ASSESSING REINFORCERS UNDER PROGRESSIVE SCHEDULE REQUIREMENTS

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Recent research findings suggest that reinforcing stimuli may be differentially effective as response requirements increase. We extended this line of research by evaluating responding under increasing schedule requirements via progressive-ratio schedules and behavioral economic analyses. The differential effectiveness of preferred stimuli in treating destructive behavior maintained by automatic reinforcement also was examined. Results showed that one of two stimuli was associated with more responding under increasing schedule requirements for the 4 participants. Furthermore, stimuli associated with more responding under increasing schedule requirements generally were more effective in treating destructive behavior than stimuli associated with less responding. These data suggest that progressive-ratio schedules and behavioral economic analyses may be useful for developing a new technology for reinforcer identification. From a clinical perspective, these results suggest that two reinforcers may be similarly effective for low-effort tasks and differentially effective for high-effort tasks.

DESCRIPTORS: automatic reinforcement, behavioral economics, progressive-ratio schedules, reinforcer assessment

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A large body of literature has been established describing various techniques for identifying highly preferred and effective reinforcers for individuals with developmental disabilities (e.g., DeLeon & Iwata, 1996; Fisher et al., 1992; Roane, Vollmer, Ringdahl, & Marcus, 1998). After a stimulus has been identified as preferred from an array of potential items, an assessment typically is conducted to determine if the stimulus will increase and maintain a response. In most reinforcer assessments, preferred stimuli are presented for each occurrence of a behavior that is already in the participant's repertoire

(e.g., reaching, sitting in an area, pressing a microswitch). The use of simple operants that require little or no shaping and dense reinforcement schedules (e.g., a continuous schedule) may promote rapid identification of reinforcement effects by minimizing the potentially confounding effects of other variables (e.g., response difficulty, ratio strain; Fisher & Mazur, 1997; Piazza, Fisher, Hagopian, Bowman, & Toole, 1996).

Few studies have directly evaluated factors that may influence the outcome of reinforcer assessments. However, one factor that appears to affect reinforcer efficacy is the schedule requirement (DeLeon, Iwata, Goh, & Worsdell, 1997; Tustin, 1994). As mentioned above, responses typically are reinforced on a fixed-ratio (FR) 1 schedule during reinforcer assessments. Alternatively, reinforcement can be delivered on an intermittent schedule. For example, under an FR 20 schedule, reinforcement is delivered con-

tingent on 20 responses. In the Tustin study, individuals with developmental disabilities were exposed to various schedule requirements (e.g., FR 1, FR 2, FR 5, FR 10, FR 20) for button pressing. For 1 participant, one of two stimuli (i.e., attention or combined visual and auditory stimulation) was presented in a single-operant arrangement following one or more occurrences of the target response. Response rates were equivalent for the stimuli under low schedule requirements (i.e., FR 1). However, as schedule requirements increased, one stimulus maintained higher levels of responding than the other stimulus. Similar results were obtained using a concurrent-schedules arrangement with another participant. Thus, results indicated that relative preference and reinforcer potency changed as schedule requirements increased.

DeLeon et al. (1997) exposed 2 individuals with developmental disabilities to increasing schedule requirements under a concurrent-schedules arrangement. The concurrent responses (switch presses) produced qualitatively similar stimuli (food) contingent on the completion of a predetermined ratio requirement. Multiple sessions were conducted under each schedule requirement, which included FR 1, FR 2, FR 5, and FR 10. Under relatively dense schedules (FR 1, FR 2), participants distributed similar amounts of responding across the two response options (i.e., they showed equal preference for the stimuli). However, as schedule requirements increased (FR 5, FR 10), participants allocated more responding toward one of the options (i.e., they showed a preference for one of the stimuli). Thus, DeLeon et al. extended the findings of Tustin (1994) by demonstrating shifts in preference under increasing schedule requirements. Collectively, results of these two studies suggested that slight increases in schedule requirements may (a) magnify the relative preference for one stimulus over other available stimuli and

(b) alter the reinforcing efficacy of a given stimulus.

The relation between reinforcer effectiveness and schedule requirement has important implications for the clinical use of reinforcers. For example, schedule thinning is commonly incorporated into reinforcement-based programs for increasing adaptive behavior and decreasing maladaptive behavior in individuals with developmental disabilities. In these cases, reinforcers that will maintain treatment effects across increasing schedule requirements must be identified. Reinforcement effects obtained during typical reinforcer assessments may have limited generality to treatment efficacy when schedule thinning and other complex reinforcement arrangements are used (e.g., differential reinforcement of other behavior [DRO]; Fisher & Mazur, 1997).

Tustin (1994) and DeLeon et al. (1997) suggested that the efficacy of reinforcers under increasing schedule requirements should be assessed frequently as part of ongoing program development. However, the methodologies employed in these studies required repeated exposure to various schedule values across an extended time period (e.g., approximately 43 total sessions in the DeLeon et al. study). More practical methods for identifying reinforcers have been evaluated in recent studies (DeLeon & Iwata, 1996; Roane et al., 1998). This line of research should be extended to assessments of reinforcer effectiveness under varying schedule requirements.

Progressive-ratio (PR) reinforcement schedules, which have been used in basic research to evaluate reinforcement effects (e.g., Findley, 1958; Hodos, 1961), might eliminate the need for extended exposure to each schedule value. Under PR schedules, response requirements change from ratio to ratio within the course of a session. Schedule requirements typically increase arithmetically within a session until no responding occurs

for a prespecified time period. The last schedule requirement completed is referred to as the "breaking point." Relative reinforcement effects are identified by comparing the breaking points and corresponding number of responses associated with each reinforcer. For example, Hodos showed that the average breaking point exhibited by 4 rats under PR schedules was positively related to the concentration level of sweetened condensed milk. Basic studies on PR schedules suggest that they may be useful for rapidly identifying differential reinforcer efficacy under increasing schedule requirements (e.g., Baron, Mikorski, & Schlund, 1992; Hodos & Kalman, 1963).

Performance under different schedule parameters also may be evaluated from the perspective of behavioral economics. Briefly, behavioral economics examines operant behavior as an interaction between price (i.e., schedule requirements) and consumption (i.e., number of reinforcers obtained). In relation to this terminology, the demand for a particular reinforcer is indicated by the amount of responding a subject will emit to obtain it as its price increases. Thus, more potent reinforcers should be associated with relatively higher levels of responding and consumption across increasing price requirements than less potent reinforcers. Hursh (1984) and Tustin (1994) described several ways to analyze data within a behavioral economic framework. *Work-rate* functions may be used to assess changes in the rate of responding (work) across increasing schedule requirements (price), whereas *reinforcer-demand* functions may be used to assess changes in the rate of reinforcement (consumption) as schedule requirements (price) increase. It is hypothesized that work-rate functions will show that responding persists at a higher rate for more potent reinforcers than for less potent reinforcers as schedule requirements increase. Reinforcer-demand functions should depict higher rates of con-

sumption under increasing schedule requirements for more potent reinforcers. Finally, the slope of the line depicting consumption at each schedule value should be steeper for less potent reinforcers (i.e., reinforcer consumption should be less stable) than that for more potent reinforcers. Although these methods have been used infrequently in applied research, they would permit multiple evaluations of data generated from a rapid assessment of responding under PR schedules. Multiple analyses may be especially useful when a limited amount of data are available to identify functional relations (Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993).

In light of recent findings by Tustin (1994) and DeLeon et al. (1997), additional research is warranted on methods for identifying effective reinforcers under increasing schedule requirements, as well as on the utility of these methods for developing effective behavior programs. Procedures from the basic laboratory (i.e., PR schedules and behavioral economic analyses) may be helpful for developing an applied technology in this area (Mace & Wacker, 1994). Thus, the purpose of the current study was to extend previous findings by determining whether PR schedules and behavioral economic data analysis methods are useful for differentiating among preferred stimuli in a relatively brief manner. In Experiment 1, the reinforcing efficacy of preferred stimuli was compared under PR schedules. To evaluate the utility of this assessment, the effectiveness of these reinforcers when incorporated into various treatments for destructive behavior was compared in Experiment 2.

EXPERIMENT 1: REINFORCER ASSESSMENT
Method
Participants and Settings

Four individuals with developmental disabilities participated in Experiment 1. All

participants had been referred for the assessment and treatment of severe behavior problems. Bucky was an 18-year-old man who had been diagnosed with moderate mental retardation. He could follow routine requests and communicated through one-phrase utterances. Bucky's primary destructive behavior was self-injury. Sandie was a 13-year-old girl who had been diagnosed with Sanfillipo syndrome and severe mental retardation. She could follow some simple requests but had limited expressive language skills. Sandie's primary referral problems were pica and hand mouthing. Throughout the study, Sandie received a constant dosage of Risperdal. Joel was a 13-year-old boy who had been diagnosed with autism and severe mental retardation. Joel could follow some simple instructions and communicated primarily through idiosyncratic gestures. Joel had been referred for treatment of pica, elopement, disruption, and coprophagia. He received a constant dosage of Risperdal throughout the study. Sue was a 15-year-old girl who had been diagnosed with autism and severe mental retardation. Sue had limited receptive and expressive communication skills. Her primary destructive behaviors included self-injury, pica, and screaming. During the course of this investigation, Sue received constant dosages of Risperdal and Cogentin. Bucky attended a school for individuals with developmental disabilities. Sandie, Joel, and Sue were patients at a hospital unit specializing in the assessment and treatment of severe behavior disorders.

