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ANALYSES OF RESPONSE–STIMULUS SEQUENCES IN DESCRIPTIVE OBSERVATIONS

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Descriptive observations were conducted to record problem behavior displayed by participants and to record antecedents and consequences delivered by caregivers. Next, functional analyses were conducted to identify reinforcers for problem behavior. Then, using data from the descriptive observations, lag-sequential analyses were conducted to examine changes in the probability of environmental events across time in relation to occurrences of problem behavior. The results of the lag-sequential analyses were interpreted in light of the results of functional analyses. Results suggested that events identified as reinforcers in a functional analysis followed behavior in idiosyncratic ways: after a range of delays and frequencies. Thus, it is possible that naturally occurring reinforcement contingencies are arranged in ways different from those typically evaluated in applied research. Further, these complex response–stimulus relations can be represented by lag-sequential analyses. However, limitations to the lag-sequential analysis are evident.

DESCRIPTORS: conditional probability, descriptive analysis, developmental disabilities, lag-sequential analysis

Much has been learned in recent years about the role of reinforcement in the maintenance of severe problem behavior. For example, functional analysis methods developed by Iwata, Dorsey, Slifer, Bauman, and Richman (1982/1994) have shown that severe behavior disorders are usually learned operant behavior. Functional analyses usually involve the arrangement of reinforcement contingencies that specify a reinforcer delivery following the target response (i.e., the probability of a reinforcer given an occurrence of problem behavior is 1.0) but no reinforcer delivery if the target response does not occur (i.e., the probability of a reinforcer given no response is 0). A reinforcer has been identified when response rates are higher in one condition than in other conditions.

Recently, in descriptive analysis research, potential reinforcement contingencies have been examined in naturally occurring human interactions (Borrero & Vollmer, 2002; Thompson & Iwata, 2001, 2007; Vollmer, Borrero, Wright, Van Camp, & Lalli, 2001).

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Because no experimental manipulation is made, descriptive analyses cannot be used to identify reinforcers. However, there are other potential uses of descriptive analyses. First, descriptive analyses might help to operationally define appropriate or inappropriate behavior. Second, descriptive data might shed light on the baseline rate, latency, duration, or intensity of target behavior. Third, descriptive analyses might be used to identify common behavioral consequences. For example, Thompson and Iwata (2001) demonstrated that self-injury emitted by individuals with developmental disabilities was predictive of subsequent delivery of attention by staff. Fourth, descriptive analyses can be useful when observing how reinforcers interact with behavior under ordinary circumstances. For this use of descriptive analysis, a functional analysis should be conducted to identify reinforcers. The descriptive data can then be used to describe relations between reinforcement and behavior in natural interactions. For example, Borrero and Vollmer related descriptive data to the matching law after identifying reinforcers via functional analysis. It is important to note that this use of descriptive analysis is not necessarily for the purpose of clinical assessment. Rather, this approach might be used to better understand how contingencies of reinforcement work in natural interactions. It is this usage of descriptive analysis that is the focus of the current study.

One method of data analysis for descriptive data involves the use of conditional probabilities (e.g., Lerman & Iwata, 1993). Conditional probabilities reflect the probability of observing one event (e.g., a putative reinforcer, such as attention) given the occurrence of another event (e.g., a response, such as self-injury). Such comparisons can be used to describe relations between events that happen after responses and those events that happen either independent of, before, or in the absence of responses.

One advantage of conditional probability analyses is that they can be used to interpret data in light of a conceptualization of contingency, such as that described by Catania (1998). Catania accounted for reinforcement effects as the result of interactions between two conditional probabilities: the probability of a reinforcer given a response and the probability of a reinforcer given no response. For example, in a given environment, the probability of attention given self-injury might be .8, and the probability of attention given the nonoccurrence of self-injury might be .2. If self-injury is shown to occur primarily in the attention condition of a functional analysis and is shown to persist in the .8 versus .2 conditional probability arrangement in the natural environment, it suggests that the reinforcement contingency that maintains problem behavior has been described.

Vollmer et al. (2001) examined naturally occurring interactions using conditional probabilities. They tracked the delivery of potential reinforcers such as attention, access to materials, and escape from demands. Many of the interactions they examined involved what appeared to be a blend of response-dependent and response-independent events; that is, reinforcers were likely to occur following behavior as well as in the absence of behavior. Thus, the authors used a conceptualization of contingency similar to that of Catania (1998) to interpret the data. More specifically, they empirically distinguished possible positive, negative, and neutral contingencies by comparing the probability of observing an event following behavior to the unconditional or background probability of that event (the probability of observing that event following randomly selected points during the observation). Positive contingencies were those in which the conditional probability of an event was higher than the unconditional probability. Negative contingencies were those in which the conditional probability of an event was lower than the unconditional probability. One limitation of the study was that a functional analysis was not conducted to determine the stimulus functions of the events tracked during the descriptive analysis.

Emerson, Thompson, Reeves, Henderson, and Robertson (1995) analyzed naturally occurring contingencies using a method called lag-sequential analysis. They compared the probability of putative reinforcers following target behavior to the probability of observing those events independent of behavior (unconditional probability). Traditional methods of calculating conditional probability usually produce one test value and one comparison value per observation. Conversely, lag-sequential analyses can produce conditional probabilities for every second before and after a target response. This method allows more precise descriptions of how the probability of observing an event changes before and after some point of reference (usually occurrences of the target response).

Functional analysis methods can provide empirical support for the reinforcing functions of events observed during a descriptive analysis. To date, Emerson et al. (1995) is the only published examination of lag-sequential analyses that was informed by functional analyses. However, the functional analyses in that study were limited because they were conducted in conjunction with an existing treatment protocol that consisted of delivery of a mild reprimand and diversion following severe self-injury and aggression.

Another way to address response–stimulus relations in the natural environment is to use multiple evaluations of contingency on the same set of data. Multiple evaluations are important for at least two reasons: (a) No single statistic can appropriately summarize the degree to which a given environment might support behavior, and (b) the best measures of contingency strength are not yet known. Therefore, a broader picture of the relations in effect would at least increase the chances that investigators contact the important ones.

The purpose of the current study was to examine and evaluate how reinforcement contingencies that support severe problem behavior might work in the natural environment. Initially, data were collected using a descriptive analysis. Following the descriptive analysis, a functional analysis was conducted to provide empirical demonstrations of the stimulus functions of events observed during the descriptive analysis. Then, multiple measures of contingency, including lag-sequential analyses, were taken from the descriptive analysis data sets and interpreted.

METHOD

Participants and Settings

Four adolescents who had been referred for the assessment and treatment of severe problem behavior participated. Two had been admitted to an inpatient facility, and 2 attended a school for individuals with developmental disabilities. These individuals participated in some or all of a series of three descriptive analysis studies, including the present study (the other studies were Sloman et al., 2005, and St. Peter et al., 2005). However, different features of the descriptive data were used in all of the studies, and the data were used for different purposes. The ages listed below reflect participant status at the beginning of data collection.

Alice was a 14-year-old girl who had been diagnosed with childhood disintegrative disorder. She engaged in aggression and disruption, which consisted of hitting people and throwing items. Greg was an 8-year-old boy who had been diagnosed with autism and mild mental retardation and engaged in screaming. Amy was a 14-year-old girl who had been diagnosed with moderate mental retardation and engaged in self-injury. Jasmine was a 14-year-old girl with no formal diagnosis who engaged in aggression and disruption, which consisted of slapping people and throwing items, respectively.

