Carter. When Mark and Mitch were given a choice among their six most highly ranked edible items prior to each session, some variability in responding was observed during these sessions for both participants, but response rates during the last session of the run were slightly lower than those observed during the first on only 1 of the 3 initial days for Mark and on 1 of the 4 initial days for Mitch. A brief reversal to the single-reinforcer, repeated-reinforcement sessions replicated the AO effects observed for both participants during Study 1, in that response rates during the last session of the run were lower than those observed during the first on all 3 days for Mark and on 3 of 4 days for Mitch. When pre-session choice of reinforcers was again introduced, response rates during the last session of the run were only slightly lower than those observed during the first on 2 of 5 days for Mark and on 1 of 5 days for Mitch. It should also be noted that Mark never selected his most highly ranked item during the first

session of any run; in fact, Mark never selected this item earlier than the fifth session. Similarly, Mitch never selected his most highly ranked item first. In addition, Mark's and Mitch's lowest responses occurred on sessions in which Skittles® and jellybeans, respectively, were used as reinforcers; this was possibly due to the additional time required to consume these items relative to the other less chewy items.

Carter participated in two types of varied-reinforcer conditions. When his six most highly ranked edible items were varied in pairs across sessions, his responding was extremely variable but was only slightly lower during the last session of the run than during the first on 1 of the 6 days during which the condition was initially introduced. In addition, his response rates during all sessions in this condition were much higher than those observed during any of the single-reinforcer repeated-reinforcement sessions conducted in Study 1. During the brief reversal to the single-reinforcer repeated-reinforcement sessions, Carter's overall response rates decreased, and responding during the last session of the run was lower than that observed during the first on all 4 days. When the across-session varied-reinforcement condition was reintroduced, overall response rates and response variability again increased. In examining his data, we noticed that lower response rates were always associated with pairings of items that included a chewy item (Twizzlers® or jellybeans), thus prompting a minor modification to the condition. When the varied-reinforcement condition was altered slightly to include the delivery of all reinforcers during all sessions, less variability in responding was observed, and response rates during the last session of the run were slightly lower than those observed during the first on 2 of 6 days. Again, overall response rates observed during this phase were higher than those observed during the single-reinforcer repeated-reinforcement sessions in Study 1.

The right side of Figure 4 shows results of Study 3 for Donald, Robert, Doug, and Greg.

All 4 participants were first given a choice among their six most highly ranked edible items prior to each session. Some variability in responding was observed during these sessions for all participants, but response rates during the last session of the run were lower than those during the first on 4 of 4 days for Donald, 4 of 5 days for Robert, 3 of 3 days for Doug, and 2 of 3 days for Greg. Next, the seven repeated-reinforcement sessions were spread out across the day. Response rates during the last session of the run (conducted after lunch) were lower than those during the first (conducted before lunch) on each day for all 4 participants. Next, all 4 participants were exposed to the varied-reinforcer condition. A general decreasing trend in responding was observed across sessions for all participants, and response rates during the last session of the run were lower than those during the first on 4 of 4 days for Donald, 2 of 3 days for Robert, 4 of 4 days for Doug, and 3 of 3 days for Greg. Finally, Robert and Doug were exposed to the intermittent reinforcement schedule (FR 2), during which response rates during the last session were lower than those during the first on all 4 days for both participants.

Collectively, the results shown in Figure 4 indicated that the pre-session choice of reinforcers, the increased break between reinforcement sessions, and the within-session varied delivery of reinforcers had no effect on mitigating the AO effects that Donald, Robert, Doug, and Greg showed during repeated-reinforcement sessions in Study 1. The intermittent schedule of reinforcement was similarly ineffective for Robert and Doug in mitigating the AO effect resulting from repeated consumption of a specific edible reinforcer across a series of reinforcement sessions.

GENERAL DISCUSSION

We evaluated the independent effects of reinforcer consumption across sessions and meal consumption prior to sessions on operant

performance in Study 1 by observing changes in response rates during repeated-reinforcement sessions, and by comparing response rates during sessions conducted prior to and following lunch. Response rates decreased across repeated-reinforcement sessions for 7 of 9 participants, suggesting a loss of reinforcer effectiveness due to repeated consumption of highly preferred edible items. Decreased response rates during postmeal reinforcement sessions relative to premeal sessions were observed for 3 of 9 participants, suggesting that, overall, meal consumption had less of a deleterious effect on performance than did repeated consumption of reinforcers.