Sessions for Bucky were conducted in a small, unused room at his school. The room contained a table, two chairs, a small desk, and various materials that were unavailable during sessions. Sessions for Sandie, Joel, and Sue were conducted in fully padded rooms (3 m by 3 m) at the hospital. The rooms contained a table and two chairs.

Response Measurement and Reliability

Trained observers collected data on laptop computers. They were seated either in unobtrusive positions within the therapy room or behind one-way observation windows. During the stimulus preference assessment, observers collected data on the number of times each stimulus was selected by a participant (defined as the participant reaching for an item with either hand). Data were calculated by dividing the number of trials in which an item was selected by the total number of trials in which the item was presented. This number was multiplied by 100% to yield the percentage of trials in which each item was selected. Stimuli were then ranked from high to low preference based on these percentages.

During the reinforcer assessment, data were collected on the frequency of targeted responses (defined individually) and on reinforcer delivery. The target response for Bucky was pressing a button (1 cm by 1 cm). The target response for Sandie was moving an unconnected light switch from right to left or from left to right. The target response for Joel and Sue was touching a red piece of paper taped to a table (measuring 10 cm by 10 cm for Joel and 12 cm by 12 cm for Sue). Data were calculated by adding the number of responses emitted during each session to the total number emitted during previous sessions to yield the cumulative number of responses emitted during baseline and reinforcement conditions.

Interobserver agreement data were collected during 100% of all stimulus choice assessments and during 65.1% of the reinforcer assessment sessions. Exact agreement was calculated by comparing observer agreement on the exact number of occurrences or nonoccurrences of a response during each 10-s interval. The agreement coefficient was computed by dividing the number of exact agreements on the occurrence or nonoccur-

rence of behavior by the number of agreements plus disagreements and multiplying by 100%. Agreement averages for item selection during the stimulus preference assessment were as follows: Bucky, 100%; Sandie, 94% (range, 88% to 100%); Joel, 96.9% (range, 84% to 100%); and Sue, 96.9% (range, 84% to 100%). Exact agreement averages for the target response during the reinforcer assessment were as follows: Bucky, 92.9% (range, 84.8% to 98.2%); Sandie, 97.9% (range, 90.8% to 100%); Joel, 99.3% (range, 96.9% to 100%); and Sue, 96.9% (range, 84.8% to 100%).

Procedure

Preference assessment. A stimulus preference assessment was first conducted with each participant to identify an array of preferred stimuli (Fisher et al., 1992). Stimuli included in this assessment were based on caregiver report of preferred items or informal observations of the participants. The number of stimuli (e.g., musical toy, fire truck, and keyboard) included in each assessment was 16 for Bucky, 11 for Sandie, 12 for Joel, and 11 for Sue. Each stimulus was paired with every other stimulus twice, and stimulus pairs were presented in a random order. At the beginning of each presentation, the therapist held a pair of stimuli in front of the participant and prompted him or her to make a choice (e.g., saying, "Pick one of these"). Participants selected a stimulus by reaching toward the item, and they received access to the selected item for 20 s. After the 20-s interval elapsed, the stimulus was withdrawn, and two different stimuli were presented in the same manner. Simultaneous approaches toward the stimuli were blocked.

Two highly ranked stimuli that were chosen on a similar percentage of trials were used in the subsequent reinforcer assessment. The percentage of trials in which the stimuli were approached varied across participants (from 50% to 90%). Thus, the stimuli used in the reinforcer assessment may not have included the highest ranked stimuli from the array; however, the stimuli were among the top three in the preference assessment.

Reinforcer assessment. The reinforcing efficacy of the two similarly ranked items from the preference assessment was compared. The reinforcer assessment was conceptualized as a behavioral economic assessment because changes in response rate and reinforcer consumption were evaluated across increasing schedule requirements (price). During baseline, no contingencies were arranged for the emission of the target response (i.e., pressing a button or touching a card). During the reinforcement phase, the reinforcing effects of the stimuli were evaluated in a multielement design using a single-operant arrangement. Each stimulus was presented for 20 s contingent on the completion of a progressive number of responses. That is, a PR reinforcement schedule was implemented in which the number of responses required to obtain reinforcement increased following the completion of the previous requirement. Schedule requirements increased throughout the course of each session, and the same schedule was in effect for each stimulus. Ratio requirements for each participant increased across the session until no responses were emitted for 5 min (Tustin, 1994). Thus, session length and the number of reinforcers earned varied as a function of response persistence. Following the completion of each session, the schedule requirement was reset to the lowest value (i.e., PR Step Size 1) for the subsequent session. The order of sessions alternated across days, and two to four sessions were conducted daily. The assessment continued until clear separation or no separation in responding occurred for at least three sessions with each stimulus.

Schedule requirements were chosen for

each participant based on informal observations of their responding prior to and during baseline. For each participant, a schedule was developed that was hypothesized to progress rapidly enough to reveal a difference in relative response rates. However, to prevent rapid ratio strain, PR schedules for some participants included two exposures to each ratio requirement. The PR schedules for Sandie and Sue were identical and involved additive increases (i.e., one response was added to the requirement each time the schedule was increased) with two exposures to each requirement before the schedule progressed during the session. The schedule requirement for Joel also increased in an additive fashion, but each ratio requirement was presented just once per session. For Bucky, schedule requirements were approximately doubled at each requirement, and each ratio requirement was presented twice before the schedule increased. Both rapid (Bucky and Joel) and gradual (Sandie and Sue) schedule progressions were used to evaluate the reinforcer assessment methodology under various schedule arrangements. Specific schedule requirements for each participant are presented in Table 1.

Data Analysis

Results of the reinforcer assessment were analyzed in four ways for each participant. Recall that the more potent reinforcer was hypothesized to be associated with more responding (as indicated via work-rate functions), a higher breaking point, and more reinforcer consumption (as indicated via reinforcer-demand functions) across increasing schedule requirements. The primary dependent measure for the reinforcer assessment was the number of responses associated with the stimuli under increasing response requirements. Therefore, for the first data analysis method, the cumulative number of responses emitted across sessions was compared for each item. The average breaking

Table 1
Progressive-Ratio (PR) Schedule Requirements
During the Reinforcer Assessment

Partici-pant	Schedule requirement
Bucky	PR 1, PR 1, PR 2, PR 2, PR 5, PR 5, PR 10, PR 10, PR 20, PR 20
Sandie	PR 1, PR 1, PR 2, PR 2, PR 3, PR 3
Joel	PR 1, PR 2, PR 3, PR 4, PR 5, PR 6, PR 7, PR 8, PR 9, PR 10
Sue	PR 1, PR 1, PR 2, PR 2, PR 3, PR 3, PR 4, PR 4, PR 5, PR 5, PR 6, PR 6, PR 7, PR 7, PR 8, PR 8, PR 9, PR 9, PR 10, PR 10, PR 11, PR 11, PR 12, PR 12, PR 13, PR 13, PR 14, PR 14, PR 15, PR 15

point for each stimulus was identified by determining the final schedule requirement completed by the participant in each session, adding the breaking points, and dividing by the total number of sessions. For the third data analysis method, work-rate functions were analyzed to compare relative response rates across each schedule requirement. Work-rate functions were calculated by adding the total number of responses emitted for each ratio requirement (across sessions) to yield the total number of responses under each schedule. Finally, reinforcer-demand functions were analyzed to assess changes in reinforcer consumption as schedule requirements increased. Reinforcer-demand functions were calculated by adding the number of reinforcers earned at each ratio requirement (across sessions) to yield the total number of reinforcers earned under each schedule. These data analysis methods were employed to clarify the relationship between responding and schedule requirement because participants were exposed to rapidly increasing schedules during a limited number of sessions. In summary, these analyses revealed the total number of responses associated with each stimulus (cumulative responses), the final schedule requirement completed by the participant (average break-

ing point), the number of responses emitted at each schedule requirement (work-rate functions), and the number of reinforcers earned at each schedule requirement (reinforcer-demand functions).

<p style="text-align:center;">RESULTS AND DISCUSSION</p>

Preference Assessment

Figure 1 shows the outcome of each participant's stimulus preference assessment. All participants approached at least two items among the three highest ranked stimuli on an equal percentage of trials. The items identified for comparison in the reinforcer assessment were a microphone and musical toy (Bucky), a teether and musical toy (Sandie), a fire truck and a hand-pin toy (Joel), and a keyboard and radio (Sue).

