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THE EFFECTS OF REINFORCEMENT MAGNITUDE ON FUNCTIONAL ANALYSIS OUTCOMES

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The duration or magnitude of reinforcement has varied and often appears to have been selected arbitrarily in functional analysis research. Few studies have evaluated the effects of reinforcement magnitude on problem behavior, even though basic findings indicate that this parameter may affect response rates during functional analyses. In the current study, 6 children with autism or developmental disabilities who engaged in severe problem behavior were exposed to three separate functional analyses, each of which varied in reinforcement magnitude. Results of these functional analyses were compared to determine if a particular reinforcement magnitude was associated with the most conclusive outcomes. In most cases, the same conclusion about the functions of problem behavior was drawn regardless of the reinforcement magnitude.

DESCRIPTORS: autism, developmental disabilities, functional analysis, reinforcement magnitude

The functional analysis methodology developed by Iwata, Dorsey, Slifer, Bauman, and Richman (1982/1994) has been used to identify the reinforcing consequences of various behavior disorders, including self-injurious behavior (SIB), aggression, pica, stereotypy, and noncompliance (see Hanley, Iwata, & McCord, 2003, for a review). This methodology has allowed clinicians to develop individualized function-based treatments based on reinforcement and extinction, thus decreasing the need for punishment-based treatments (Pelios, Morren, Tesch, & Axelrod, 1999).

Despite the utility of these procedures, the function of problem behavior may not always be identified during functional analyses (e.g., Conners et al., 2000; Hanley et al., 2003; Iwata, Pace, et al., 1994). A number of procedural variations and refinements have been made to the functional analysis methodology in response to undifferentiated results. Most modifications have been made to either the experimental design, the types of antecedents and consequences evaluated, or the method by which the data were analyzed (e.g., Bowman, Fisher, Thompson, & Piazza, 1997; Day, Rea, Schussler, Larsen, & Johnson, 1988; Iwata, Duncan, Zarcone, Lerman, & Shore, 1994; Mace, Page, Ivancic, & O'Brien, 1986; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993).

Much less attention has been given to other reinforcement parameters that may influence functional analysis results, such as the schedule, quality, or magnitude of the tested reinforcers. For example, the effects of different reinforcement schedules on the outcomes of functional analysis have not been directly examined, although intermittent schedules derived from descriptive assessments have been used in several studies (e.g., Lalli & Casey, 1996; Mace et al., 1986). Compared to continuous reinforcement schedules, intermittent schedules might increase the likelihood of obtaining clear functional analysis outcomes. Lovaas, Freitag, Gold, and Kassorla (1965), for example, compared the effects of a continuous schedule of attention to a variable-ratio 5 schedule on rates of SIB.

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Higher rates of SIB occurred under the intermittent schedule. Although high rates may increase the probability that a response will contact a particular reinforcement contingency, such rates may be unnecessary or unsafe, and intermittent schedules may make problem behavior more resistant to extinction during treatment (Iwata, Vollmer, & Zarcone, 1990).

Several studies have focused on the type or quality of attention provided for problem behavior. For example, in several studies problem behavior was demonstrated to be maintained by attention from peers but not by attention from adults (e.g., Broussard & Northup, 1997; Lewis & Sugai, 1996; Northup et al., 1995). Similarly, Fisher, Ninness, Piazza, and Owen-DeSchryver (1996) found that a participant's problem behavior was more sensitive to contingent attention in the form of verbal reprimands than to contingent attention in the form of random statements. Some studies have also examined the effects of quality of tangible reinforcers on the outcomes of functional analyses. In Mueller, Wilczynski, Moore, Fusilier, and Trahant (2001), for example, the restriction of high-preference toys during the tangible condition resulted in higher rates of aggression than did restriction of less preferred toys for 1 participant. These results suggest that quality of reinforcement may affect the occurrence of problem behavior during functional analyses.

The duration or magnitude of the reinforcer also may be an important parameter. In the extant literature, the duration of reinforcement has varied from 5 s to 120 s within and across functional analysis studies and often appears to have been selected arbitrarily. For example, a brief reinforcement duration (i.e., 5 s) was used during the attention condition in Iwata et al. (1982/1994), whereas 20 s or 30 s of attention has been used in other studies (e.g., Hoch, McComas, Thompson, & Paone, 2002). Day et al. (1988) varied the reinforcement duration in the tangible condition from 10 s to 30 s. Piazza et al. (1997) provided 40-s access to reinforcement during all test conditions of a functional analysis of elopement, and McCord, Thomson, and Iwata (2001) sometimes provided potential reinforcers for up to 120 s in a functional analysis of problematic behavior during transitions.

Brief reinforcement durations often are used so the behavior can contact the consequence repeatedly in a relatively short period of time (Hanley et al., 2003). However, the functions of problem behavior may not be identified if responding is rapidly extinguished due to insufficient amounts (i.e., short durations) of reinforcement. The possible role of extinction in the results of a functional analysis was noted in at least one study after problem behavior gradually decreased to zero during the assessment (see McCord, Iwata, Galensky, Ellingson, & Thomson, 2001). On the other hand, large magnitudes may result in low rates of problem behavior due to satiation or because the reinforcer occupies a large proportion of the session time, during which problem behavior may be unlikely to occur (Roane, Lerman, Kelley, & Van Camp, 1999). Also, a particular target behavior may necessitate a larger reinforcement magnitude for practical reasons. For example, the amount of time needed to retrieve a participant during a functional analysis of elopement may dictate the duration of the reinforcement interval.

Although reinforcement magnitude may affect functional analysis outcomes, this variable has been directly evaluated in only one study. Fisher, Piazza, and Chiang (1996) compared the results of two separate functional analyses. In one functional analysis, attention was delivered for 5 s and all other potential reinforcers were delivered for 30 s. In the other functional analysis, all potential reinforcers were delivered for 30 s. Results of the functional analysis with unequal reinforcement resulted in the highest rates of problem behavior in the attention condition. By contrast, rates of problem behavior were similar across all test conditions with equal reinforcement durations. The authors concluded that levels of problem behavior were much higher in the attention condition when attention was delivered for just 5 s because the establishing operation (EO; Michael, 1993) was present more often, and not because attention was the functional reinforcer. Results also suggested that levels of responding in each test condition should be compared to those in the control condition rather than to each other if different magnitudes are used across conditions.

Results of other studies suggest that reinforcement magnitude may affect functional analysis outcomes. For example, Roscoe, Iwata, and Rand (2003) found that for 1 participant, rates of signing increased as reinforcement magnitude decreased. For another participant, rates of responding were similar under the small- and medium-magnitude conditions but higher under both of these conditions relative to the large-magnitude condition. Results of other applied studies, however, indicate that reinforcement magnitude may not substantially influence responding in single-operant arrangements (e.g., Ecott, Foate, Taylor, & Critchfield, 1999; Lerman, Kelley, Van Camp, & Roane, 1999; Lerman, Kelley, Vorndran, Kuhn, & LaRue, 2002).