Descriptive Analysis

Descriptive observations were conducted during interactions between participants and their care providers (parents or teachers) using the methods described by Vollmer et al. (2001).

Observers used a computerized data-collection system to simultaneously record environmental events and instances of problem behavior. Environmental events were divided into two classes: those that may serve as potential reinforcers (attention, absence of instructions, and access to tangible items) and those that may serve as potential establishing operations (EOs; low attention, instruction presentation, and restricted access to materials). Environmental events were scored as duration measures. Specifically, observers pressed a key on the computer or touch screen to indicate the onset of the event and again after termination of the event.

Environmental events were operationally defined in mutually exclusive and exhaustive categories such that when the potential reinforcer for one kind of event was observed and recorded, its corresponding potential EO was turned off. For example, observers turned off the low-attention key and turned on the attention key during a transition from low attention to the delivery of attention. Having data collectors record both the occurrence and nonoccurrence of environmental events independently allowed us to be more confident about the state of a given event without having to make inferences given the absence of behavior on the part of the observer. It also allowed us to correct or omit errors based on inconsistencies in the data (e.g., having both a potential EO key and its corresponding reinforcer off at the same time). This procedure is described in more detail under the section on *Data Preparation*.

It was possible for more than one potential EO or reinforcer to be scored at the same time. For example, periods of low attention and restricted access to materials could overlap. However, periods of EOs could not overlap with their corresponding reinforcers; periods of low attention could not be scored at the same time as periods of attention (i.e., low attention and attention were mutually exclusive categories).

Observers scored "task on" at the occurrence of the first instruction (academic or otherwise) since "task off" was last scored. An *instruction* was defined as a spoken command to initiate, continue, or complete a preacademic, academic, vocational, life-skill, or self-care activity. Observers continued to score "task on" until either the task materials (and prompts from the therapist) were withdrawn, the caregiver turned away, or 10 consecutive seconds passed without the presentation of additional instructions. "Task off" was scored at the cessation of "task on." "Attention on" was scored at the occurrence of any spoken statement by the caregiver directed to the participant or physical contact between the caregiver and participant. This meant that nearly all initiations of demands or "task on" were accompanied by "attention on." However, there were many situations in which "attention on" could have been scored without "task on" (e.g., brief or extended social interactions or praise). "Attention on" continued to be scored until 3 consecutive seconds passed without either a spoken statement or physical contact by the caregiver, at which point "attention off" was scored. "Access to materials" was scored when toys, food items, or play materials were currently being manipulated by the participant, were within reach of the participant when seated, or were no longer being manipulated but had not been restricted by a caregiver. "Restricted access" was scored during all other times.

For Amy and Jasmine, instructions tended to occur during circle time (e.g., "Point to today on the calendar," or "Point to the picture with more money") or unstructured time (e.g., "pick that up" or "sit down"). For Greg and Alice, instructions often involved self-care tasks (e.g., "get dressed" or "brush your teeth"). The nature of the instructions meant that most were not accompanied by the simultaneous delivery of play items. Therefore, it was usually not necessary to distinguish between the delivery of play materials and the delivery of work materials because the latter rarely happened. When demands were accompanied by the delivery of materials (e.g., if the caregiver handed the participant a block and an empty container and said, "Put the block in the bucket"), observers were instructed to err on the side of not scoring the delivery of materials.

Problem behavior included aggression, disruption, and self-injurious behavior. *Aggression* was defined as throwing objects within 1 m of another person or hitting, kicking, pushing, pulling, biting others, or attempts to do so. *Disruption* was defined as throwing objects (but not within 1 m of another person); climbing on furniture; forceful contact of the hand or feet with tables, walls, or floors; and property destruction, including tearing of books or magazines, breaking writing instruments, and drawing on walls. *Self-injury* was defined as forceful contact with the head or hand and hard surfaces, self-pinching, self-choking, and hair pulling.

For Alice and Greg and their parents, descriptive observations were conducted on an inpatient unit that specialized in the treatment of severe problem behavior. Observations were conducted in hospital rooms that contained a sofa, chairs, and table. Additional materials (e.g., toys, books, magazines, videocassettes, television) were also available in the room. Observations were conducted over a period of 1 to 7 weeks, and the total observation time summed to 100 and 110 min, respectively. Individual observation periods lasted between 10 and 20 min, depending on the activity. For these participants, initial observations were unstructured; however, after it became apparent that both caregivers had a tendency to avoid situations that evoked problem behavior, we prompted caregivers to create those situations. Specifically, we asked Alice's caregiver to "show us what happens when you're busy and can't talk to Alice," and we asked both caregivers to "show us what happens when Alice [Greg] cannot have something she [he] wants." The environment was not physically arranged by the experimenter prior to these sessions, but the caregiver was free to use any of the materials already present in the room.

For Amy and Jasmine and their teachers, observations were conducted in their classrooms. Classrooms typically contained chairs, desks, and a sofa. Additional materials (e.g., toys, books, magazines, work materials) were also present. In addition to the participant and the teacher, one or more aides and several students were present. Observations were conducted over a period of 2 to 3 weeks, and the total observation time summed to 130 and 190 min, respectively. Individual observations lasted between 10 and 30 min, depending on the activity. Observations conducted in the classrooms were unstructured, because problem behavior was readily apparent and because it was considered too intrusive to the ongoing classroom activities for the teacher to interrupt planned activities.

An effort was made to conduct descriptive analyses until at least five instances of problem behavior were observed over at least 180 min of observation. However, a high frequency and severity of problem behavior necessitated movement toward functional analysis and treatment earlier than planned for Alice, Greg, and Amy.

Functional Analysis

Following the descriptive analysis, a functional analysis was conducted using procedures similar to those described by Iwata et al. (1982/1994). The same data-collection system used during the descriptive analysis was also used during the functional analysis. In addition, attempts were made to incorporate attention, demands, and preferred items similar to those observed during the descriptive analysis. Functional analyses were conducted in a vacant hospital room on the unit for Alice and Greg and in a spare classroom for Amy and Jasmine. All functional analysis sessions lasted 10 min. Four test conditions and one control condition were alternated in a multielement design. During the control condition, participants were provided with access to preferred materials and continuous attention. Occurrences of problem behavior resulted in no programmed consequences.

An attention condition was implemented to test whether problem behavior was reinforced by therapist attention. During the attention condition, participants had access to preferred materials, as identified by a free-operant preference assessment (Roane, Vollmer, Ringdahl, & Marcus, 1998) while the therapist pretended to work. Occurrences of problem behavior produced 30 s of access to attention, which consisted of a brief reprimand, statements of comfort, and physical contact.

A tangible condition was implemented to test whether problem behavior was reinforced by access to preferred materials. During the tangible condition, participants were provided with continuous attention while the therapist interacted with the participants' preferred materials. Occurrences of problem behavior produced 30 s of access to the preferred materials.

An escape condition was implemented to test whether problem behavior was reinforced by escape from demands. Instructional tasks or demands were selected on the basis of interviews with primary care providers and observations conducted during the descriptive analysis. During the escape condition, each participant sat at a table with work tasks. The therapist guided the participant through the tasks using a graduated, three-prompt sequence (Horner & Keilitz, 1975). The sequence consisted of a verbal prompt, a model of the appropriate response, and physical guidance to complete the appropriate response. Compliance resulted in brief praise and immediate presentation of the next demand. If the participant did not comply within 10 s, the next step in the sequence was initiated. Occurrences of problem behavior produced a 30-s break from demands.