Reinforcer Assessment

Figure 2 shows the results of the reinforcer assessment for Bucky. The upper panel shows the cumulative number of responses emitted for each item across sessions with the PR schedule. During baseline, decreasing levels of responding occurred. During reinforcement, more responding occurred when behavior produced access to the microphone than when behavior produced access to the musical toy. Recall that the highest ratio requirement completed under the PR schedule (i.e., the breaking point) has been used in previous studies to evaluate relative reinforcer value. The average breaking point for the microphone was PR Step Size 10 (range, PR Step Size 2 to PR Step Size 20), whereas the average breaking point for the musical toy was PR Step Size 5 (range, no responding to PR Step Size 10; average breaking points are not depicted in the figure). The middle panel shows the work-rate functions (i.e., average number of responses across ratio requirements). More responding (work) occurred for the microphone than for the musical toy across increasing schedule requirements. A similar number of responses were emitted

with either stimulus under the first three ratio requirements, whereas clear response differentiation occurred at the higher requirements (e.g., PR Step Size 10 and PR Step Size 20). This indicates that Bucky responded more across increasing schedule requirements when behavior produced access to the microphone. The bottom panel of Figure 2 shows the reinforcer-demand functions for Bucky (i.e., average number of reinforcers earned across ratio requirements). Across all schedule requirements, access to the microphone was earned more frequently than access to the musical toy. Collectively, these results suggest that the microphone was a more potent reinforcer than the musical toy under increasing schedule requirements.

The outcome of the reinforcer assessment for Sandie is shown in Figure 3. Both stimuli were associated with low cumulative numbers of responding and low breaking points. However, as shown in the upper panel, slightly more responding was associated with the teether than with the musical toy. The breaking points also differed slightly for the two stimuli: The average breaking point was PR Step Size 2 (range, no responding to PR Step Size 3) for the teether and PR Step Size 1 (range, no responding to PR Step Size 2) for the musical toy. The middle panel shows the work-rate functions for Sandie. Across the three schedule requirements, more responding was associated with the teether relative to the musical toy. As shown in the bottom panel, Sandie also earned access to the teether more frequently than access to the musical toy. These results suggest that neither stimulus was a highly potent reinforcer under the PR schedules but that the teether was more effective than the musical toy.

Figure 4 shows the results for Joel. Across sessions with the PR schedules, more responding was associated with the hand-pin toy than with the fire truck (see upper panel). The average breaking point also was
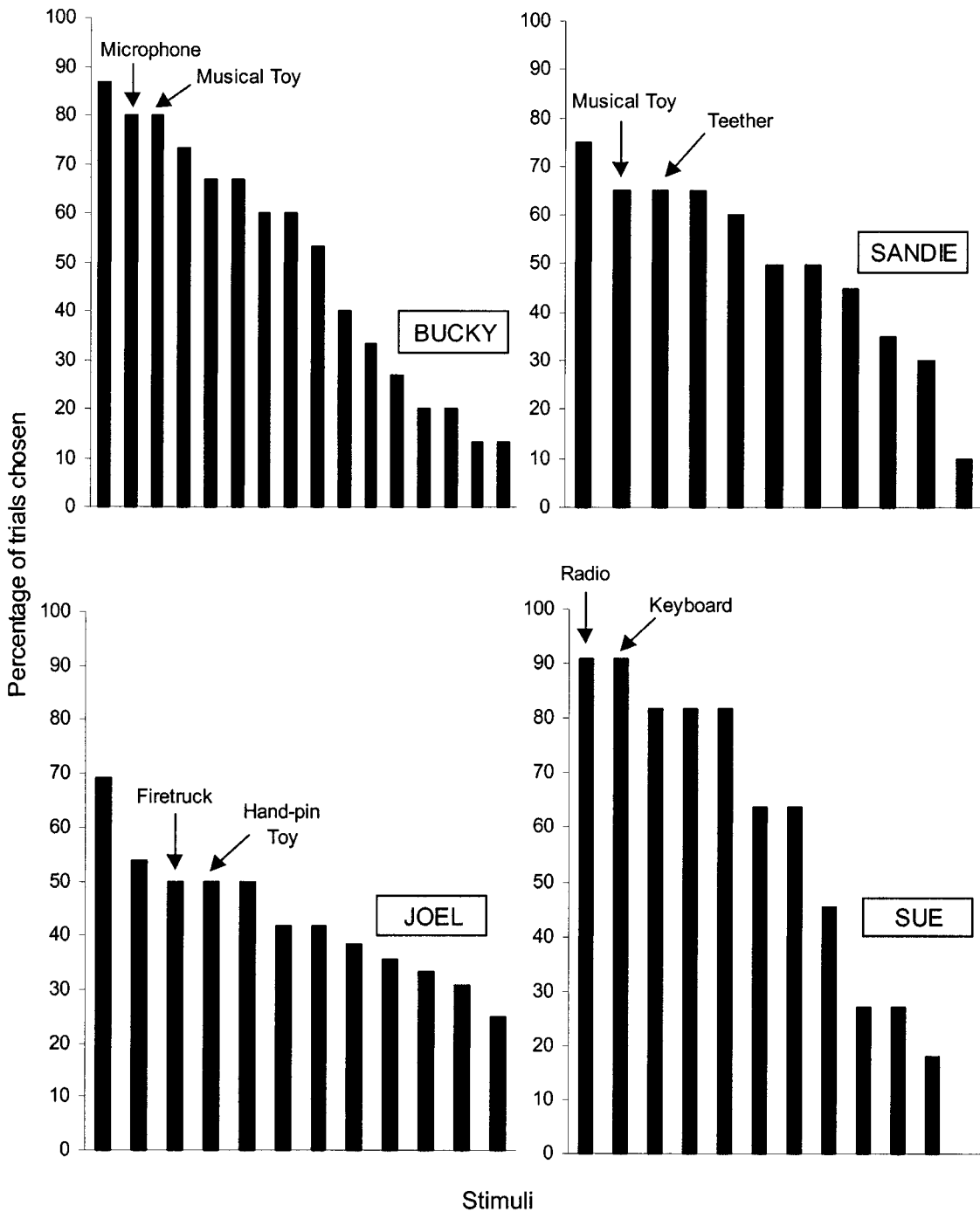
Figure 1.   Percentage of trials in which items were selected during the stimulus preference assessment.