Results of basic research on reinforcement magnitude also have yielded inconsistent outcomes. In a number of studies, response rate increased as reinforcement magnitude increased (e.g., Hutt, 1954; Jenkins & Clayton, 1949; Reed, 1991; Reed & Wright, 1988; Stebbins, Mead, & Martin, 1959). For example, Jenkins and Clayton found that key pecking in pigeons was higher when followed by 5-s access to food than when followed by 2-s access to food. Other studies have obtained an inverse relation between reinforcement magnitude and response rates (e.g., Belke, 1997; Lowe, Davey, & Harzem, 1974; Premack, Schaeffer, & Hundt, 1964; Reed, 1991; Staddon, 1970). In the Belke investigation, for example, rats received 30 s, 60 s, or 120 s of wheel running contingent on lever presses. Lever pressing decreased as the reinforcement duration was increased, and the author suggested that the results were due to satiation effects.

It is difficult to reconcile conflicting findings on reinforcement magnitude because different procedures have been used. However, the relation between reinforcement magnitude and response rate may depend on the type of reinforcer delivered. In most basic and applied studies on reinforcement magnitude, reinforcers were different than those typically evaluated in functional analyses of problem behavior (e.g., access to food rather than attention or escape from demands). Thus, additional applied research is needed. The purpose of the current investigation was to examine the impact of reinforcement magnitude on the results of functional analyses.

METHOD

Participants and Settings

Six children who had been diagnosed with autism or moderate to severe developmental disabilities participated in the study. These were the first 6 children referred for the assessment and treatment of problem behavior after the inception of the study. (One other child participated, but results of her functional analyses were inconclusive across all reinforcement magnitudes; thus, her results are not reported.) Five of the 6 participants were blind or visually impaired (Tyler had normal vision); 4 of these attended a school for visually impaired students. The remaining 2 children attended self-contained classrooms for students with developmental disabilities in regular public schools. Meadow was a 7-year-old girl who exhibited aggression. Nick was a 6-year-old boy who exhibited disruption, aggression, and SIB. Tony, a 4-year-old boy, exhibited SIB. Tyler, a 3-year-old boy, engaged in aggression. Max was a 7-year-old boy who engaged in SIB and aggression. Adel, a 9-year-old girl, engaged in SIB and whining.

Adel spoke in full sentences and answered simple questions. Nick mainly used one- to two-word utterances to communicate and engaged in delayed echolalia. Tyler communicated by pulling people towards objects or pointing. Meadow, Tony, and Max did not have any expressive language skills. All of the participants except Meadow and Tony followed one-step instructions. All participants had limited self-help skills (e.g., 5 of the participants were not toilet trained, all required assistance with grooming and dressing, and 1 participant could not feed herself).

A doctoral student collected initial information about possible functions of each child's behavior by interviewing parents and teachers and observing the child in the classroom. Doctoral students served as therapists during all functional analysis conditions. The functional analyses were conducted at each participant's school in a room other than the participants' classroom (i.e., a student lounge at the school for the visually impaired and the cafeteria or small storage room at the public school). The rooms generally contained tables, chairs, and other materials that were specific to the experimental conditions in effect (e.g., toys, instructional materials). Sessions were conducted 4 to 5 days per week, and three to four sessions were conducted per day. All sessions were 10 min in length.

Response Measurement, Reliability, and Procedural Integrity

Hitting (recorded for Meadow, Tyler, and Max) was defined as forceful contact of an open or closed hand with another person's body. *Grabbing* (recorded for Meadow, Tyler, and Max) was defined as wrapping the fingers tightly around another person's body part or clothing. *Scratching* (recorded for Meadow and Max) was defined as scraping the fingernails across another person's skin. *Disruption* (recorded for Nick) was defined as throwing objects. *Biting* (recorded for Nick and Tyler) was defined as closure of the teeth against any part of another person's body. *Head hitting* (recorded for Nick, Tony, and Max) was defined as forceful contact between an open or closed hand and the head. *Head banging* (recorded for Tony and Max) was defined as forceful contact between the head and hard surfaces. *Pinching* (recorded for Tyler) was defined as tightly squeezing another person's skin between two fingers. *Face or body scratching* (recorded for Max) was defined as scraping of the fingernails across the skin on the face or body. *Kicking* (recorded for Max) was defined as forceful contact of the foot with another person. *Hand biting* (recorded for Adel) was defined as the teeth closing against the skin on the hand or wrist. *Whining* (recorded for Adel) was defined as grunts that were louder than normal conversational level, high-pitched screams, or saying "no."

Previously trained graduate or undergraduate students served as observers. The frequency of each participant's target behavior was recorded on laptop computers. Data on the target behavior were converted to a rate measure for each session by dividing the number of responses that occurred during the session by the number of minutes in the session (10 min). Reinforcer access time was not removed from the total session time prior to data calculation (see further discussion below).

Interobserver agreement was assessed by having a second data collector observe behavior simultaneously but independently during a mean of 50% of the sessions (range, 32% to 76%) for each child. Interobserver agreement was determined by dividing each session into consecutive 10-s intervals and comparing agreements and disagreements of the two observers. Agreements were defined as the same number of responses scored within a given 10-s interval. Within a session, agreement coefficients were calculated by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100%. Across participants, mean interobserver agreement of problem behavior was 93% (range, 85% to 100%).

Data also were collected on the therapists' behavior using frequency and duration recording to evaluate the extent to which the potential reinforcers were delivered as planned during each functional analysis. During the demand condition, *escape* was defined as the period of time in which the therapist removed the demand materials, no longer delivered instructions, and turned away from the participant. During the attention condition, *attention delivery* was defined as the period of time in which the therapist directed verbal and physical interaction (e.g., reprimands and other statements of concern) toward the participant. During the tangible condition, *tangible delivery* was defined as the period of time in which the therapist provided the participant with preferred items.

For each session, the length of each reinforcement interval was examined to determine the degree of agreement between the interval length specified by the condition and the actual length arranged by the therapist. For an agreement to be scored, the length of the reinforcement interval had to fall within a specific range depending on the reinforcement magnitude. During the small-magnitude (3-s) functional analysis, an agreement was scored if the potential reinforcer was delivered between 1 s and 8 s. During the medium-magnitude (20-s) functional analysis, an agreement was scored if the potential reinforcer was delivered between 15 s and 25 s. During the large-magnitude (120-s) functional analysis, an agreement was scored if the potential reinforcer was delivered between 110 s and 130 s. For each session, integrity of the relevant reinforcer delivery was calculated by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100%. Across participants, mean integrity of reinforcer delivery was 90% (range, 80% to 96%).