The 2 participants whose performance was affected by neither the repeated-reinforcement sessions nor the premeal-postmeal comparison (Lance and Jerry) participated in Study 2, in which the combined effects of these variables were examined. Again, neither participant's performance showed an effect, in that response rates during premeal and postmeal repeated-reinforcement sessions were similar across all days. It is possible that AO effects may have been observed for Lance and Jerry (and perhaps more rapidly for the other 7 participants) if the experimental task had required greater response effort to complete, or if an alternative response (and reinforcer) were concurrently available. As an applied example, DeLeon, Fisher, Herman, and Crosland (2000) accurately predicted that an individual's aggressive responses would occur at higher rates than appropriate mands when rates of reinforcement for both responses were equal (i.e., mands were more effortful), but that appropriate mands would occur at higher rates when they were reinforced on a richer schedule than aggressive responses (i.e., aggressive responses were more effortful). Thus, given a more effortful (or concurrently available) target response in the current study, more consistent decreases in performance may have been observed.

In Study 3, we evaluated the effects of four manipulations in mitigating the AO effect

observed for 6 participants during the repeated-reinforcement condition: (a) pre-session choice from among six reinforcers, (b) increased break between sessions, (c) varied delivery of reinforcers, and (d) intermittent reinforcement. Only the pre-session choice and varied-reinforcer conditions showed any effect in mitigating response decrements, in that only 2 of 6 and 1 of 5 participants exposed to these conditions, respectively, showed maintenance in performance.

The current results extended previous research on motivating operations (Gottschalk et al., 2000; Roscoe, Iwata, & Rand, 2003; Vollmer & Iwata, 1991) by showing that the reinforcing effectiveness of edible items diminishes as a function of continued consumption. With only two exceptions (Lance and Jerry), participants' response rates decreased during repeated-reinforcement sessions. Results of Study 1 also partially replicated those reported by Zhou et al. (2002) in showing a postmeal AO effect for 3 of 9 participants. Moreover, our analysis of response rates during repeated-reinforcement sessions extended the results of the Zhou et al. study by suggesting that the number of reinforcers consumed may have a greater deleterious effect on performance than the consumption of a meal shortly before a reinforcement session. The data presented by Zhou et al. have practical implications by suggesting that more favorable outcomes during training sessions in which food is used as reinforcement may be achieved when sessions are conducted before regularly scheduled meals (or, alternatively, when a certain amount of time has passed since the previous meal). The current results extended those implications to include the possibility that more favorable performance outcomes may be achieved when few, rather than many, food-reinforcement sessions are conducted on a given day.

Although only two of the manipulations to the repeated-reinforcement condition in Study 3 showed any beneficial effect, this evaluation

provides a foundation for future researchers and practitioners who observe decrements in responding when edible items are used as reinforcers. Mark's performance was maintained during the condition in which he was presented a choice from among multiple preferred edible items prior to each session. This result was consistent with findings reported by Fisher et al. (1997) and DeLeon et al. (2001). Preference for specific foods may change frequently and may be particularly susceptible to an AO such as recent consumption. As suggested by DeLeon et al., allowing a participant to select the reinforcer prior to sessions may better accommodate these subtle changes than preference assessments that are done long before sessions are conducted. Although the exact behavioral mechanism responsible for this phenomenon is unknown, both Fisher et al. and DeLeon et al. suggested that reinforcer selection has the same effect as reinforcer variation. In Study 3, Mark's choices of reinforcers essentially created a varied-reinforcement condition in that, with the exception of three sessions across the 56 total sessions in the choice conditions, he selected a different reinforcer prior to each session. Similarly, Mitch selected the same reinforcer in succession on only four occasions across the 45 total sessions in the choice conditions. Whereas pre-session choice conditions were used in the current study in an effort to maintain responding, a similar avenue for future research might be to evaluate the effects of within-session choice on mitigating AO effects, because previous findings (Geckeler et al., 2000; Graff & Libby, 1999) suggest that such procedures might increase reinforcer variation and maintain performance. However, the overall influence of choice in the present study seems limited, in that it had no effect on mitigating performance decrements for 4 of 6 participants. Results for these participants were more consistent with the findings described by Smith et al. (1995) and Lerman et al. (1997), who observed that participant-selected reinforc-

ers produced no greater effects on responding than those selected by the experimenters.

Carter's results during the varied-reinforcement conditions were consistent with those described previously by Egel (1980, 1981), in that the varied delivery of reinforcers resulted in higher response rates relative to those observed during the single-reinforcer repeated-reinforcement condition. Considerable variability in responding was observed when Carter was exposed to the across-session varied-reinforcement condition, and his lower response rates among a run of sessions were associated with edible items that required more time to chew. In an attempt to reduce this variability, we delivered all reinforcers during all sessions in Carter's final varied-reinforcement condition. Because this manipulation produced comparable increases in response rates relative to the single-reinforcer repeated-reinforcement condition yet reduced the range of variability relative to the across-session varied-reinforcement condition, we used the within-session varied-reinforcement condition with subsequent participants.