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Figure 2.   Cumulative number of responses across sessions of the reinforcer assessment (upper panel) and outcomes of the work-rate function (middle panel) and reinforcer-demand function (bottom panel) analyses for Bucky. The discontinuation of the data path for the musical toy is indicative of the fact that Bucky never responded (middle panel) or obtained reinforcement (bottom panel) at the higher schedule requirements.
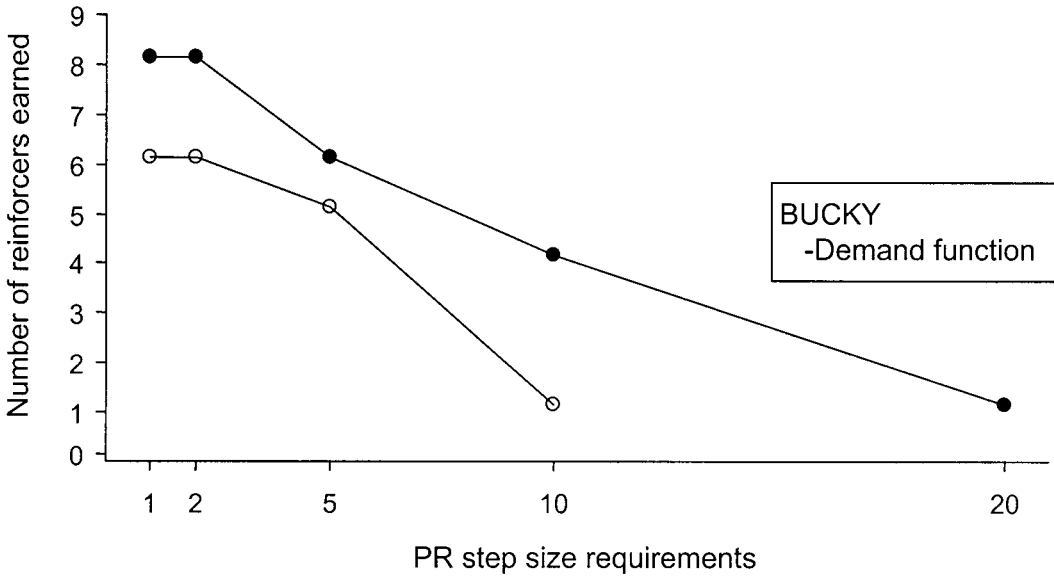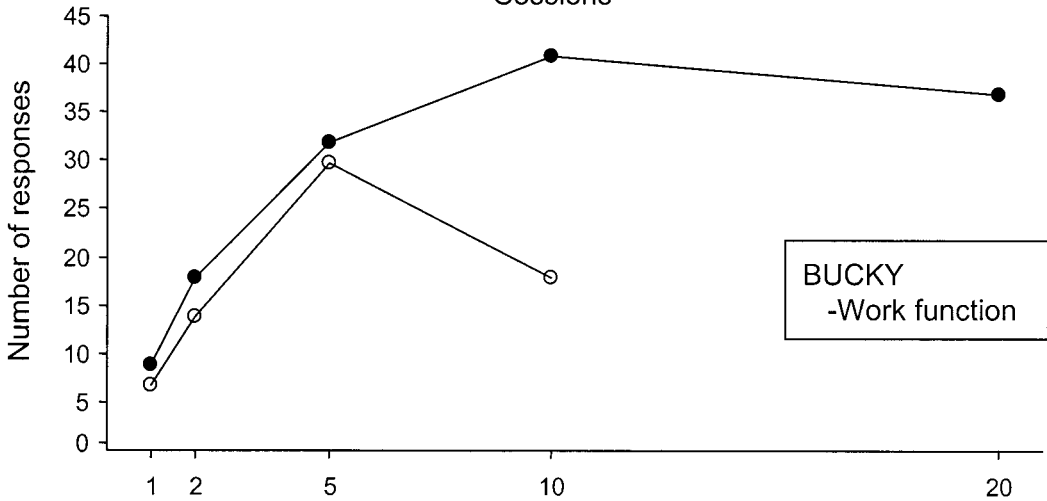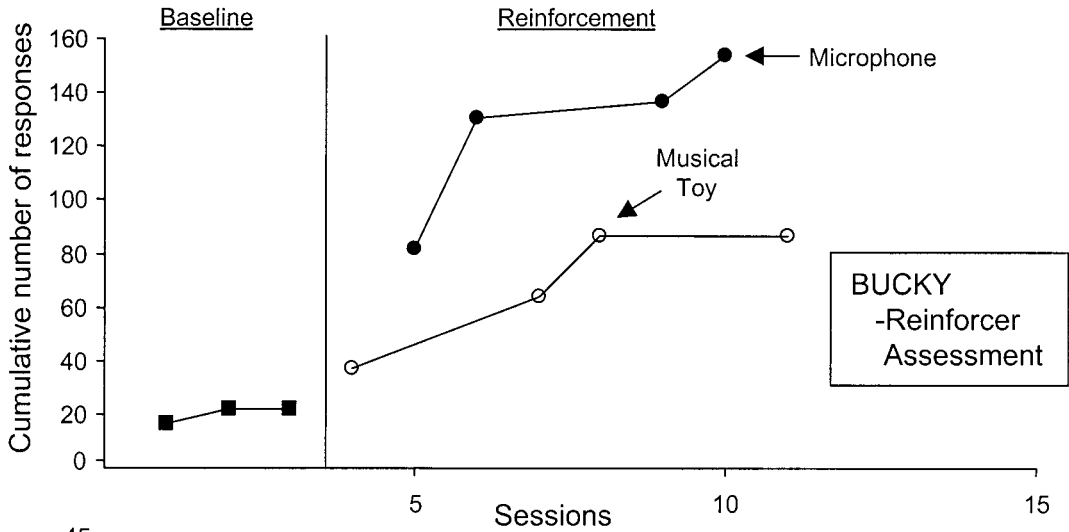
higher for the hand-pin toy (PR Step Size 8; range, PR Step Size 7 to PR Step Size 8) than for the fire truck (PR Step Size 3; range, PR Step Size 1 to PR Step Size 3). The work-rate graph indicates that, across increasing ratio requirements, a higher number of responses was associated with the hand-pin toy than with the fire truck. The reinforcer-demand function shows that the hand-pin toy and fire truck were equally consumed at PR Step Size 1. However, as ratio requirements increased, consumption of the hand-pin toy persisted while consumption of the fire truck decreased. Thus, although both stimuli appeared to be equally potent reinforcers at low schedule requirements, the hand-pin toy was more effective than the fire truck under increasing schedule requirements.

Figure 5 shows the outcome of Sue's reinforcer assessment. The radio produced a much higher cumulative number of responses than the keyboard under the PR schedule (see upper panel). Large differences also were obtained in the average breaking points for the two stimuli (i.e., PR Step Size 12; range, PR Step Size 7 to PR Step Size 15, for the radio and PR Step Size 4; range, no responding to PR Step Size 11, for the keyboard). The work-rate function indicates that more responding was associated with the radio than with the keyboard across all ratio requirements. (Due to technical problems with the data-collection apparatus, Sue's work-rate data for the radio are slightly inflated beyond the number of responses that were dictated by the schedule requirement.) Furthermore, the reinforcer-demand function indicates that Sue earned access to the radio more frequently than access to the key-

board across all ratio requirements. Together, results of Sue's reinforcer assessment indicated that the radio was a more effective reinforcer than the keyboard across increasing schedule requirements.

In summary, one stimulus was associated with greater response persistence under increasing schedule requirements for all participants, an outcome that was consistent with previous findings (DeLeon et al., 1997; Tustin, 1994). These results suggested that stimuli selected on the same percentage of trials during a commonly used preference assessment (Fisher et al., 1992) had different reinforcement values as the requirements for responding increased rapidly across the session. The relative potency of these reinforcers under increasing ratio requirements was shown in the cumulative, work-rate, and reinforcer-demand analyses, as well as in the average breaking point associated with the stimuli. Results also suggest that PR schedules allow a relatively expeditious examination of shifts in reinforcer preference or value under increasing schedule requirements. The assessment was completed in an average of eight sessions for each participant, and each session lasted an average of 13.6 min.

EXPERIMENT 2: TREATMENT ANALYSIS

The identification of potent reinforcers for use in differential and noncontingent reinforcement procedures is important for treating destructive behavior, especially behavior that is maintained by automatic reinforcement (e.g., Piazza, Fisher, Hanley, Hilker, & Derby, 1996; Vollmer, Marcus, & LeBlanc, 1994). In these cases, reinforce-