During the small-magnitude functional analysis, the potential reinforcers were actually delivered for an average of 6 s (range, 4 s to 7 s). The potential reinforcers were actually delivered for an average of 23 s (range, 21 s to 25 s) during the medium-magnitude functional analysis. During the large-magnitude functional analysis, the potential reinforcers were actually delivered for an average of 122 s (range, 119 s to 125 s).

Procedure

Preference assessment. Prior to conducting the functional analyses, preference assessments were conducted for each participant to identify highly preferred toys (and edible items for Tyler) for the toy-play and tangible conditions and low to moderately preferred toys for the attention condition. For Meadow, Tony, Tyler, and Adel, a concurrent-operants preference assessment was conducted using procedures similar to those described by Fisher et al. (1992), which was modified for their visual impairments as described by Paclawskyj and Vollmer (1995). For Nick and Max, a single-operant preference assessment similar to that described by DeLeon, Iwata, Conners, and Wallace (1999) was used because these participants did not choose between two items presented to them. For Nick, an informal preference assessment was conducted every few days because his preferences appeared to change frequently. During this assessment, several items were presented to Nick one at a time for a brief period, and the items that he held and did not throw were considered preferred. The same toys were presented during each informal preference assessment. Thus, the specific toys (e.g., Slinky®, feather boa, massager, beads, Koosh® ball) used during the tangible and toy-play conditions varied based on Nick's preferences, whereas the items were held constant across the relevant conditions for all other participants.

General functional analysis. Each participant was exposed to functional analyses with conditions that incorporated relatively small, medium, and large magnitudes of reinforcement (described below). Thus, each participant was exposed to three separate functional analyses. Attention, demand, no-interaction, and toy-play conditions were alternated in a multielement design for each functional analysis. A tangible condition was included if direct observation in the classroom or teacher or caregiver report indicated that the removal or restriction of tangible items and access to these items may have been related to the child's problem behavior. A no-interaction condition was not included if the participant's only problem behavior was aggression. A no-interaction condition was included for Meadow because she was reported to engage in SIB. However, SIB did not occur during any of the functional analyses, so data from the no-interaction sessions are not included in her results. The procedures in each functional analysis condition were similar to those described by Iwata et al. (1982/1994).

During all attention conditions, the therapist provided the participant with moderately preferred toys and then engaged in an activity (e.g., read a magazine). Contingent on the occurrence of a target behavior, the therapist delivered verbal reprimands (e.g., saying "Don't do that, you are going to hurt yourself.") for a specific period of time, based on the reinforcement magnitude that was in effect. All other behavior displayed by the participant was ignored.

Prior to the tangible condition, the participant was provided with 1 to 2 min of access to a preferred item. At the beginning of the session, the therapist restricted access to that preferred item. Contingent on the occurrence of a target behavior, the participant received access to the preferred item for a prespecified interval (based on the magnitude in effect), after which the item was removed until another target behavior occurred. All other behavior displayed by the participant was ignored. The tangible condition was included in the functional analyses for Nick, Tony, Tyler, and Max. A Koosh® ball and a massager were used for Tony, crackers were used for Tyler, and a keyboard and a radio were used for Max.

During the demand condition, instructions were presented to the participant using a graduated prompting sequence (i.e., verbal, gestural, and physical prompts). Contingent on compliance, the participant received brief verbal praise (e.g., "good job"). If at any point the participant engaged in a target behavior, the participant was provided with a break that varied in length based on the magnitude condition in effect. During the break, the task materials were removed and the therapist turned away from the participant for the entirety of the reinforcement interval.

During the no-interaction condition, no materials were available and only the observers were present in the room. The observers did not interact with the participant, and there were no programmed consequences for the occurrence of problem behavior. Finally, in the toy-play condition, the participant was provided with continuous noncontingent attention and highly preferred items throughout the session. No demands were delivered, and no programmed consequences were provided for the target behavior.

During the initial functional analysis phase (when the first reinforcement magnitude was evaluated), sessions continued until levels of responding in one or more of the test conditions were consistently higher than those in the control condition. The length of each remaining functional analysis was roughly matched to that of the initial functional analysis. That is, an attempt was made to hold constant the number of data points in a given condition across reinforcement magnitudes. In a few cases, additional sessions were conducted due to trends in responding (see the Results for further explanation). For all analyses, a function was indicated if responding was consistently higher in the test condition than in the control.

Variations in reinforcement magnitude. Three magnitude durations were chosen that were within the range of those reported in published studies but were specifically selected to maximize differences in the relative durations. During the small-magnitude functional analysis, all sessions were conducted in a manner that was identical to that described above. However, the participants received attention, a break, or access to materials for 3 s contingent on the occurrence of problem behavior. Three seconds was selected because it was deemed to be the smallest practically possible value to implement. During the medium-magnitude functional analysis, all of the conditions were identical to those described above except that the participant received 20-s access to the potential reinforcers. During the attention condition, verbal reprimands, which were similar to those delivered during the small-magnitude functional analysis, were repeated during the 20-s reinforcement interval (i.e., a series of 3-s statements was delivered). A 20- to 30-s reinforcement duration is commonly used during functional analyses (e.g., Day et al., 1988); thus, 20 s was selected as the medium-magnitude duration. Finally, in the large-magnitude functional analysis, all of the conditions were identical to those described above except that the participant received 120-s access to the potential reinforcers. During the attention condition, the same type of verbal reprimands used during the small- and medium-magnitude functional analyses were repeated for 120 s. A 120-s duration was selected as the large-magnitude value because that was the longest reinforcement interval found among studies on functional analysis (i.e., McCord, Thomson, & Iwata, 2001).

Experimental Design

The first reinforcement magnitude evaluated was varied across participants to control for potential sequence effects. Two participants were first exposed to the small reinforcement magnitude, 3 participants were first exposed to the medium reinforcement magnitude, and 1 participant was first exposed to the large reinforcement magnitude. The order in which the participants were exposed to the two remaining reinforcement magnitudes also was varied across participants. The magnitudes were presented in ascending order (small, medium, large) for Tyler and Adel and in descending order (large, medium, small) for Max. For the 3 remaining participants, the medium magnitude was either followed by the small magnitude and then the large magnitude (Nick and Tony) or vice versa (Meadow).

RESULTS

For all participants, the same conclusion about the functions of problem behavior was drawn regardless of the reinforcement magnitude. For Meadow, rates of aggression were consistently higher in the attention condition than in the control condition of each functional analysis (Figure 1, top), indicating that aggression was maintained by social-positive reinforcement in the form of attention. In fact, rates were similarly high and variable across all magnitudes, with at least 80% of the data points above all of those in the control condition during each functional analysis.