Alone and no-consequence conditions were conducted to test whether problem behavior would persist in the absence of social consequences (automatic reinforcement). No-consequence conditions were conducted for Amy, and alone conditions were conducted for Alice. Only one alone session was conducted for Greg because he rarely engaged in problem behavior outside social contexts, and he attempted to leave the room during the session (data not included). A no-consequence condition was considered for Jasmine, but it would have been difficult to control for therapist reactions (i.e., flinching) to Jasmine's aggression. During either condition, toys and all other potentially preferred materials were removed from the room, and therapist attention was restricted. The only difference between the no-consequence and alone conditions was whether or not adults were present. No-consequence conditions were conducted at the school sites, where it was required that adults remain in the room with students at all times. Alone conditions were conducted on the inpatient unit where one-way windows were available. Occurrences of problem behavior during either condition resulted in no programmed consequences.

Interobserver Agreement

To calculate interobserver agreement for behavior, data from both observers were divided into consecutive 10-s bins, and the smaller number of events recorded by one observer was divided by the larger number of events recorded by the other observer (Iwata, Pace, Cowdery, & Miltenberger, 1994). For behavior and environmental events scored using a duration measure, the smaller number of seconds was divided by the larger number of seconds within the 10-s bins, and the obtained values were averaged for the entire session for all duration measures. In the case in which both observers agreed that zero responses occurred, the interval was scored as 100% agreement. The same calculation methods were used in both the descriptive and functional analyses.

A second independent observer simultaneously and independently scored 36% of observations during the descriptive analysis. Mean interobserver agreement for problem behavior was 96% (range, 90% to 99%). Mean interobserver agreement for relevant environmental events was 86% (range, 82% to 91%).

A second observer recorded data for 58%, 41%, 46%, and 91% of Alice's, Greg's, Amy's, and Jasmine's functional analysis sessions, respectively. Mean agreement for problem behavior was 98% (range, 93% to 100%) for Alice, 90% (range, 79% to 100%) for Greg, 95% (range, 65% to 100%) for Amy, and 98% (range, 96% to 100%) for Jasmine.

Data Preparation

Prior to conducting the lag-sequential analysis, the descriptive analysis data were reviewed for errors that were then either corrected or omitted. Three kinds of errors were identified in the data. First, there was often a delay between the beginning of a session and the time during which the first event or occurrence of problem behavior was recorded. These delays ranged between 0 and 4 s (median, 2 s). This was corrected for by subtracting the delay to the first key from the session duration and the start and stop times of every event or occurrence of problem behavior in the session. Second, keys for EOs and their corresponding reinforcers were sometimes scored in such a way that the events overlapped. For example, the key for "attention on" may not have been turned off until 2 s after "attention off" was turned on, meaning that both were on at the same time (which, according to their mutually exclusive definitions, was impossible). This was corrected for by setting the offset time of the former key to the onset time of the latter. Third, the data contained periods of time during which neither an EO key nor its corresponding reinforcer was scored. If the time during which neither key was scored was greater than 10 s, then that session was omitted from the analysis relevant to those keys. This resulted in one session being removed from the no-demand analysis for Alice and one session being removed from the no-demand analysis for Jasmine. These changes had only minor effects on the subsequent analyses and resulted in no changes to conclusions based on the data.

Lag-Sequential Analysis

A lag-sequential analysis is a procedure used to identify repeated sequences of events and has been used to analyze complex social interactions (Emerson et al., 1995; Sackett, 1979). Time-based lag-sequential analysis allows the calculation of conditional probabilities both backwards and forwards in time relative to a criterion event (G. P. Sackett, personal communication, October 26, 2005). Lag-sequential analyses were conducted by first organizing the data according to each participant and then performing the analysis for each putative reinforcer.

In this study, conditional probabilities (the probability of a potential reinforcer given an instance of problem behavior) were calculated for the 120 s before and the 120 s following instances of problem behavior. Conditional probabilities of potential reinforcers were calculated by dividing the number of times the potential reinforcer was observed at that specific time (with respect to problem behavior) by the number of opportunities there were to observe potential reinforcers at that specific time. The number of opportunities was equal to the number of times problem behavior occurred minus the number of observations that would have fallen outside the session. For example, if 100 instances of problem behavior occurred and attention occurred 20 times in the first second after problem behavior, the conditional probability would have been .20. Suppose (for the purposes of describing these calculations) that 25 of those 100 instances of problem behavior occurred during the last second of the observation. Under those conditions, there would have been 25 fewer opportunities to observe attention in the second following problem behavior. Therefore, the number of opportunities would have been 75 instead of 100 and the conditional probability would have been .27 (20 of 75). This description for the calculation of conditional probabilities entails that each obtained probability is an aggregate. Specifically, it is the proportion of observations (at a specific point in time in relation to the occurrence of problem behavior) in which a potential reinforcer was observed.

Several window sizes were informally evaluated prior to the study. This evaluation determined that window sizes could be increased to span up to 240 s and still clearly depict changes in probability within the 10 s immediately surrounding behavior. Therefore, a total window size of 240 s was chosen to capture as large a sample as possible. (Readers who wish to consider only more immediate changes can easily do so by obscuring the ends of the figures using a sheet of paper.)

Conditional probabilities were calculated for environmental events surrounding each instance of problem behavior, independent of intervening instances of problem behavior. This meant that the observation windows overlapped if two or more instances of behavior occurred within 120 s of each other. For example, if problem behavior occurred at Seconds 200 and 215, conditional probabilities were calculated for the first instance from Second 80 to Second 320 and for the second instance from Second 95 to Second 335. Therefore, the conditional probability should be interpreted to mean the proportion of instances of problem behavior that were either preceded or followed by a potential reinforcer (at the specific time in question). An alternative method could have been to calculate conditional probabilities for each second before and after problem behavior until another instance of problem behavior was observed. However, we believed that results from such an approach would have been more difficult to interpret and contained implicit assumptions about the effects of intervening occurrences of problem behavior on reinforcers rather than simply a description of the temporal relation between behavior and potential reinforcers.

Conditional probabilities of potential reinforcers were also calculated for the nonoccurrence of problem behavior. This calculation was identical to the lag-sequential analysis described above, with one exception. The probability of observing potential reinforcers was calculated for each of the 120 s before and after every second that did not contain problem behavior. This is in contrast to the previous calculation that examined each of the 120 s before and after each instance of problem behavior.

Unconditional probabilities of potential reinforcers were also calculated. This calculation was identical to the above analyses, with one exception. The probability of observing potential reinforcers was calculated for each of the 120 s before and after every second in the observation.