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Figure 3.   Cumulative number of responses across sessions of the reinforcer assessment (upper panel) and outcomes of the work-rate function (middle panel) and reinforcer-demand function (bottom panel) analyses for Sandie. The discontinuation of the data path for the musical toy is indicative of the fact that Sandie never responded (middle panel) or obtained reinforcement (bottom panel) at the higher schedule requirements.
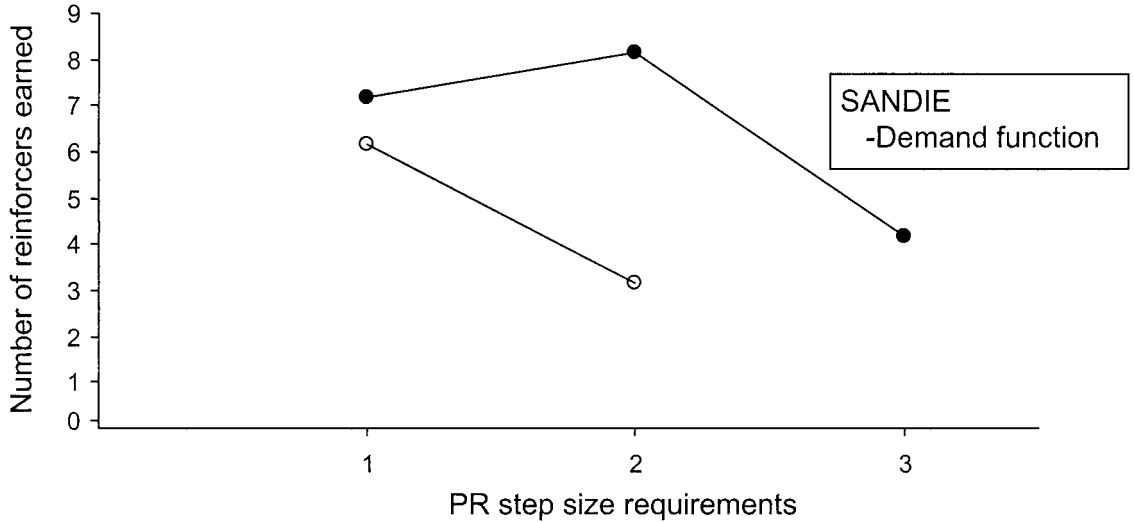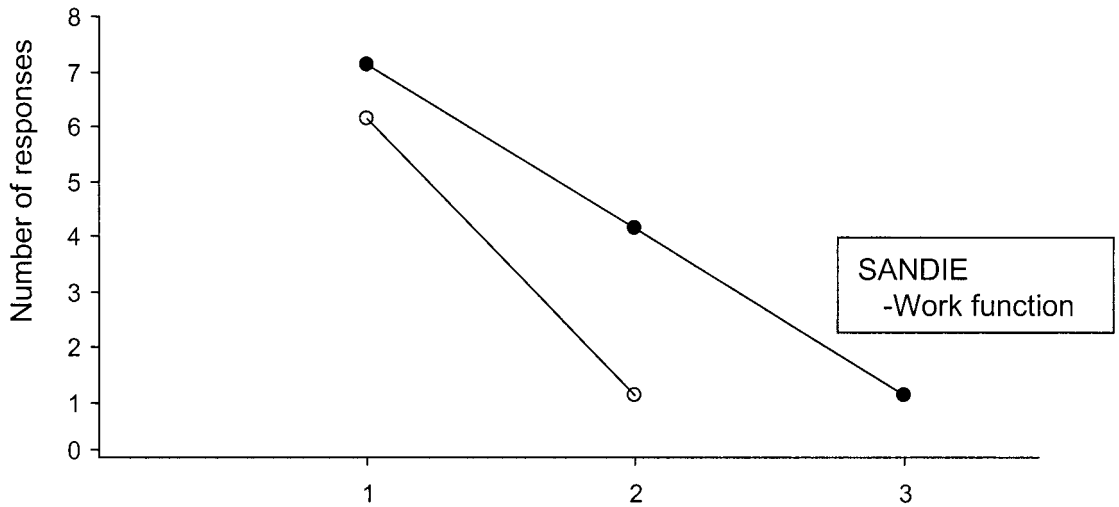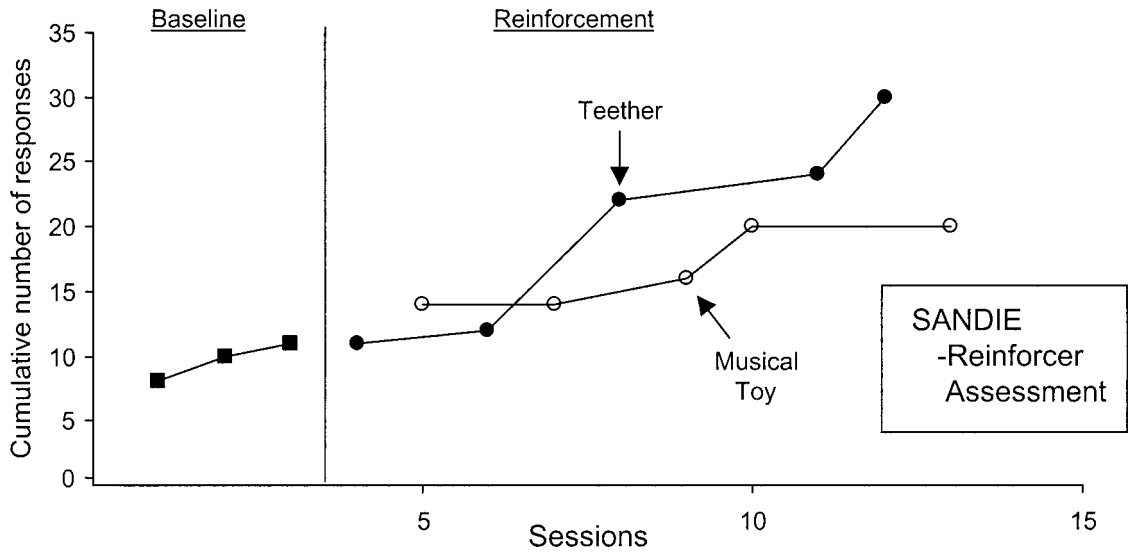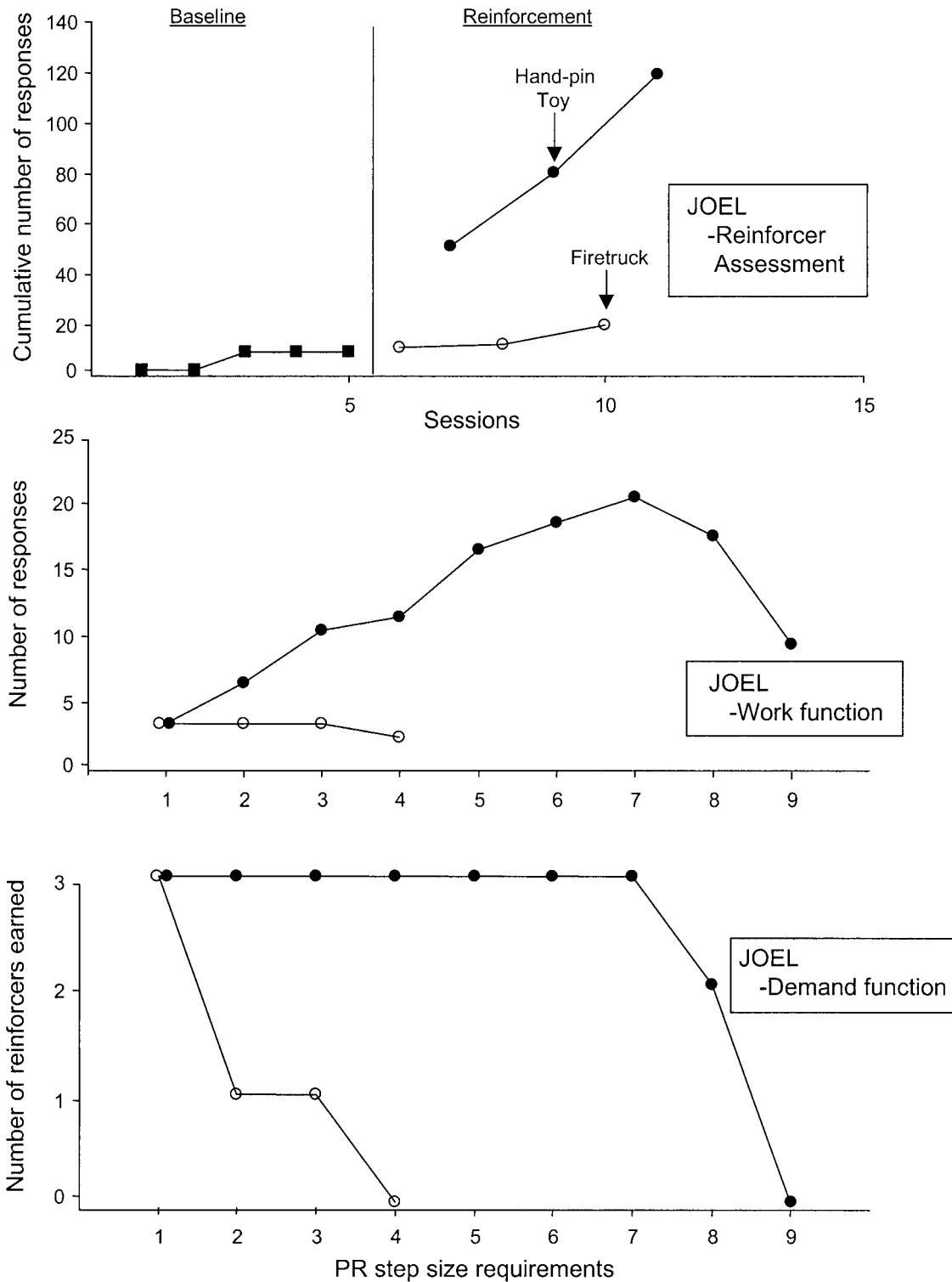
Figure 4. Cumulative number of responses across sessions of the reinforcer assessment (upper panel) and outcomes of the work-rate function (middle panel) and reinforcer-demand function (bottom panel) analyses for Joel. The discontinuation of the data path for the fire truck is indicative of the fact that Joel never responded (middle panel) or obtained reinforcement (bottom panel) at the higher schedule requirements.

ment-based treatments typically involve the contingent or noncontingent availability of stimuli that compete with the reinforcer that maintains destructive behavior. It is possible that the differential effects of the stimuli obtained in Experiment 1 would predict the differential effectiveness of these stimuli as reinforcers in treatment programs for destructive behavior maintained by automatic reinforcement. Thus, the correspondence between responding under PR schedules and levels of destructive behavior under various reinforcement-based treatments was examined in Experiment 2 to evaluate the utility of the reinforcer assessment.

<div align="center">METHOD</div>

Participants and Settings

Three of the individuals from Experiment 1 (Bucky, Sandie, and Sue) participated in Experiment 2. During the course of his hospital admission, Joel displayed no occurrences of destructive behavior; thus, he was not included in Experiment 2. Of the destructive responses displayed by the participants, one behavior was chosen for treatment in this experiment (other destructive responses were treated through additional methods). Specifically, all participants engaged in at least one topography of destructive behavior that was maintained by automatic reinforcement (see below). Sessions for the functional analyses and treatment analyses were conducted in the same rooms as in Experiment 1.