For Nick, levels of problem behavior in the demand condition were higher than those in the control condition across all three reinforcement magnitudes, indicating that problem behavior was maintained by social-negative reinforcement in the form of escape from demands (Figure 1, bottom). During the medium-, small-, and large-magnitude functional analyses, the majority of data points in the demand condition were elevated above all of those in the control. However, rates of problem behavior were substantially higher during the small-magnitude demand condition ($M = 7.6$ responses per minute) than during the medium- and large-magnitude demand conditions ($M = 1.5$ and $M = 0.5$, respectively).

Rates of SIB for Tony were higher in the tangible and demand conditions than in the

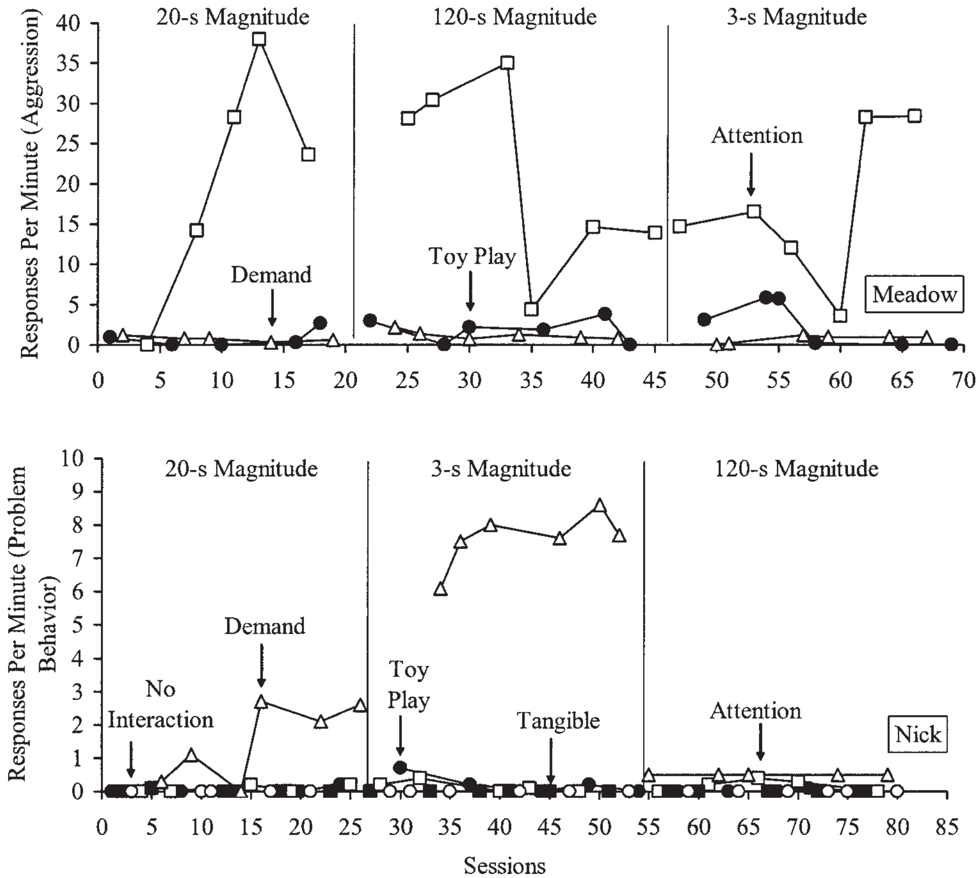

Figure 1. Responses per minute of aggression for Meadow (top) and responses per minute of SIB, aggression, and disruption for Nick (bottom) across conditions of each functional analysis.

control condition during all functional analyses, indicating that his behavior was maintained by social-positive reinforcement in the form of access to tangible items and by negative reinforcement in the form of escape from instructions (Figure 2, top). To assist visual inspection, data from the tangible and demand sessions also are displayed in separate graphs with data from the control sessions (see middle and bottom panels). During the medium-, small-, and large-magnitude functional analyses, the majority of the data points in the tangible condition were above all of those in the control condition. Likewise, all of the data points in the demand condition were higher than all of those in the control condition across the different magnitudes.

Results for Tyler are shown in Figure 3. Data from the tangible and demand sessions also are displayed with data from the control sessions in separate graphs to assist visual inspection (see middle and bottom panels). Rates of aggression were highest during the tangible condition of the small- and medium-magnitude functional analyses, suggesting that his behavior was maintained by social-positive reinforcement in the form of access to food. However, levels of aggression in the tangible condition were not as clearly differentiated from those in the control condition under the large magnitude (see middle panel). Just three of six data points were higher than those in the control condition. During the demand conditions, levels of aggression were not consistently higher than those in