The lag-sequential analysis calculations described above were altered slightly to produce a measure called *within-EO* (Vollmer et al., 2001). For within-EO lag-sequential analysis calculations, instances of problem behavior were included only if they occurred during the absence of the putative reinforcer. For example, when calculating the within-EO lag-sequential analysis of attention given problem behavior, instances of problem behavior were included only when they occurred during the absence of antecedent attention (i.e., during "attention off"). Suppose 30 instances of problem behavior were recorded during a given observation. If 20 of those instances of problem behavior occurred in the presence of an EO, only those 20 were used to calculate the conditional probability of a potential reinforcer. The calculations for conditional probability given the nonoccurrence of behavior and unconditional probability were conducted by evaluating the probability of potential reinforcers 120 s before and after seconds without problem behavior and every second, respectively, while the EO was in place. For all of the within-EO calculations, the observation window was free to fall outside the EO. The probability of a potential reinforcer can only increase following behavior; therefore, the useful comparison is between the conditional probability of a potential reinforcer following behavior and the unconditional probability or the probability of a potential reinforcer following the nonoccurrence of behavior.

Custom software was written by the first author to conduct the lag-sequential analyses. The software was initially written in Visual Basic; however, running the analysis required more than 20 hr of computation for a single data set using a Pentium IV 2-Ghz processor. Subsequently, the software was rewritten in C and required less than a minute to compute a single data set. Validation of the software was performed by repeatedly comparing the outputs of both programs to sets of lag-sequential analysis data that were calculated by hand.

All contingencies were identified using visual inspection of the plotted lag-sequential analysis data. We did not conduct statistical tests of significance because we could not find compelling evidence that a statistically significant difference (between the comparison conditional probability values) was a necessary condition to observe reinforcement effects. In addition, it seemed intuitive that problem behavior could be maintained in the absence of a statistically significant difference. For example, Skinner (1956) showed that even a single instance of a reinforcer presentation was sufficient to maintain behavior.

RESULTS

Functional Analysis

Figure 1 shows the functional analysis results for Alice, Greg, Amy, and Jasmine. Results for Alice showed the highest levels problem behavior in the attention and escape conditions, suggesting that her problem behavior was reinforced by attention and escape. Results for Greg showed the highest levels of problem behavior in the tangible condition. This suggested that his problem behavior was reinforced by access to tangible items. Results for Amy showed higher rates of problem behavior during tangible and escape conditions than in the control. This suggested that her problem behavior was reinforced multiply by access to tangible items and escape from demands (note that the functional analysis results for Amy were previously reported by St. Peter et al., 2005, but are reproduced here for convenience). Results for Jasmine showed high rates across every test condition. Thus, her problem behavior was multiply reinforced by access to tangible items, access to attention, and escape from demands.

Descriptive Analysis

Alice, Greg, Amy, and Jasmine were observed while interacting with their caregivers for approximately 100, 110, 130, and 190 min, respectively. During that period, Alice emitted 40 instances of problem behavior. In addition, her caregivers implemented approximately 67 min of attention, 91 min of access to toys, and 81 min of breaks from tasks (rounded to the nearest minute). During Greg's observations, he emitted 33 instances of problem behavior. His caregivers implemented approximately 86 min of attention, 53 min of access to toys, and 81 min of breaks from tasks. During Amy's descriptive analysis, she emitted 469 instances of problem behavior. Her caregivers implemented approximately 44 min of attention, 108 min of access to toys, and 101 min of breaks from tasks. During Jasmine's descriptive analysis, she emitted 25 instances of problem behavior. Her caregivers implemented approximately 37 min of attention, 81 min of access to toys, and 170 min of breaks from tasks.

Lag-Sequential Analyses

The purpose of the study was to examine the pattern of environmental events most similar to reinforcers identified via the functional analysis. Therefore, only lag-sequential analyses of events identified as reinforcers by the functional analysis are presented below. In the interest of space, only Jasmine's lag-sequential analysis of no demands and Amy's lag-sequential analysis of access to tangible items are presented. In addition, Jasmine's within-EO lag-sequential analysis was removed because only one instance

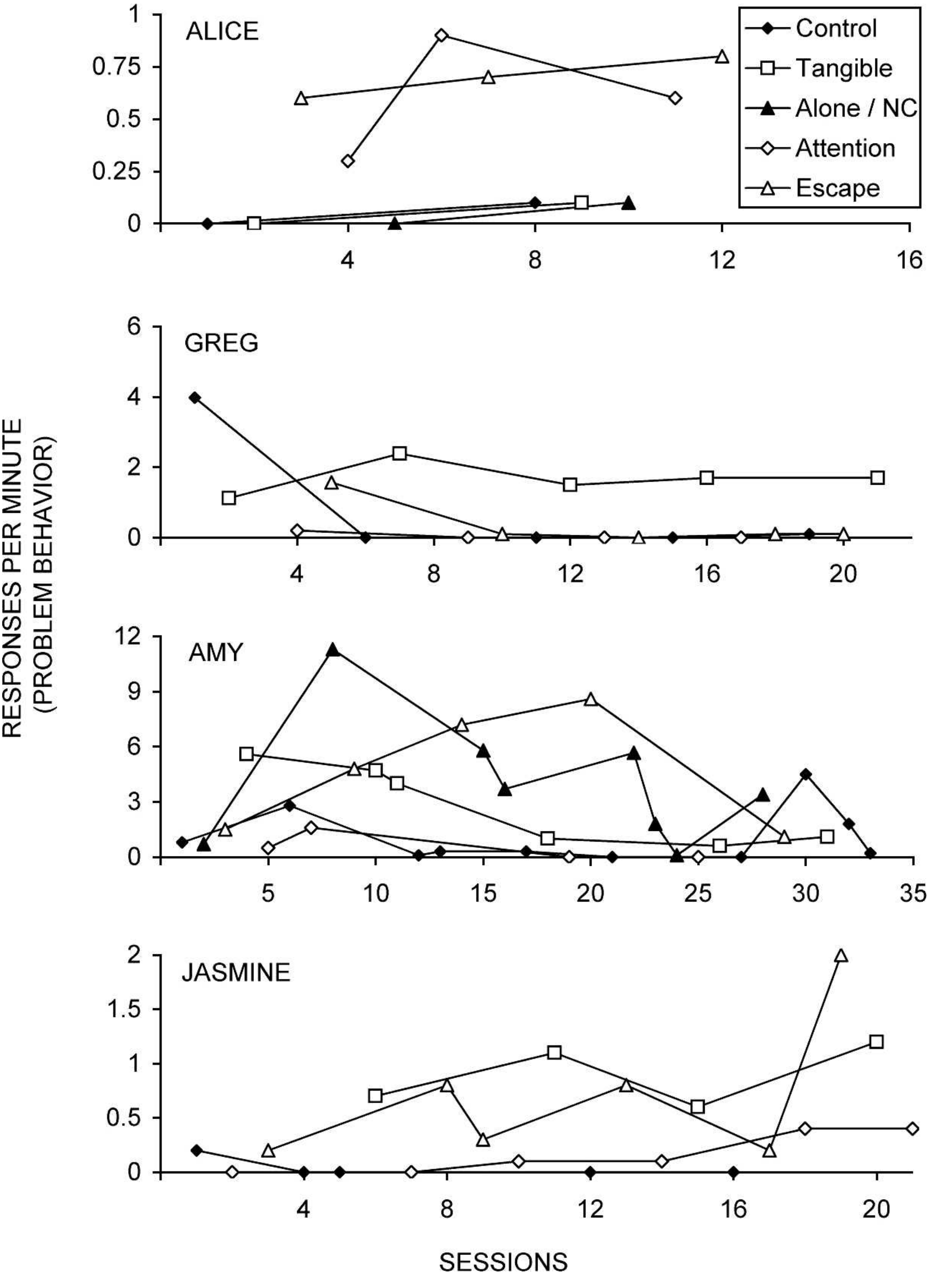

Figure 1. Functional analysis results for Alice, Greg, Amy, and Jasmine.

of problem behavior occurred while demands were being presented. The remaining analyses may be obtained from the first author.