Response Measurement and Reliability

Hand scratching (Bucky) was defined as scraping the fingernails across the hand in a forward or backward motion and rubbing the hand on a hard or rough surface (e.g., clothing, a desk). *Hand mouthing* (Sandie) was defined as insertion of the fingers (i.e., the first knuckle) past the plane of the lips. *Screaming* (Sue) was defined as a brief (e.g., 1 s to 2 s) vocalization above conversational level. An alternative response also was iden-

tified for each participant as part of treatment with differential reinforcement of alternative behavior (DRA). The alternative responses were stuffing a piece of paper into an envelope (Bucky) and placing a plastic block in a bucket (Sandie and Sue).

During the functional analyses and treatment analyses, observers collected data on the frequency of destructive behavior and alternative responses. The resulting frequencies were divided by the session length to yield the rate of responding (in minutes). Exact agreement was calculated using the same procedures described in Experiment 1. Agreement was assessed during 66% of the functional analysis sessions and during 64% of the treatment sessions. Exact agreement for destructive behavior during the functional analysis averaged 98.0% (range, 81.7% to 100%) for Bucky, 94.8% (range, 81.2% to 100%) for Sandie, and 98.6% (range, 95.6% to 100%) for Sue. Agreement averages for destructive behavior during the treatment analyses were as follows: Bucky, 95.7% (range, 48.0% to 100%); Sandie, 95.8% (range, 84.9% to 100%); and Sue, 99.3% (range, 94.9% to 100%). Interobserver agreement averages for alternative behavior during DRA were as follows: Bucky, 95.9% (range, 86.7% to 100%); Sandie, 96.2% (range, 75.2% to 100%); and Sue, 97.8% (range, 91.7% to 100%).

Procedure

A multielement functional analysis similar to that described by Iwata, Dorsey, Slifer, Bauman, and Richman (1982/1994) was conducted to identify the variable that maintained each participant's destructive behavior. The functional analysis consisted of three test conditions (alone, attention, demand) plus a control condition (toy play). Following completion of the functional analysis, reinforcement-based treatments were implemented for each participant.

Three treatments were evaluated for each

participant. The baseline condition for each treatment was identical to the alone condition of the functional analysis. During noncontingent reinforcement (NCR), the participant was observed alone in the session room while he or she had continuous access to one of the two reinforcers assessed in Experiment 1. During DRO, a therapist was present in the room with the participant but did not interact with the participant. Reinforcement (20-s access to one of the two reinforcers) was delivered if the participant did not engage in the problem behavior for a prespecified interval (i.e., the DRO interval). If destructive behavior occurred during the DRO interval, the interval was reset. The DRO interval for each participant was based on the mean interresponse time for destructive behavior during baseline. During DRA, the participant received access to one of the two reinforcers for 20 s contingent on the emission of an alternative response. Across all treatments, no programmed consequences were arranged for destructive behavior. With one exception, treatments with the two stimuli were compared in a multielement design (Bucky's DRO was evaluated in a reversal design). Four to ten sessions were conducted daily, and all sessions lasted 10 min. All treatments continued until a clear response pattern emerged (i.e., a 50% or greater reduction in destructive behavior relative to baseline for three consecutive sessions, or less than a 50% reduction in destructive behavior after sufficient exposure to the procedure). These three interventions were selected because they are commonly used to treat behavior maintained by automatic reinforcement (Piazza, Fisher, Hanley, Hilker, & Derby, 1996; Vollmer et al., 1994), and because

they involve different response requirements (i.e., no requirement other than stimulus interaction [NCR], the occurrence of an alternative response [DRA], and the omission of destructive behavior [DRO]).

RESULTS AND DISCUSSION

Figure 6 shows the outcomes of the functional analyses. High rates of responding occurred in the alone condition (Bucky) or across all test conditions (Sandie and Sue). (Functional analysis results for Bucky are reproduced from Roane, Lerman, Kelley, & Van Camp, 1999.) For Sandie and Sue, a series of extended alone sessions were conducted to determine whether destructive behavior would persist in the absence of social consequences (Vollmer, Marcus, Ringdahl, & Roane, 1995). Results of these analyses indicated that all participants' destructive behavior was maintained by automatic reinforcement.

Table 2 presents a summary of treatment outcomes when the low- versus high-preference stimuli were used in the three reinforcement-based interventions for each participant. The high-preference stimuli were those associated with more responding in the reinforcer assessment from Experiment 1 (i.e., the microphone for Bucky, the teether for Sandie, and the radio for Sue). The low-preference stimuli were those associated with less responding in the reinforcer assessment (i.e., the musical toys for Bucky and Sandie and the keyboard for Sue).

Three general findings were obtained across the comparison of low- and high-preference stimuli during the treatment evaluations. First, the two stimuli were differentially effective in treating problem behavior,

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Figure 5. Cumulative number of responses across sessions of the reinforcer assessment (upper panel) and outcomes of the work-rate function (middle panel) and reinforcer-demand function (bottom panel) analyses for Sue. The discontinuation of the data path for the keyboard is indicative of the fact that Sue never responded (middle panel) or obtained reinforcement (bottom panel) at the higher schedule requirements.
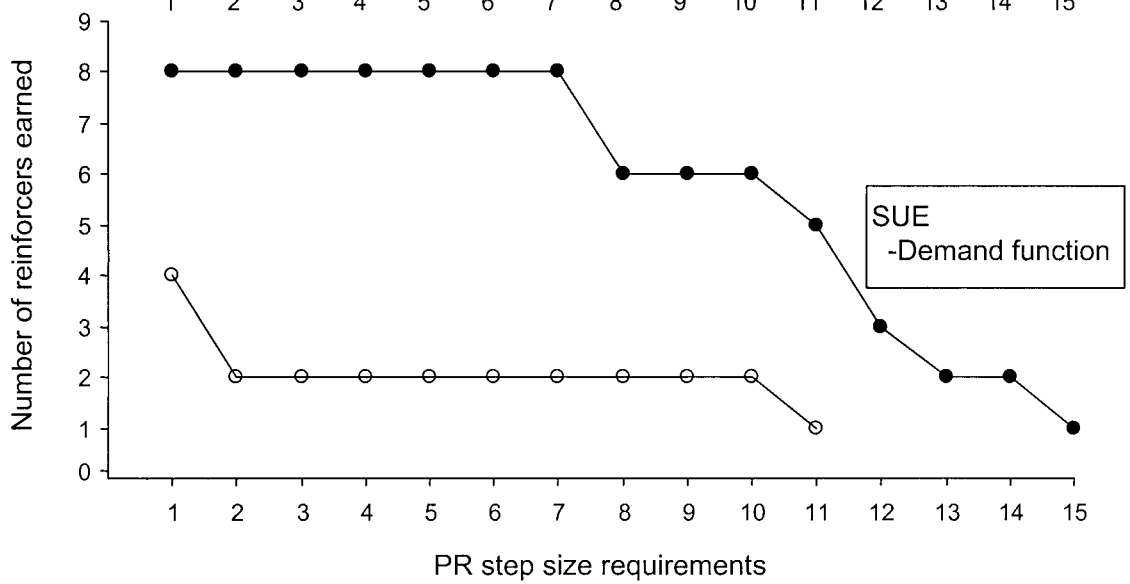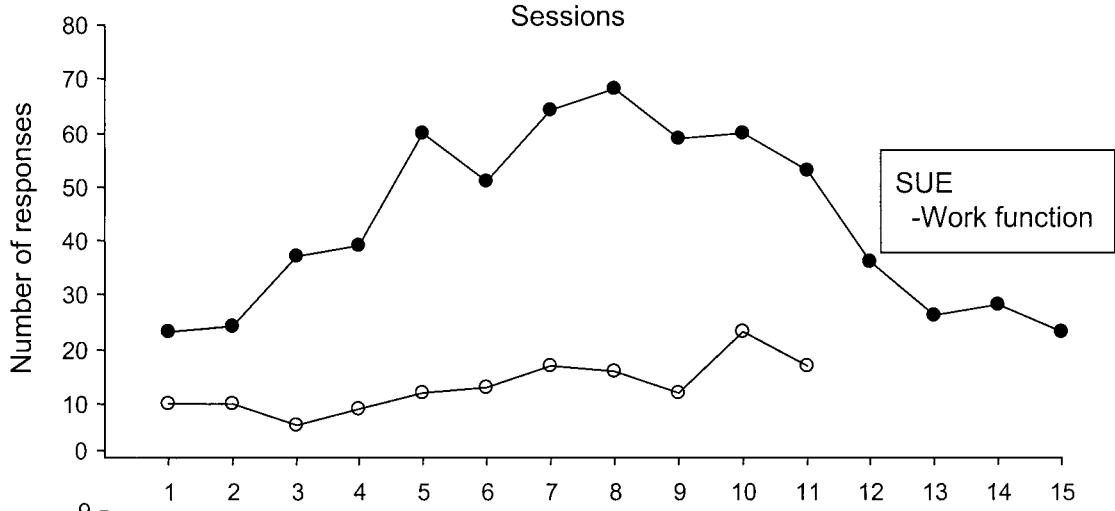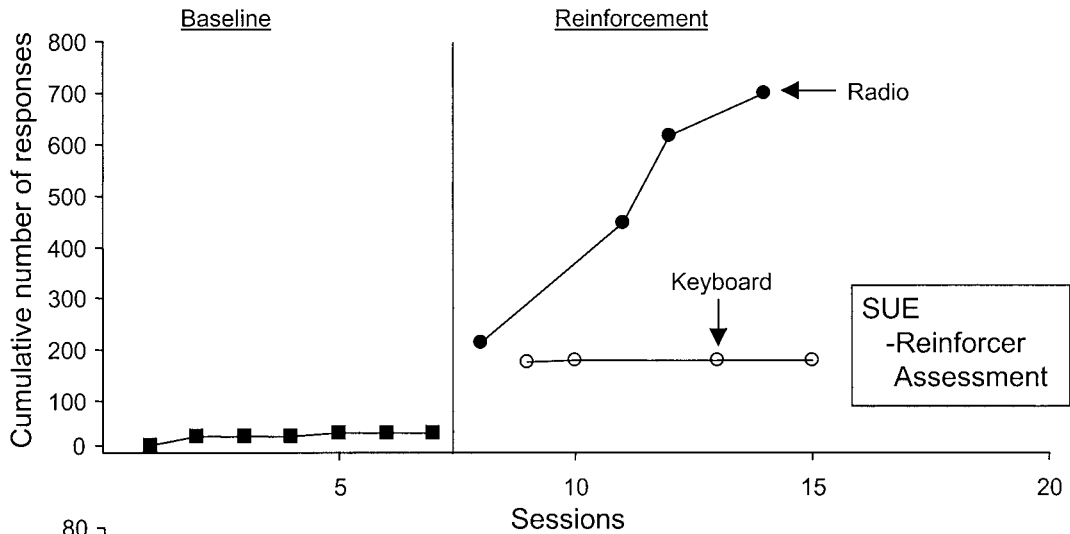
Figure 6.   Number of responses per minute of destructive behavior across sessions of the functional analyses.