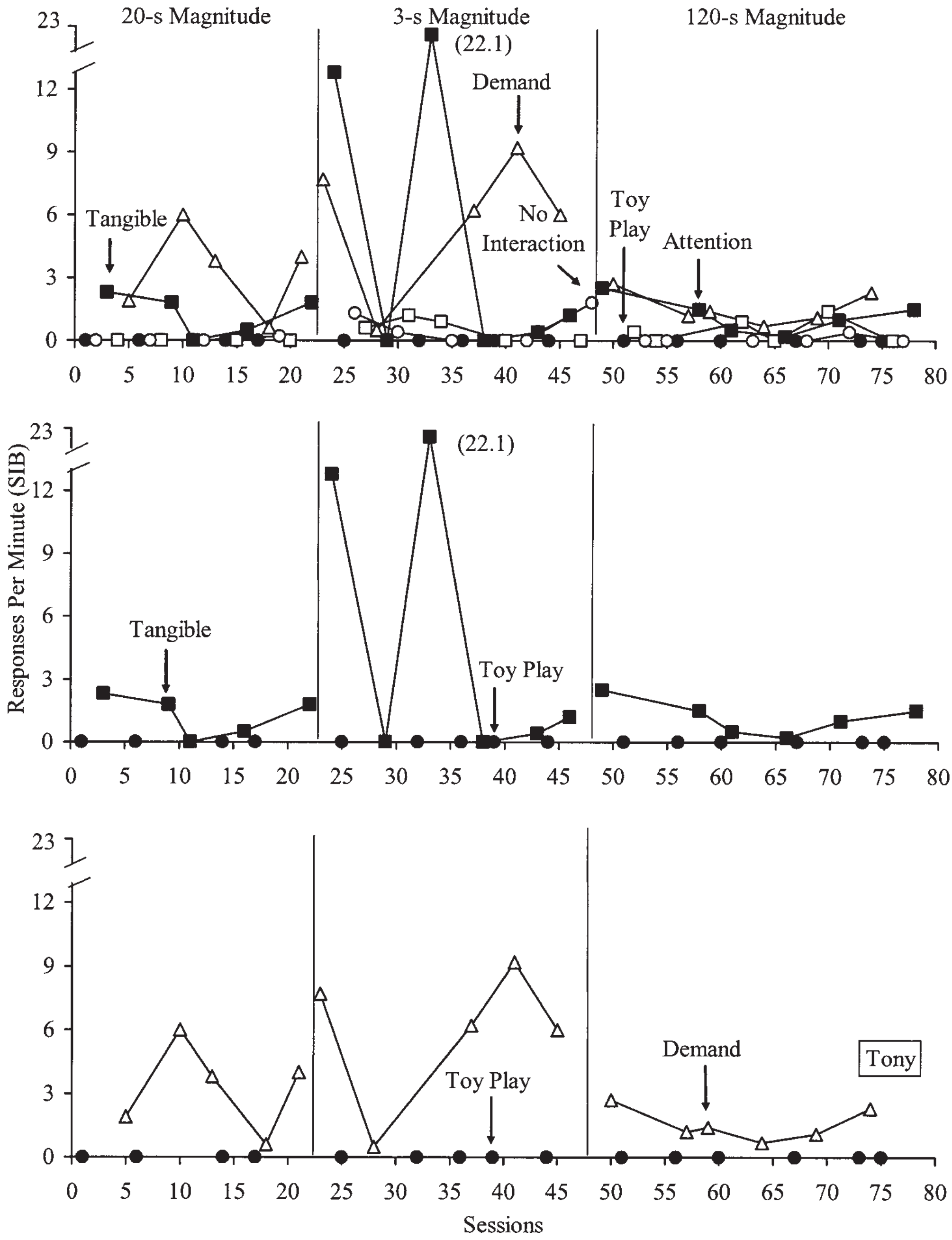

Figure 2. Responses per minute of SIB for Tony across conditions of each functional analysis (top) and during the tangible and control conditions (middle) and the demand and control conditions (bottom) of each functional analysis.

the control condition; thus, an escape function was not clearly indicated for Tyler.

For Max, rates of SIB and aggression were consistently higher in the demand condition than in the control condition, regardless of the reinforcement magnitude (Figure 4, top). This finding indicates that his problem behavior was maintained by escape from demands.

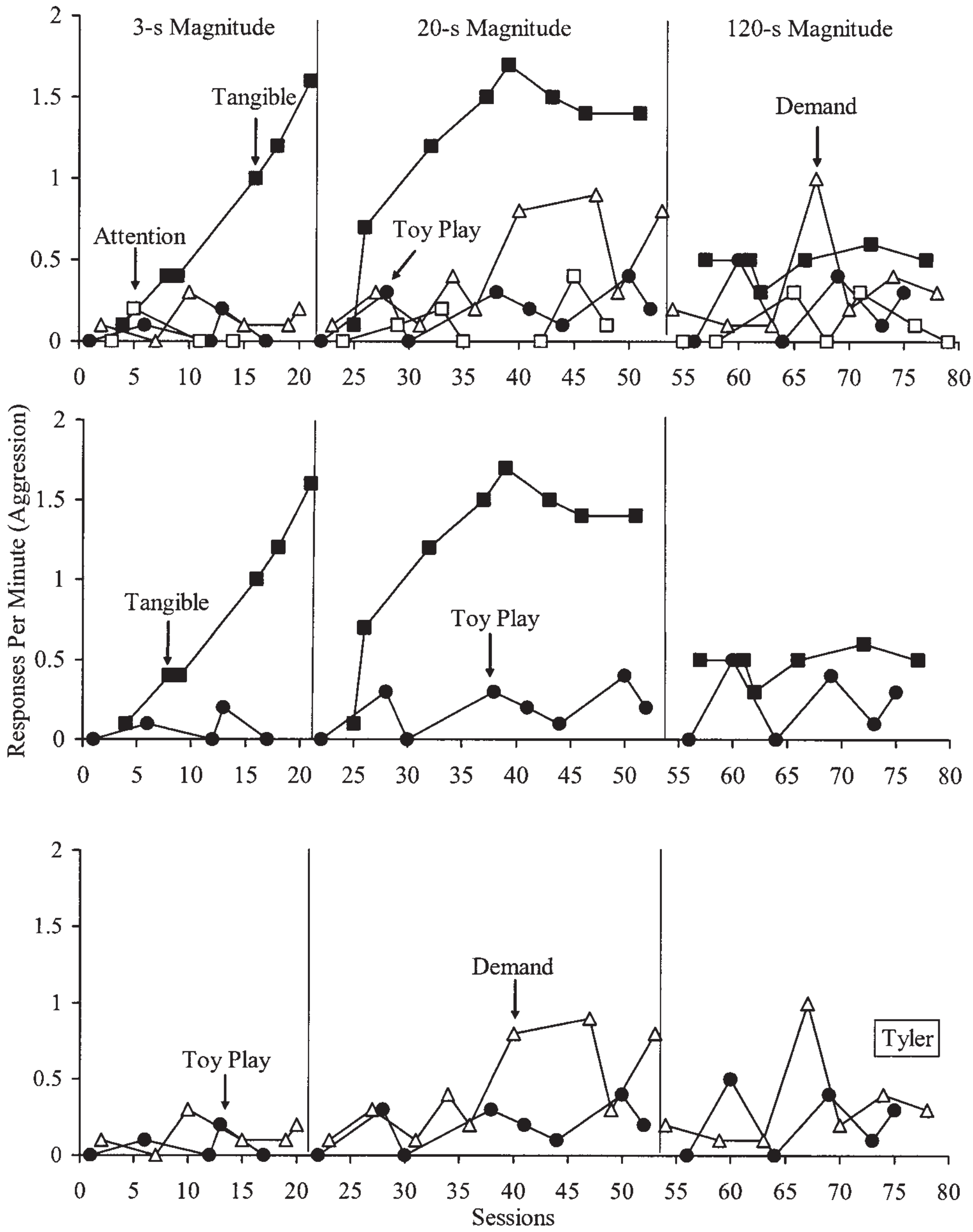

Figure 3. Responses per minute of aggression for Tyler across conditions of each functional analysis (top) and during the tangible and control conditions (middle) and the demand and control conditions (bottom) of each functional analysis.

A similar finding was obtained for Adel, indicating that SIB and whining were maintained by escape from demands (Figure 4, bottom). However, responding in the demand condition was substantially higher under the small-magnitude functional analysis (M = 4.83 responses per minute) than under the medium- and large-magnitude functional analyses (M = 1.88 and M = 0.5, respectively).