Neither the increased break between sessions nor the intermittent reinforcement condition was effective in mitigating Donald's, Robert's, Doug's, or Greg's performance decrements. No previous research exists to specifically support the effectiveness of the increased-break manipulation, but logic and results described by Gottschalk et al. (2000) suggest that a period of deprivation from access to food reinforcement might yield favorable results. This would be akin to allowing a longer time to pass following meal consumption before initiating training sessions in which edible items are used as reinforcers. The break we selected (10 min) was arbitrarily determined, and it is possible that a longer yet still practical break (i.e., less than 48 hr, as described by Gottschalk et al.) may produce better results. The intermittent reinforcement schedule produced partially favorable results for Robert in that his response rates

during the initial sessions of a run were considerably higher than those observed during any previous condition, but these response rates decreased noticeably across sessions. Essentially, Robert appeared to engage in higher rates of switch pressing to contact rates of reinforcement similar to those of previous conditions, yet decreases in responding were still observed. Perhaps thinner schedules of intermittent reinforcement (e.g., FR 5, FR 10) may have been effective in attenuating AO effects while maintaining high rates of switch pressing, but these schedules were not evaluated in the current study. Future researchers may examine the effects of such intermittent schedules of reinforcement on mitigating decreases in responding across sessions.

Given the inconsistent effects observed with the various independent variables we examined in Study 3, a general implication of these findings is that food reinforcement may not maintain responding when many sessions are conducted on a daily basis. In addition, performance decrements related to the continued use of food as a reinforcer may be difficult to reverse. However, it has been demonstrated repeatedly that food is an effective reinforcer in establishing a wide range of adaptive skills and performances; thus, we are not advocating the discontinued use of edible items as reinforcers. In fact, it is not clear that the performance decrements observed in the current experiment were problematic. Consider, for example, Mark's performance during repeated-reinforcement sessions in Study 1: Even though his response rates during the last session of a run were as much as 23 responses per minute lower than those during the first (see the third and fifth repeated-reinforcement blocks of sessions in Study 1), he continued to respond at relatively steady rates (4.2 responses at the end of the third run and 18.6 at the end of the fifth). Further, response rates were observed to decrease to zero in only 7 of 48 repeated-reinforcement blocks of sessions for the 7 participants who demonstrated AO effects in

Study 1. Thus, although performance decrements were observed for 7 of 9 participants in the repeated-reinforcement condition, responding usually continued at low rates even after the consumption of a large number of edible reinforcers.

Still, one may want to consider alternative reinforcement strategies to facilitate more consistent progress during acquisition as well as long-term maintenance of performance. For example, Rincover and Newsom (1985) showed more efficient discrimination learning and longer maintenance of correct responding when sensory consequences were used as reinforcers relative to edible items. Other alternatives might involve the transfer of control from primary to conditioned reinforcers (such as praise) or the delivery of tokens contingent on responding during repeated training sessions, which can later be exchanged for edible reinforcers. Further research to evaluate the effectiveness of these and other strategies in mitigating AO effects is warranted.

Finally, it should be noted that we described decreases in participants' response rates following consumption of either edible reinforcers or meals as an AO effect (i.e., satiation). It is possible, however, that these response decrements might be viewed as the outcome of *habituation*, that is, a decrease in responsiveness simply as a function of repeated stimulus presentation (see Murphy, McSweeney, Smith, & McComas, 2003) rather than the consumption of food. Our study was not designed specifically to address this distinction, but two manipulations—changing the task or changing the reinforcer—would have been informative. Under either procedure, performance would be expected to increase if response decrements prior to the manipulations were due to habituation rather than satiation. Although the experimental task was held constant for all participants, decreases in responding were never observed for 2 participants (Lance and Jerry), and performance was recovered and maintained for 3 participants when choice of reinforcers

(Mark and Mitch) and varied reinforcers (Carter) were introduced as independent variables. Thus, results for 5 of 9 participants suggested that changes in performance could not be attributed to habituation to the experimental task. Further, performance was not recovered for 4 participants when reinforcers differed as a function of either participant choice or varied presentation of reinforcers. Thus, results for 4 of 7 participants suggest that it is unlikely that decreases in performance were due to habituation to the reinforcing stimulus. Given the limitations of the current experiment in addressing the satiation-habituation distinction, future researchers may consider evaluating these strategies in a more direct manner.

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