Initial examination of the data revealed no visible differences between the data paths depicting the unconditional probability of potential reinforcers and the conditional probability of potential reinforcers given the nonoccurrence of behavior for any of the participants and analyses. Therefore, the results for the unconditional probability of potential reinforcers will not be discussed below.

The names given to potential reinforcers in the following section do not attempt to differentiate between the onset of an event (e.g., a potential EO or a reinforcer) and its continued presentation. For example, the words *no demands* refer to both the transition from a period of demands to the withdrawal of demands (escape) and the continued absence of demands. However, for the sake of clarity, both are referred to as *no demands*. The same is also true for *access to toys* and *attention*.

Figures 2 through 7 show the relation between occurrences of problem behavior and an event similar to those identified as a reinforcer (via functional analyses) for that behavior for each participant. Seconds before and after problem behavior are depicted along the *x* axis, and the probability of observing the putative reinforcer is depicted along the *y* axis.

Figure 2 shows the results of Alice's lag-sequential analysis for attention. The top panel shows two data paths: the probability of attention given the occurrence of problem behavior and the probability of attention given the nonoccurrence of problem behavior. These data paths show two positive contingencies. The first positive contingency is indicated by an increase in the probability of attention given an occurrence of problem behavior starting 3 s after occurrences of problem behavior. This increase shows that attention was more likely to be observed after problem behavior than before. The second positive contingency is indicated by the difference between the probability of attention given an occurrence of problem behavior and the probability of attention given the nonoccurrence of problem behavior. This difference shows that attention was more likely to be observed following problem behavior than following any other second of the observation during which problem behavior was not observed.

The bottom panel of Figure 2 shows two data paths: the within-EO probability of attention given the nonoccurrence of behavior and the within-EO probability of attention given the occurrence of problem behavior. These data paths show a positive contingency. The positive contingency is indicated by the difference between the probability of attention given the nonoccurrence of behavior and the conditional probability of attention given behavior to the right of the vertical line indicating occurrences of problem behavior. This shows that attention was more likely to be observed following problem behavior (that occurred while attention was not delivered) compared to seconds during which problem behavior was not observed.

Figure 3 shows the results of Alice's lag-sequential analysis for no demands. The top panel shows two data paths: the probability of no demands given the occurrence of problem behavior and the probability of no demands given the nonoccurrence of problem behavior. The data show two negative contingencies and one positive contingency. The first negative contingency is depicted in the decrease in the probability of no demands (given an occurrence of problem behavior) immediately before to immediately after occurrences of problem behavior. This decrease shows that periods without demands were less likely to be observed just after problem behavior than just before problem behavior. In other words, demands were more likely following problem behavior (e.g., if Alice engaged in throwing an item, her caregivers might have instructed her to pick it up, which would produce an increase in the

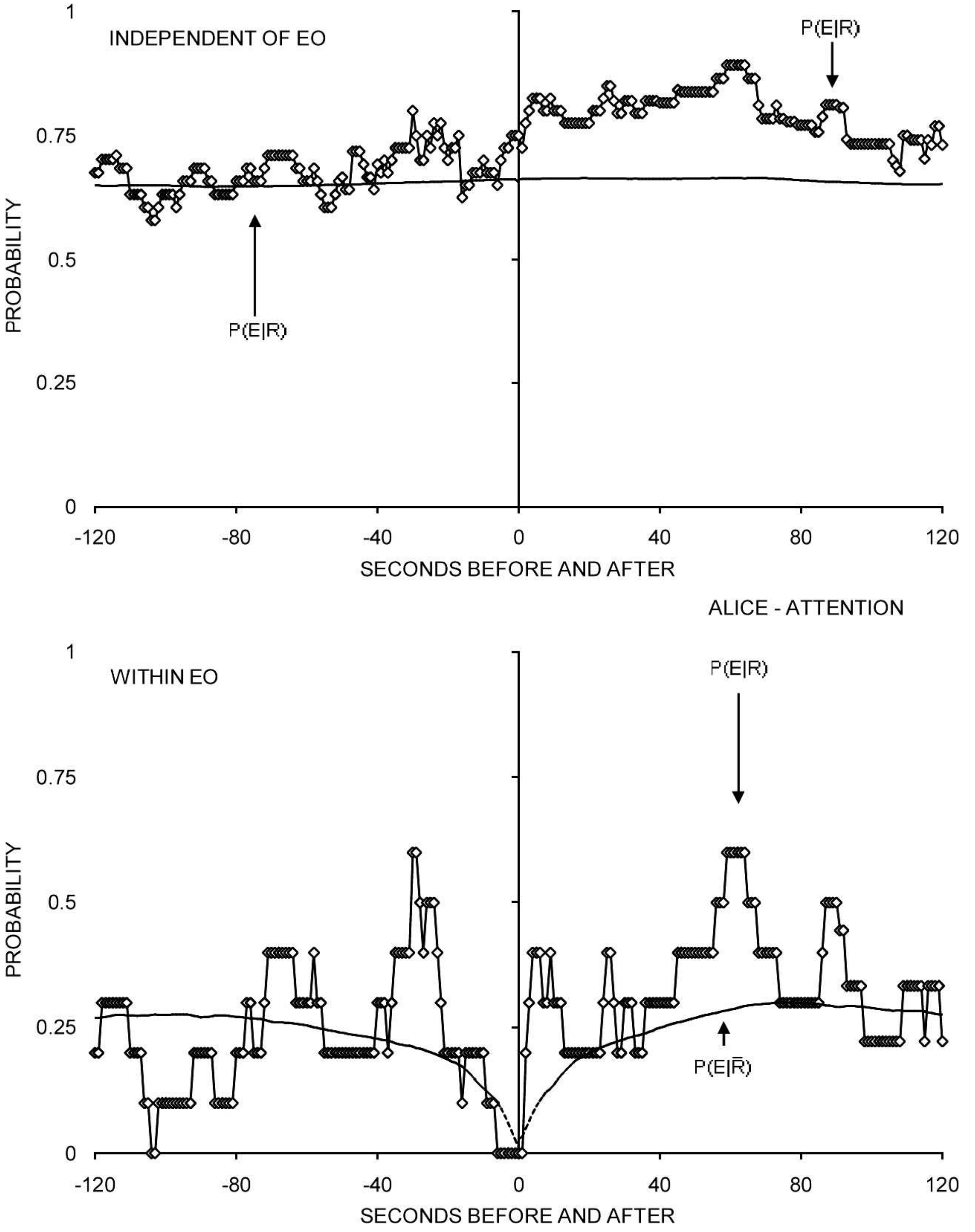

Figure 2. The lag-sequential analysis of attention for Alice. The open diamonds show the probability of attention (E) given an occurrence of problem behavior (R). The solid line shows the probability of attention given the nonoccurrence of problem behavior ($\overline{\mathrm{R}}$).