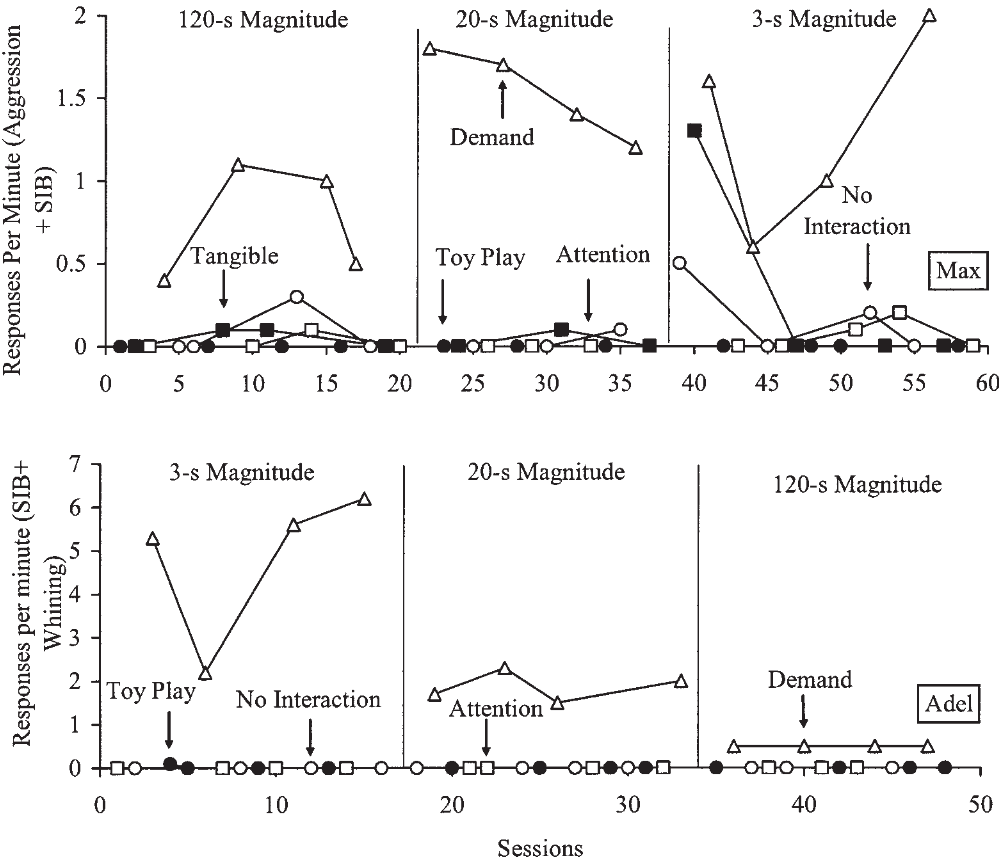

Figure 4. Responses per minute of aggression and SIB for Max (top) and responses per minute of SIB and whining for Adel (bottom) across conditions of each functional analysis.

DISCUSSION

Functional analysis results were similar across different reinforcement magnitudes for all participants. Although results of some previous studies indicate that reinforcement magnitude may be an important variable to consider during functional analyses, the current results suggest that reinforcement magnitude is not a critical determinant of functional analysis outcomes. Thus, it may be acceptable for clinicians and researchers to use a wide range of reinforcement magnitudes as long as a consistent magnitude is used across all conditions of the functional analysis (see Fisher, Piazza, & Chiang, 1996).

It was surprising to find that a 3-s reinforcement magnitude was adequate to maintain problem behavior, especially when the reinforcer was escape from demands or access to tangible items (toys). For example, the size of the break was not much longer than a break that might naturally occur between instructional trials of a teaching session. Response patterns that would have indicated extinction effects (i.e., initial high rates of responding followed by a gradual decline in rates of responding) did not emerge under the smaller reinforcement magnitudes. However, the functional analyses were relatively brief, and responding may have been in the process of being extinguished. In fact, extinction bursts may have occurred across relevant test sessions, which could account for the increase in responding that was observed for some participants (e.g., see Tyler's data).

On the other hand, within-session patterns might have revealed extinction effects that were obscured by examining overall response rates in each session. For example, responding may have been initially high at the start of each session (and perhaps even elevated due to an extinction burst) and then decreased as the session progressed. This type of response pattern would provide tentative evidence that extinction was occurring. To examine potential extinction effects, minute-by-minute data on problem behavior across sessions of each functional analysis condition were examined. No obvious or consistent within-session patterns of extinction were found for any participant.

Within-session patterns of responding that would have indicated satiation effects (i.e., a gradual decline in responding across each session) also were examined for the large-magnitude functional analyses. No obvious within-session patterns of satiation were observed for any participant (including Tyler). It is possible that satiation effects did not influence overall responding for most participants because the session lengths were brief. In addition, satiation may occur more readily with other types of reinforcers (e.g., food) than with reinforcers like attention or escape from demands.

In most cases, the large reinforcement magnitude was associated with lower levels of problem behavior during the functional analyses, particularly for Nick and Adel. Because all sessions were 10 min long, the proportion of the session in which the reinforcer was present (e.g., the therapist was delivering attention to the participant; no demands were delivered) was much greater during the large-magnitude functional analysis than during the other analyses. Problem behavior may be less likely to occur while the functional reinforcer is being delivered (Roane et al., 1999). Thus, overall levels of problem behavior may necessarily be lower under large reinforcement magnitudes than under smaller magnitudes for this reason alone. It would have been possible to hold this variable constant across reinforcement magnitudes by excluding reinforcer delivery time from the total session time when conducting the analyses or calculating the response rates. However, this is one important factor that may influence functional analysis outcomes and, thus, should be evaluated when studying the effects of reinforcement magnitude.

Overall, the findings suggest that the specific magnitudes used in functional analyses can be selected based on other concerns. For example, smaller reinforcement magnitudes may be desirable when it is important for the behavior to contact the contingency multiple times within a brief session (Hanley et al., 2003), such as when conducting brief functional analyses or when using short-duration sessions. A small magnitude may actually ensure high levels of responding, and thus, a more easily identified function because the EO (Michael, 1993) is present more often during the session. However, high response rates may be dangerous to the participant or therapist, especially if SIB or aggression is the target behavior. Conversely, lower rates of problem behavior associated with the large reinforcement magnitude may be desirable if the individual engages in severe problem behavior. Longer reinforcement intervals also may be more practical in some cases (e.g., when assessing elopement or when evaluating reinforcers that are difficult to present and remove frequently). Finally, reinforcement magnitudes could be selected on the basis of previously identified or presumed durations of naturally occurring events.

Conclusions about the current findings should be qualified because a single-operant arrangement was used. Under a concurrent-operants arrangement, multiple responses and reinforcers are available simultaneously; this may provide a more sensitive measure of preference and reinforcer potency (Fisher & Mazur, 1997). Greater differences in responding across reinforcement magnitudes might have been obtained if the participants were able to choose between larger and smaller magnitudes.