Table 2
Summary of Treatment Effectiveness

	NCR		DRO		DRA	
Participant	High pref.	Low pref.	High pref.	Low pref.	High pref.	Low pref.
Bucky	−85.7%	+35.7%	−66.7%	−62.1%	−91.3%	−34.8%
Sandie	−78.9%	−26.3%	+29.2%	+37.5%	0%	+12.5%
Sue	−85.7%	−71.4%	0%	−37.5%	+100%	+200%

Note. A minus sign indicates reduction in destructive behavior; a plus sign indicates increase in destructive behavior.

with at least one stimulus producing a 50% or greater reduction in destructive behavior (relative to baseline). This pattern was observed in three of the nine (33%) treatment comparisons (NCR with the high-preference stimulus for Bucky and Sandie and DRA with the high-preference stimulus for Bucky). The second finding was that both stimuli were associated with a 50% or greater decrease in destructive behavior. This outcome was obtained in two of nine (22%) treatment comparisons (NCR for Sue and DRO for Bucky). For the third general finding, no treatment effects were obtained with either stimulus. That is, destructive behavior decreased by less than 50%, did not change, or increased relative to baseline. This outcome occurred in four of the nine (44%) treatment comparisons (DRO and DRA for Sandie and Sue).

Data on problem behavior representing each of these three treatment outcomes are depicted in Figure 7. An example of the first outcome (i.e., differential effectiveness of the high- vs. low-preference stimuli) is shown in the upper panel, which displays the NCR evaluation for Sandie. Moderate rates of hand mouthing were observed in the initial baseline ($M = 1.9$ responses per minute). When continuous access to alternative stimuli was provided, an immediate and sustained reduction in hand mouthing was observed with the teether ($M = 0.4$ responses per minute). By contrast, only small reductions in hand mouthing were observed when

the musical toy was presented continuously ($M = 1.4$ responses per minute).

The middle panel shows the outcome of Bucky's DRO evaluation, which illustrates the second general finding (i.e., 50% or better reduction in destructive behavior with both stimuli). During the first baseline phase, high rates of hand scratching were observed ($M = 3.9$ responses per minute). The first item introduced into treatment (the microphone) produced a modest decrease in hand scratching ($M = 1.3$ responses per minute). A reversal to baseline showed a reemergence of hand scratching with rates somewhat lower than those of the initial baseline ($M = 2.9$ responses per minute). Upon introduction of treatment with the second item (i.e., the musical toy), a modest reduction in hand scratching was again observed ($M = 1.1$ responses per minute). Results of Bucky's DRO analysis revealed that neither item produced substantial decreases in behavior; however, the high-preference stimulus produced a slightly greater reduction in destructive behavior (66.7%) than the low-preference stimulus (62.1%).

The lower panel, which displays the results of Sue's DRA, provides an example of the third outcome (i.e., no clear reduction in destructive behavior was observed with either stimulus). Low, variable rates of screaming occurred in baseline ($M = 0.1$ responses per minute). When DRA was implemented, levels of screaming with both the high-preference stimulus (radio; $M = 0.2$ responses
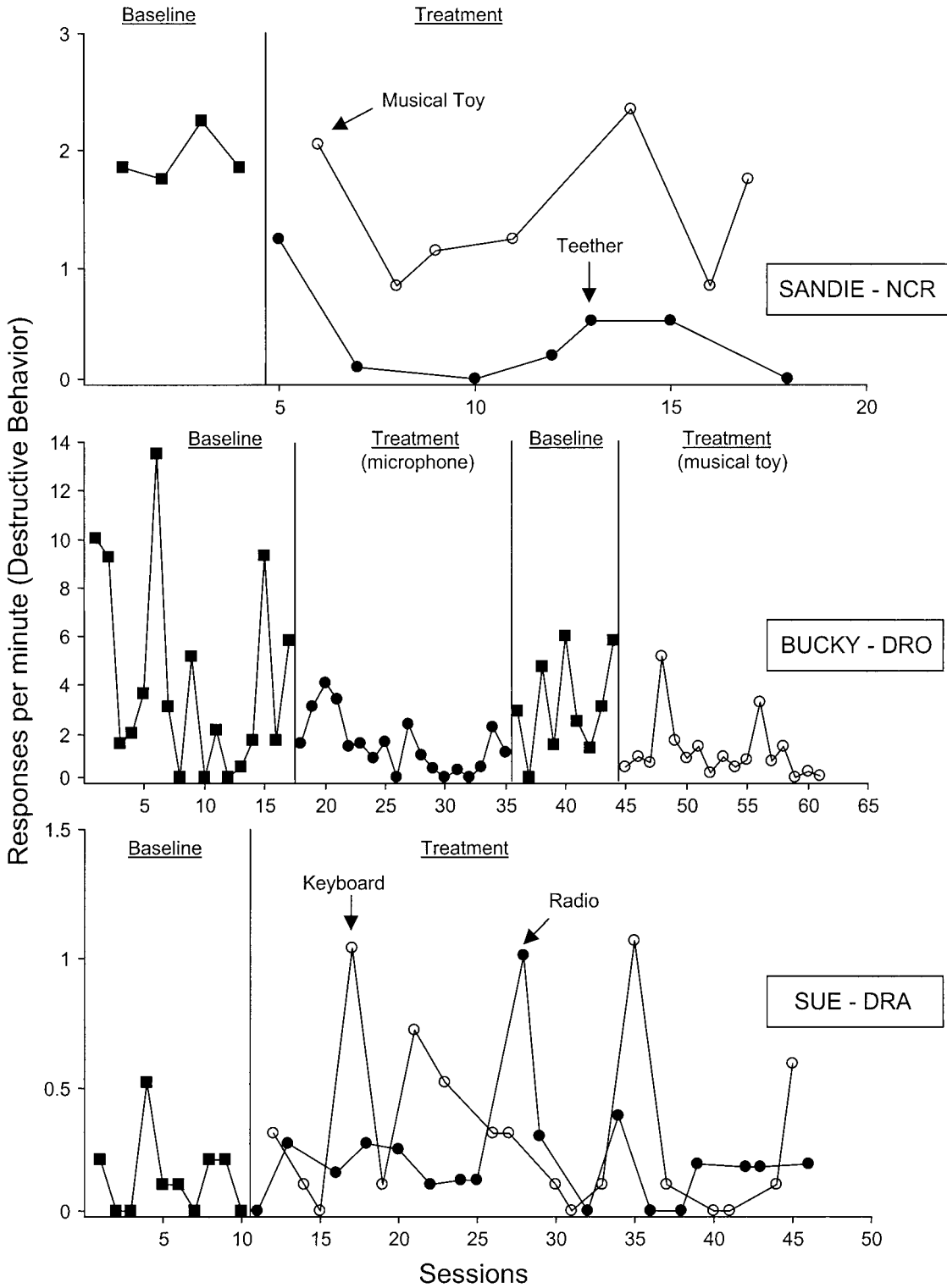
Figure 7.   Number of responses per minute of destructive behavior during the NCR evaluation for Sandie (upper panel), the DRO evaluation for Bucky (middle panel), and the DRA evaluation for Sue (bottom panel).

per minute) and the low-preference stimulus (keyboard; $M = 0.3$ responses per minute) were similar to those observed during baseline.