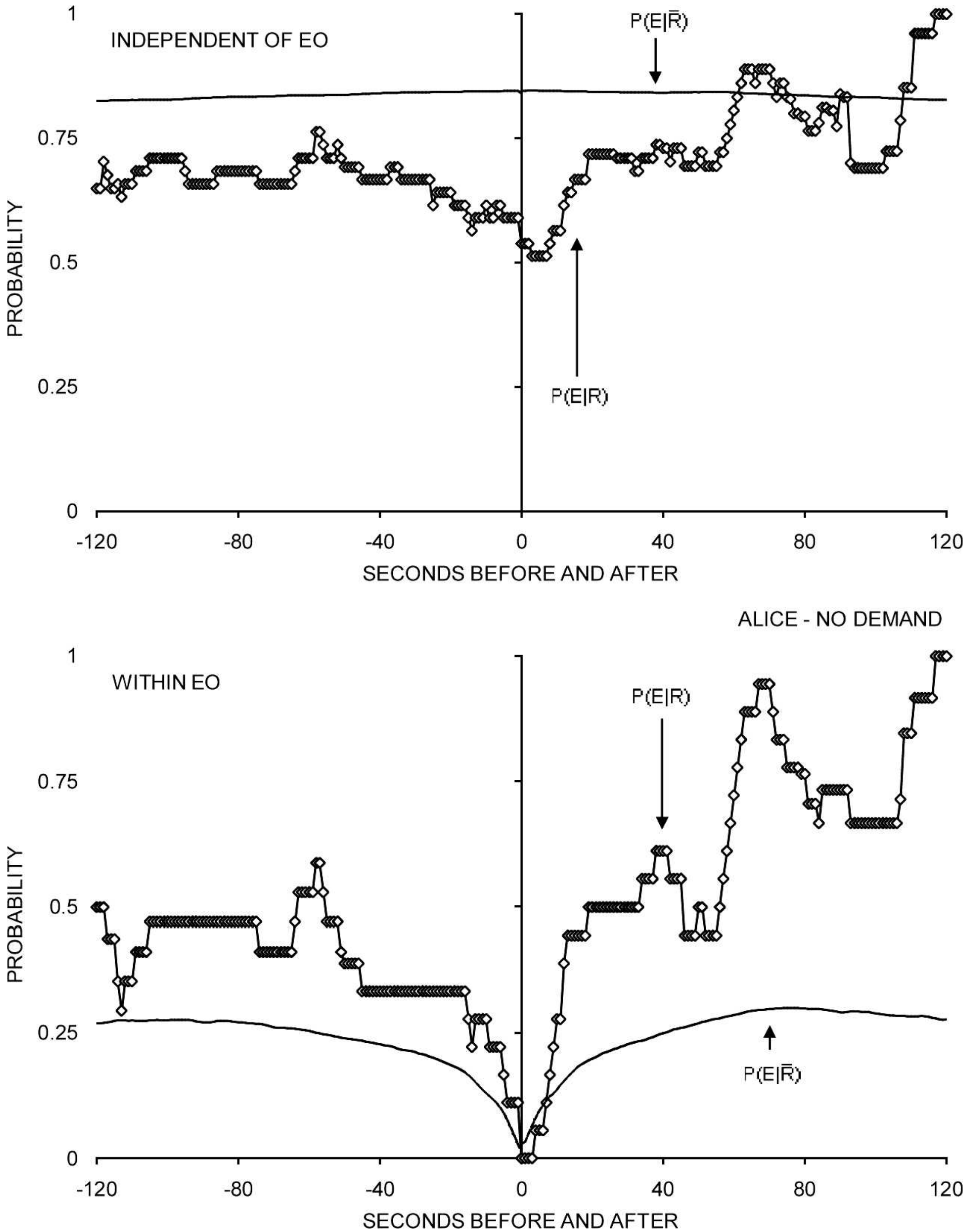

Figure 3. The lag-sequential analysis of no demands for Alice. The open diamonds show the probability of no demands (E) given an occurrence of problem behavior (R). The solid line shows the probability of attention given the nonoccurrence of problem behavior ($\overline{R}$).

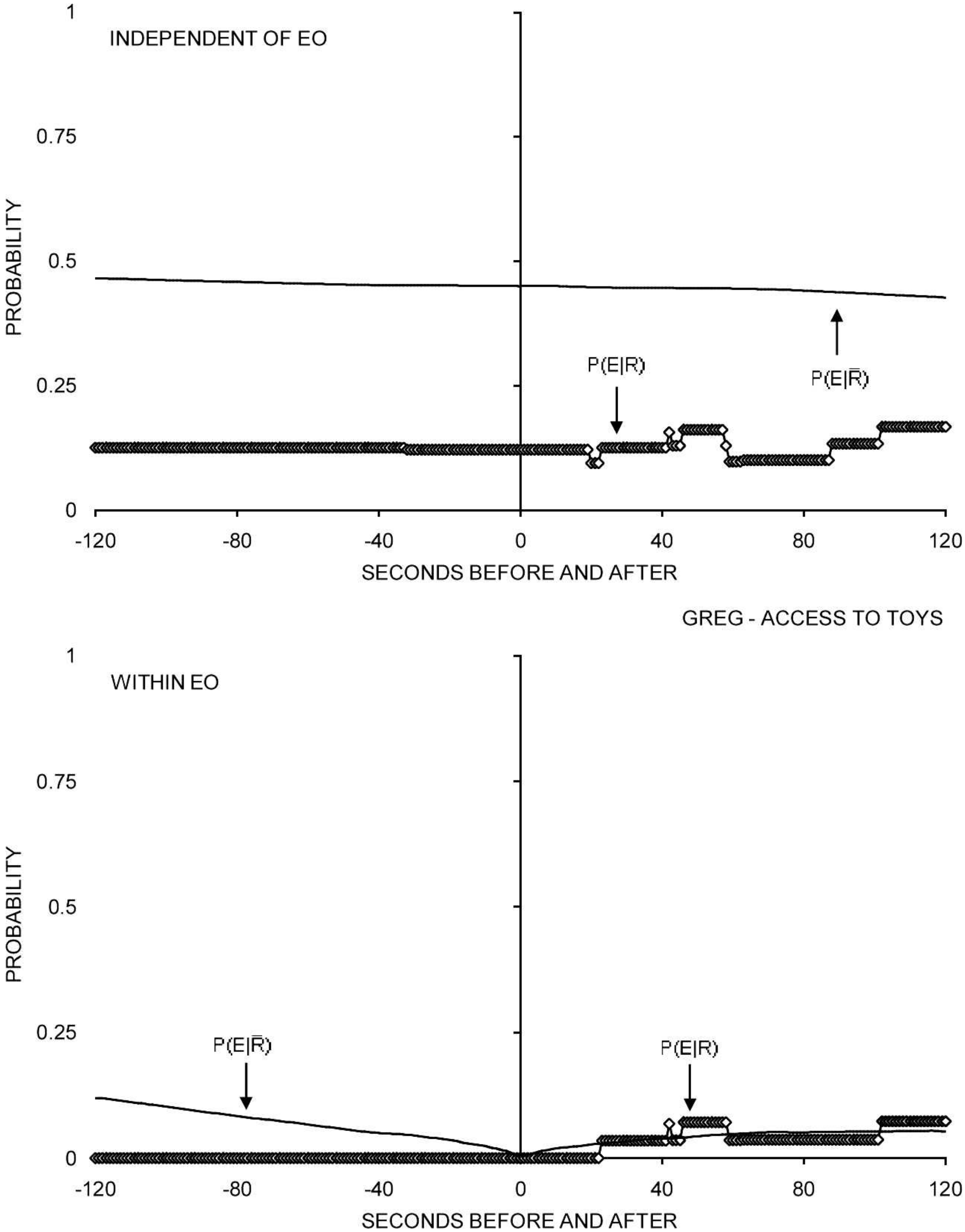

Figure 4. The lag-sequential analysis of access to toys for Greg. The open diamonds show the probability of access to toys (E) given an occurrence of problem behavior (R). The solid line shows the probability of access to toys given the nonoccurrence of problem behavior ($\overline{R}$).