The study contains additional limitations that warrant discussion. First, in some cases, replications of a particular functional analysis may have been beneficial for drawing conclusions about the effects of magnitude on responding. Second, the study was limited to putative reinforcers that are commonly evaluated in functional analyses of problem behavior. Different results may be obtained with other idiosyncratic reinforcers (e.g., Bowman et al., 1997). Third, each functional analysis contained only 14 to 16 sessions. If the analyses had been extended, extinction or satiation effects may have been observed under certain reinforcement magnitudes or additional analyses (e.g., Vollmer, Marcus, Ringdahl, & Roane, 1995) might have been needed to clarify the outcomes. Fourth, all of the children had been diagnosed with moderate to severe developmental disabilities, and 5 of them were blind or visually impaired. It is not clear whether the results of the study would extend to other populations. Fifth, results of the functional analyses for each participant were viewed in relation to one another. Thus, the interpretation of an earlier analysis may have influenced the interpretation of later analyses. Finally, results may have been influenced by carryover, interaction, or sequence effects. For example, different results may have been obtained for children who were exposed to the 3-s magnitude first than for children who were exposed to the 3-s magnitude last, although results did not indicate the presence of sequence effects.

Future studies should determine whether using a small reinforcement magnitude (e.g., 3 s) would improve the outcomes of brief functional analyses (e.g., Derby et al., 1992). Results of Roscoe et al. (2003) suggest that session length is important to consider in further research on reinforcement magnitude. When comparing the effects of small, medium, and large amounts of reinforcement on responding, Roscoe et al. examined rates of responding when the medium-magnitude reinforcer was delivered during 10-min sessions versus 30-min sessions. Rates of responding during 10-min medium-magnitude sessions were much higher than those during 30-min sessions, but were similar to those observed during 10-min small-magnitude sessions. It is not clear whether the reinforcer durations that are commonly used in functional analysis research are representative of those used in the natural environment. In the current investigation, participants received access to the potential reinforcers for a maximum of 120 s. However, caregivers are likely to give children access to "calming" events for a much longer period. Future research should directly examine the differences between naturalistic and programmed reinforcement magnitudes.

In addition, other parameters of reinforcement (e.g., schedule, delay, quality) should be evaluated in future studies on functional analysis. For example, the outcomes of functional analyses using continuous schedules of reinforcement could be compared to those using more naturalistic schedules of reinforcement (e.g., Mace et al., 1986). Research findings that identify variables that do and do not influence assessment outcomes are important to the field and may help to advance the current technology of functional analysis.

REFERENCES

Belke, T. W. (1997). Running and responding reinforced by the opportunity to run: Effect of reinforcer duration. *Journal of the Experimental Analysis of Behavior*, *67*, 337–351.

Bowman, L. G., Fisher, W. W., Thompson, R. H., & Piazza, C. C. (1997). On the relation of mands and the function of destructive behavior. *Journal of Applied Behavior Analysis*, *30*, 251–265.

Broussard, C., & Northup, J. (1997). The use of functional analysis to develop peer interventions for disruptive classroom behavior. *School Psychology Quarterly*, *12*, 65–76.

Conners, J., Iwata, B. A., Kahng, S., Hanley, G. P., Worsdell, A. S., & Thompson, R. H. (2000). Differential responding in the presence and absence of discriminative stimuli during multielement functional analyses. *Journal of Applied Behavior Analysis*, *33*, 299–308.

Day, R. M., Rea, J. A., Schussler, N. G., Larsen, S. E., & Johnson, W. L. (1988). A functionally based approach to the treatment of self-injurious behavior. *Behavior Modification*, *12*, 565–589.

DeLeon, I. G., Iwata, B. A., Conners, J., & Wallace, M. D. (1999). Examination of ambiguous stimulus preference with duration-based measures. *Journal of Applied Behavior Analysis*, *32*, 111–114.

Derby, K. M., Wacker, D. P., Sasso, G., Steege, M., Northup, J., Cigrand, K., et al. (1992). Brief functional assessment techniques to evaluate aberrant behavior in an outpatient setting: A summary of 79 cases. *Journal of Applied Behavior Analysis*, *25*, 713–721.

Ecott, C. L., Foate, B. L., Taylor, B., & Critchfield, T. S. (1999). Further evaluation of reinforcer magnitude effects in noncontingent schedules. *Journal of Applied Behavior Analysis*, *32*, 529–532.

Fisher, W. W., & Mazur, J. E. (1997). Basic and applied research on choice responding. *Journal of Applied Behavior Analysis*, *30*, 387–410.

Fisher, W. W., Ninness, H. A. C., Piazza, C. C., & Owen-DeSchryver, J. S. (1996). On the reinforcing effects of the content of verbal attention. *Journal of Applied Behavior Analysis*, *29*, 235–238.

Fisher, W. W., Piazza, C. C., Bowman, L. G., Hagopian, L. P., Owens, J. C., & Slevin, I. (1992). A comparison of two approaches for identifying reinforcers for persons with severe and profound disabilities. *Journal of Applied Behavior Analysis*, *25*, 491–498.

Fisher, W. W., Piazza, C. C., & Chiang, C. L. (1996). Effects of equal and unequal reinforcer duration during functional analysis. *Journal of Applied Behavior Analysis*, *29*, 117–120.

Hanley, G. P., Iwata, B. A., & McCord, B. E. (2003). Functional analysis of problem behavior: A review. *Journal of Applied Behavior Analysis*, *36*, 147–185.

Hoch, H., McComas, J. J., Thompson, A. L., & Paone, D. (2002). Concurrent reinforcement schedules: Behavior change and maintenance without extinction. *Journal of Applied Behavior Analysis*, *35*, 155–169.

Hutt, P. J. (1954). Rate of bar pressing as a function of quality and quantity of food reward. *Journal of Comparative and Physiological Psychology*, *47*, 235–239.

Iwata, B. A., Dorsey, M. F., Slifer, K. J., Bauman, K. E., & Richman, G. S. (1994). Toward a functional analysis of self-injury. *Journal of Applied Behavior Analysis*, *27*, 197–209, (Reprinted from *Analysis and Intervention in Developmental Disabilities, 2*, 3–20, 1982)

Iwata, B. A., Duncan, B. A., Zarcone, J. R., Lerman, D. C., & Shore, B. A. (1994). A sequential, test-control methodology for conducting functional analyses of self-injurious behavior. *Behavior Modification*, *18*, 289–306.

Iwata, B. A., Pace, G. M., Dorsey, M. F., Zarcone, J. R., Vollmer, T. R., Smith, R. G., et al. (1994). The functions of self-injurious behavior: An experimental-epidemiological analysis. *Journal of Applied Behavior Analysis*, *27*, 215–240.