Regardless of the outcome for destructive behavior during DRA, rates of alternative behavior were higher with the high-preference stimulus than with the low-preference stimulus for 2 participants (Bucky and Sue). For Bucky, rates of the alternative response averaged 3.3 responses per minute (range, 1.7 to 4.7) with the microphone (high-preference stimulus) and 0.5 responses per minute (range, 0 to 1.6) with the musical toy (low-preference stimulus). For Sue, rates of alternative behavior averaged 9.8 responses per minute (range, 1.8 to 14.6) with the radio (high-preference stimulus) and 0.8 responses per minute (range, 0 to 3.8) with the keyboard (low-preference stimulus). Similar rates of alternative behavior were observed for Sandie across both stimuli (1.3 responses per minute for teether and 1.0 responses per minute for musical toy).

Collectively, results of the treatment analyses showed that a substantial proportion (44%) of the treatment conditions were ineffective in reducing destructive behavior. However, when a given treatment was effective, the stimulus identified as more preferred in the reinforcer assessment typically was more effective in reducing destructive behavior than the less preferred stimulus. Furthermore, although in some cases the two stimuli were either similarly effective (e.g., Bucky's DRO) or ineffective (e.g., Sandie's DRA), the low-preference stimulus was associated with less problem behavior than the high-preference stimulus in only one case (Sue's DRO). However, in this case, neither stimulus produced an acceptable level of change.

These data illustrate the importance of considering variations in stimulus preferences when developing reinforcement-based treatments for destructive behavior. Typical preference and reinforcer assessments do not account for possible changes in the relative effectiveness of these stimuli when they are used to alter more socially significant responses (e.g., destructive behavior maintained by automatic reinforcement; Fisher & Mazur, 1997). Results suggested that the reinforcer assessment conducted in Experiment 1 might be useful for further evaluating potential reinforcing stimuli when developing treatments.

GENERAL DISCUSSION

Results of previous studies indicated that reinforcement schedules can alter the relationship between responding and reinforcement, limiting the generality of data obtained from typical reinforcer assessments (e.g., DeLeon et al., 1997; Tustin, 1994). Results of Experiment 1 were consistent with this finding and suggested that PR schedules and behavioral economic data analysis methods may be useful for identifying this relationship in a relatively brief amount of time. Moreover, results of Experiment 2 indicated that the high-preference stimuli identified via this assessment were more likely to reduce problem behavior or increase adaptive behavior than stimuli identified as less preferred. This finding was obtained across several reinforcement-based treatments with different response requirements (i.e., from relatively low requirements [NCR] to more stringent requirements [DRO, DRA]). Thus, the current study extends previous research on reinforcer identification by providing a method for evaluating stimuli under increasing schedule requirements within the course of a single session and by evaluating the differential effectiveness of these preferred stimuli during treatment.

This study exemplifies the integration of basic and applied methods to solve clinical problems, a strategy that has been recom-

mended by many authors (e.g., Mace & Wacker, 1994). Forging stronger connections between basic and applied work may promote the development of applied technologies and reveal new basic relations through extension to application (Mace, 1994). The first potential benefit was a primary goal of the current study (i.e., to develop a new reinforcer assessment). Nevertheless, the validity and utility of this method should be investigated in further studies by comparing the outcome obtained from a rapid assessment with PR schedules to that obtained from a more extended assessment similar to that described by Tustin (1994) or DeLeon et al. (1997).

Results of the current study suggest that two stimuli may be similarly effective for low-effort tasks (or low schedule requirements), but may be differentially effective for high-effort tasks (or high schedule requirements). As noted by Fisher and Mazur (1997), stimuli that function as reinforcers under increasing schedule requirements may function as more effective reinforcers for higher effort tasks (e.g., self-help skills) than stimuli that do not function as reinforcers under increasing schedule requirements. Practitioners should therefore consider arranging reinforcer presentation according to task difficulty based on the relation between reinforcer effectiveness and response requirements. The assessment presented in the current study provides a method for identifying such a relation. For example, future research could use PR schedules to evaluate the effectiveness of stimuli as reinforcers for more typical work-related activities.

Although the use of PR schedules may require less time than other assessments (e.g., DeLeon et al., 1997), PR schedules may be impractical to arrange in some clinical situations. Therefore, future research should evaluate methods that are more efficient than the procedures used in the current investigation. Alternative assessments could

present progressive probe schedules (e.g., exposure to wide-ranging schedule requirements prior to the reinforcer assessment) or could develop specific criteria for the initial development of the PR schedule requirements. As a result, fewer PR schedules could be assessed, which may lead to a more rapid thinning of schedule requirements (relative to the reinforcer assessment presented in the current study) or to the elimination of schedule requirements that do not assist in the differentiation of stimuli.

The findings also are limited in several other respects. First, the reinforcing values of the stimuli were never evaluated under FR 1 in the absence of the PR schedule. Repeated exposure to FR 1 per se may have revealed that the stimuli were differentially effective. However, responding for the two stimuli was fairly similar under the initial PR schedule requirements across sessions for most participants (see work-rate functions), suggesting similar reinforcer effectiveness at lower schedule values.

Close inspection of response patterns across PR sessions suggests a second possible problem with this rapid assessment. Overall decreases in responding (i.e., earlier breaking points) were observed across repeated exposure to the PR schedule in some cases (i.e., with the low-preference stimulus for Sandie and Sue and with the high-preference stimulus for Bucky). Although within-session decreases are expected to occur under PR schedules, reduction in responding across sessions has not been described in the basic literature. Several factors may account for this finding. First, the decline in responding may be similar to the decrease in resistance to extinction that has been associated with previous exposure to extinction (Skinner, 1938). It is possible that the PR schedules were thinned too quickly, producing ratio strain that carried over into subsequent sessions. Second, interaction effects may have been responsible for the response degrada-

tion because access to a less preferred stimulus was rapidly alternated with access to a more preferred stimulus. If so, a reversal design may be more appropriate for evaluating reinforcers under PR schedules. Third, Baron and Derenne (2000) found that within-session responding under PR schedules was characterized by systematic increases in the duration of postreinforcement pauses. It is possible that postreinforcement pauses for these participants gradually began to exceed the predetermined session-termination criterion (i.e., 5 min), thus producing smaller breaking points across sessions. Further studies are warranted to determine if extended exposure to PR schedules would be associated with response degradation or potential carryover effects.

A third limitation of the study was the general ineffectiveness of the treatments, especially the differential reinforcement procedures. Previous research has shown that treatment effects may be compromised when problem behavior continues to produce reinforcement (e.g., Mazaleski, Iwata, Vollmer, Zarcone, & Smith, 1993; Piazza, Fisher, Hanley, Hilker, & Derby, 1996). Furthermore, the highest ranked stimulus from the initial stimulus choice assessment was not incorporated into treatment for 2 of the 3 participants. Treatment may have been more successful if problem behavior had been exposed to extinction or if more potent reinforcers had been used (e.g., Vollmer et al., 1994).

In summary, results of this study suggested that stimuli identified as similarly preferred via a commonly used preference assessment were differentially effective under increasing schedule requirements. Furthermore, stimuli that were more effective under PR schedules were more likely to produce decreases in problem behavior maintained by automatic reinforcement. Given the limited nature of this investigation, however, these results should be considered prelimi-

nary. Nevertheless, these data suggest that PR schedules offer promise for developing new applied technologies in the area of reinforcer identification.

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STUDY QUESTIONS

1. What are the advantages and disadvantages of using simple responses and dense reinforcement schedules for evaluating reinforcement effects?

2. What are progressive-ratio (PR) schedules and why might they be useful in assessing reinforcement effects?

3. Describe the procedures used in the reinforcer assessment.

4. How were the PR schedules constructed for each of the participants?

5. Summarize the general findings of Experiment 1 with respect to the four dependent measures that were examined. What do these results suggest about the utility of PR schedules?

6. Which data sets suggest that the PR schedules may not have been needed to produce differential response rates for the two reinforcers for Bucky, Sandie, and Sue?

7. Describe the noncontingent reinforcement (NCR), differential reinforcement of other be-

havior (DRO), and differential reinforcement of alternative behavior (DRA) procedures used in Experiment 2.

8. Describe at least two factors that may have contributed to the general ineffectiveness of the interventions.

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