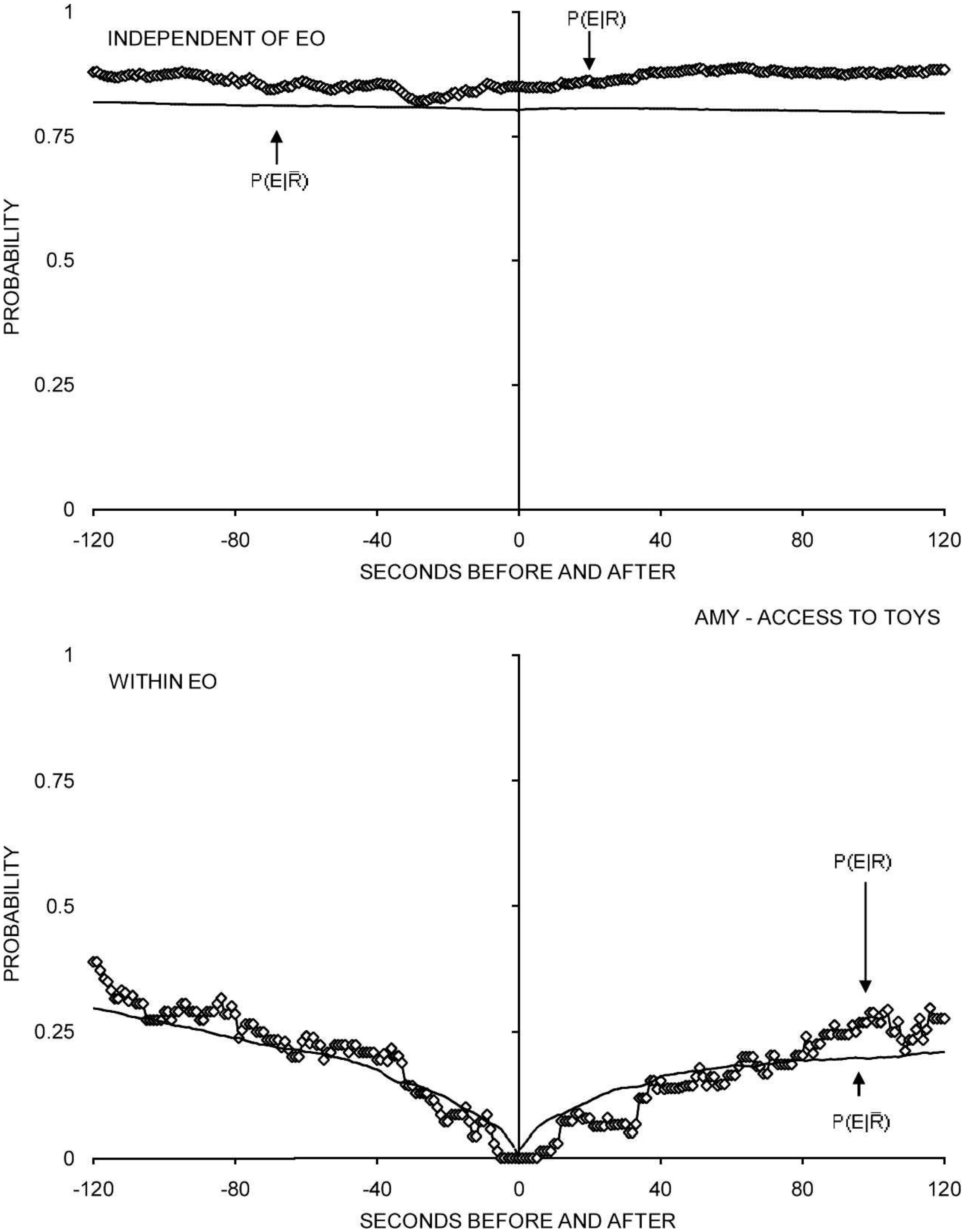

Figure 5. The lag-sequential analysis of access to toys for Amy. The open diamonds show the probability of access to toys (E) given an occurrence of problem behavior (R). The solid line shows the probability of access to toys given the nonoccurrence of problem behavior ($\overline{R}$).