Iwata, B. A., Vollmer, T. R., & Zarcone, J. R. (1990). The experimental (functional) analysis of behavioral disorders: Methodology, applications, and limitations. In A. C. Repp & N. N. Singh (Eds.), *Perspectives on the use of nonaversive and aversive interventions for persons with developmental disabilities* (pp. 301–330). Sycamore, IL: Sycamore.

Jenkins, W. O., & Clayton, F. L. (1949). Rate of responding and amount of reinforcement. *Journal of Comparative and Physiological Psychology*, *42*, 174–181.

Lalli, J. S., & Casey, S. D. (1996). Treatment of multiply controlled problem behavior. *Journal of Applied Behavior Analysis*, *29*, 391–395.

Lerman, D. C., Kelley, M. E., Van Camp, C. M., & Roane, H. S. (1999). Effects of reinforcement magnitude on spontaneous recovery. *Journal of Applied Behavior Anlaysis*, *32*, 197–200.

Lerman, D. C., Kelley, M. E., Vorndran, C. M., Kuhn, S. A., & LaRue, R. H. (2002). Reinforcement magnitude and responding during treatment with differential reinforcement. *Journal of Applied Behavior Analysis*, *35*, 29–48.

Lewis, T. J., & Sugai, G. (1996). Descriptive and experimental analysis of teacher and peer attention and the use of assessment-based intervention to improve pro-social behavior. *Journal of Behavioral Education*, *6*, 7–24.

Lovaas, O. I., Freitag, G., Gold, V. J., & Kassorla, I. C. (1965). Experimental studies in childhood schizophrenia: Analysis of self-destructive behavior. *Journal of Experimental Child Psychology*, *2*, 67–84.

Lowe, C. F., Davey, G. C. L., & Harzem, P. (1974). Effects of reinforcement magnitude on interval and ratio schedules. *Journal of the Experimental Analysis of Behavior*, *22*, 553–560.

Mace, F. C., Page, T. J., Ivancic, M. T., & O'Brien, S. (1986). Analysis of environmental determinants of aggression and disruption in mentally retarded children. *Applied Research in Mental Retardation*, *7*, 203–221.

McCord, B. E., Iwata, B. A., Galensky, T. L., Ellingson, S. A., & Thomson, R. J. (2001). Functional analysis and treatment of problem behavior evoked by noise. *Journal of Applied Behavior Analysis*, *34*, 447–462.

McCord, B. E., Thomson, R. J., & Iwata, B. A. (2001). Functional analysis and treatment of self-injury associated with transitions. *Journal of Applied Behavior Analysis*, *34*, 195–210.

Michael, J. (1993). Establishing operations. *The Behavior Analyst*, *16*, 191–206.
Mueller, M. M., Wilczynski, S. M., Moore, J. W., Fusilier, I., & Trahant, D. (2001). Antecedent manipulations in a tangible condition: The effects of stimulus preference on aggression. *Journal of Applied Behavior Analysis*, *34*, 237–240.
Northup, J., Broussard, C., Jones, K., George, T., Vollmer, T. R., & Herring, M. (1995). The differential effects of teacher and peer attention on the disruptive classroom behavior of three children with a diagnosis of attention deficit hyperactivity disorder. *Journal of Applied Behavior Analysis*, *28*, 227–228.
Paclawskyj, T. R., & Vollmer, T. R. (1995). Reinforcer assessment for children with developmental disabilities and visual impairment. *Journal of Applied Behavior Analysis*, *28*, 219–224.
Pelios, L., Morren, J., Tesch, D., & Axelrod, S. (1999). The impact of functional analysis methodology on treatment choice for self-injurious and aggressive behavior. *Journal of Applied Behavior Analysis*, *32*, 185–195.
Piazza, C. P., Hanley, G. P., Bowman, L. G., Ruyter, J. M., Lindauer, S. E., & Saiontz, D. M. (1997). Functional analysis and treatment of elopement. *Journal of Applied Behavior Analysis*, *30*, 653–672.
Premack, D., Schaeffer, R. W., & Hundt, A. (1964). Reinforcement of drinking by running: Effect of fixed ratio and reinforcement time. *Journal of the Experimental Analysis of Behavior*, *7*, 91–96.
Reed, P. (1991). Multiple determinants of the effects of reinforcement magnitude on free-operant response rates. *Journal of the Experimental Analysis of Behavior*, *55*, 109–123.
Reed, P., & Wright, J. E. (1988). Effects of magnitude of food reinforcement on free operant response rates. *Journal of the Experimental Analysis of Behavior*, *49*, 75–85.
Roane, H. S., Lerman, D. C., Kelley, M. E., & Van Camp, C. M. (1999). Within-session patterns of responding during functional analyses: The role of establishing operations in clarifying behavioral function. *Research in Developmental Disabilities*, *20*, 73–89.
Roscoe, E. M., Iwata, B. A., & Rand, M. S. (2003). Effects of reinforcer consumption and magnitude on response rates during noncontingent reinforcement. *Journal of Applied Behavior Analysis*, *36*, 525–540.
Staddon, J. E. R. (1970). Effect of reinforcement duration on fixed-interval responding. *Journal of the Experimental Analysis of Behavior*, *13*, 9–11.
Stebbins, W. C., Mead, P. B., & Martin, J. M. (1959). The relation of amount of reinforcement to performance under a fixed-interval schedule. *Journal of the Experimental Analysis of Behavior*, *2*, 351–355.
Vollmer, T. R., Iwata, B. A., Zarcone, J. R., Smith, R. G., & Mazaleski, J. L. (1993). Within-session patterns of self-injury as indicators of behavioral function. *Research in Developmental Disabilities*, *14*, 479–492.
Vollmer, T. R., Marcus, B. A., Ringdahl, J. E., & Roane, H. S. (1995). Progressing from brief assessments to extended experimental analyses in the evaluation of aberrant behavior. *Journal of Applied Behavior Analysis*, *28*, 561–576.

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STUDY QUESTIONS

1. What are the advantages and disadvantages of utilizing (a) continuous versus intermittent schedules of reinforcement and (b) brief versus long durations of reinforcement during functional analyses?

2. How was the integrity of reinforcer delivery during each functional analysis assessed?

3. Describe how the functional analyses were modified to assess the effects of each reinforcer magnitude.

4. Why do you suppose the authors used highly preferred toys during the play condition but low to moderately preferred toys during the attention condition?

5. What rationale did the authors provide for presenting the reinforcer-magnitude conditions in a varied sequence? Given the magnitude parameters chosen, what type of presentation might have yielded an order effect?

6. Describe the results obtained during the different reinforcement magnitudes.

7. What recommendations did the authors make for selecting reinforcer magnitudes during functional analyses?

8. What other variable did the authors suggest might interact with the effects of reinforcer magnitude during assessment?

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