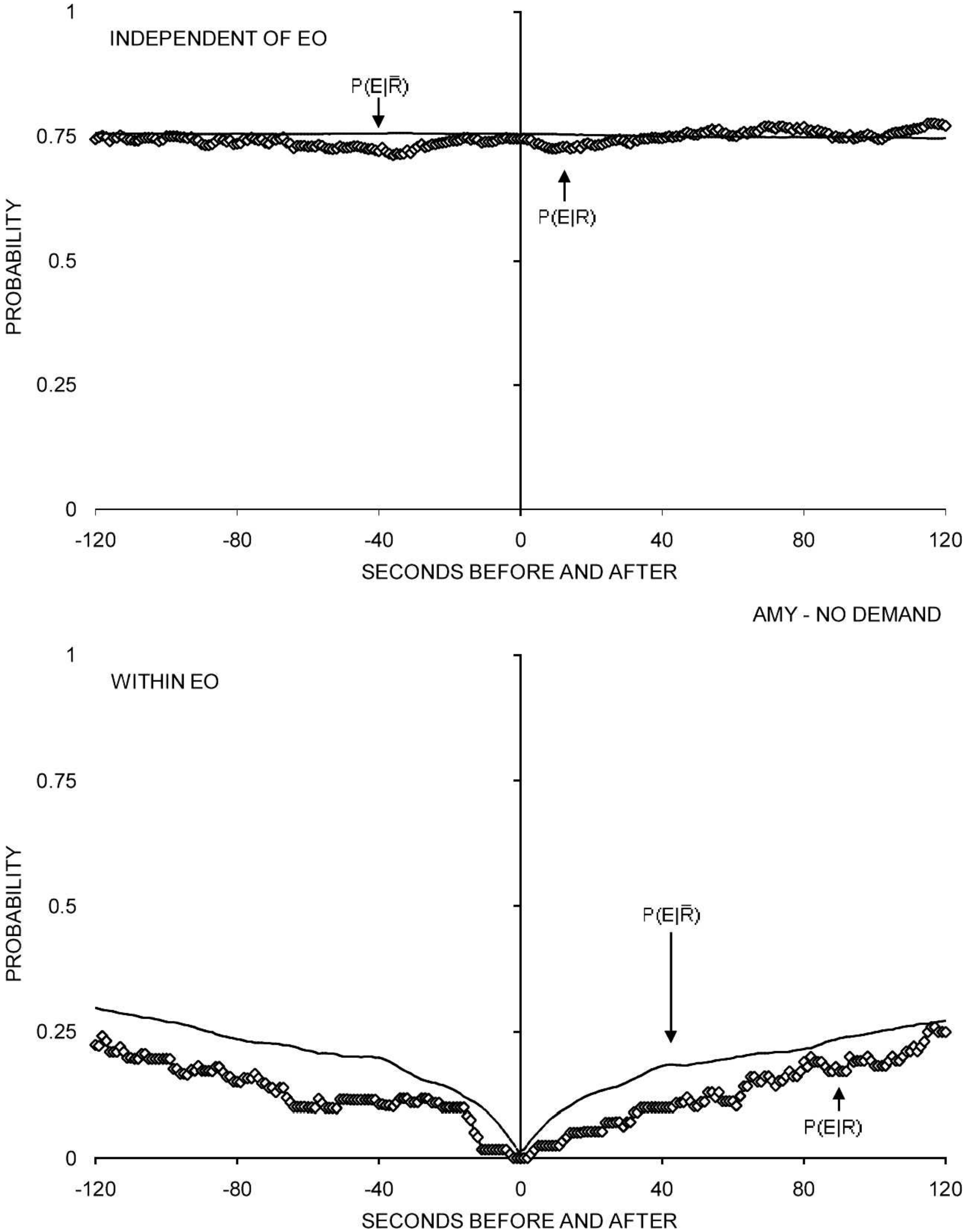

Figure 6. The lag-sequential analysis of no demands for Amy. The open diamonds show the probability of no demands (E) given an occurrence of problem behavior (R). The solid line shows the probability of no demands given the nonoccurrence of problem behavior ($\overline{R}$).

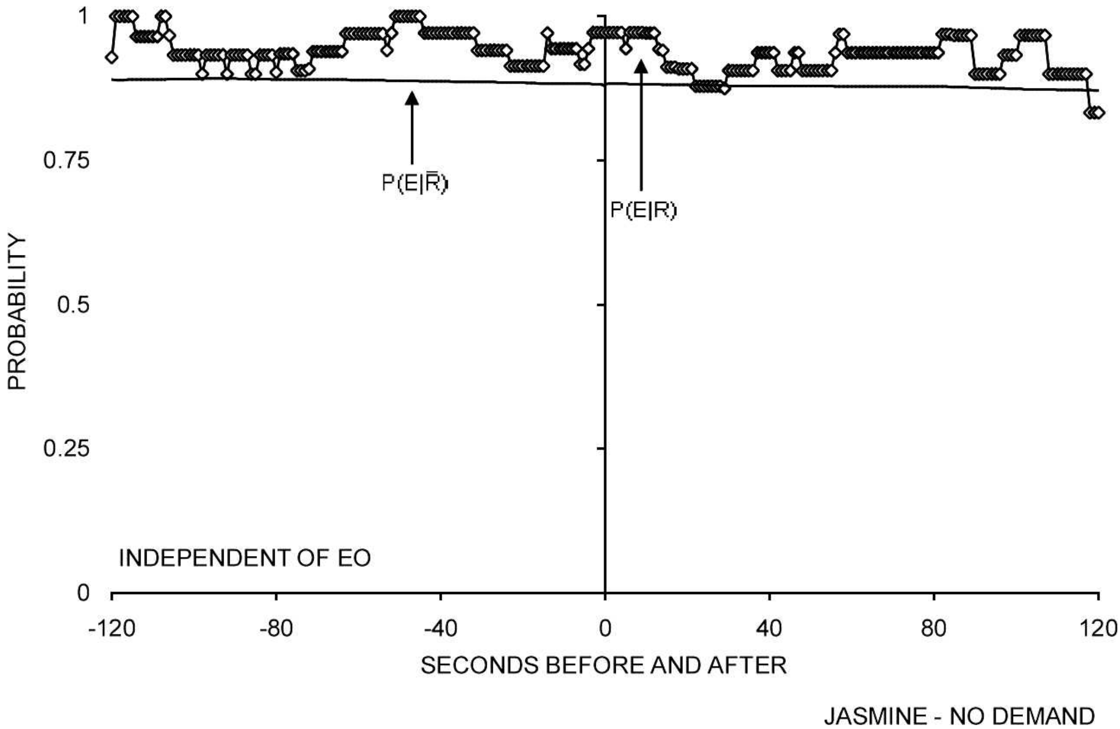

Figure 7. The lag-sequential analysis of no demands for Jasmine. The open diamonds show the probability of no demands (E) given an occurrence of problem behavior (R). The solid line shows the probability of no demands given the nonoccurrence of problem behavior ($\overline{R}$).

probability of demands following problem behavior). The second negative contingency is indicated by the difference between the probability of no demands given an occurrence of problem behavior and the probability of no demands given the nonoccurrence of problem behavior. This difference shows that periods of no demands were less likely to be observed following problem behavior than following any second of the observation during which problem behavior was not observed. The positive contingency is indicated by the upward trend in the conditional probability of no demands for most of the 120 s following behavior. As with all conclusions about functional relations based on descriptive analyses, the presence of the upward trend may not have any effect on behavior. Nonetheless, it is interesting to consider the possibility that such a change in the trend of no demands could produce a reinforcement effect.

The bottom panel of Figure 3 shows two data paths: the within-EO probability of no demands given the nonoccurrence of behavior and the within-EO probability of no demands given the occurrence of problem behavior. These data show that demands were more likely to have terminated within 10 s following seconds in which problem behavior did not occur compared to following seconds in which problem behavior did occur (a negative contingency). However, the probability of no demands following problem behavior continued to increase at a rate higher than the probability of no demands following seconds without problem behavior (a positive contingency). This suggests that although demands were never terminated within the first 3 s following problem behavior, they were more likely to have ended between 12 and 45 s after problem behavior than after seconds without problem behavior. Furthermore, this disparity was also present from 58 s to 101 s and again from 107 s to 120 s.

Figure 4 shows the results of Greg's lag-sequential analysis for access to toys. The data displayed in the top panel suggest a negative contingency. This is indicated by the difference between the probability of toys given an occurrence of problem behavior and the probability of toys given the nonoccurrence of a problem behavior. This difference shows that toys were less likely to be available following problem behavior than following any other second of the observation during which problem behavior was not observed.

The lower panel of Figure 4 shows two data paths: the within-EO probability of access to toys following the nonoccurrence of problem behavior and the within-EO probability of access to toys following the occurrence of problem behavior. Similar to the within-EO no-demands data for Alice, these data show alternating periods of negative, neutral, and positive contingencies. The probability of having access to toys was higher during the first 22 s following seconds in which problem behavior did not occur. The probability of having access to toys was comparable from 23 s to 41 s following problem behavior and following seconds not containing problem behavior. Conversely, the probability of having access to toys from 42 s to 58 s was higher following seconds containing problem behavior. At greater delays, a negative contingency was present from 59 s to 101 s, and a positive contingency was present from 102 s on.

Figure 5 shows the results of Amy's lag-sequential analysis for access to toys. The top panel shows two data paths: the probability of access to toys given the occurrence of problem behavior, and the probability of access to toys given the nonoccurrence of problem behavior. These data paths show two positive contingencies. The first positive contingency is indicated by a subtle increase in the probability of access to toys following problem behavior over time (from .8507 to .8850). This suggests that access to toys became more likely as more time passed following problem behavior. However, it was not simply the case that the probability of access to toys increased throughout the session independent of behavior, because the probability of access to toys following seconds in which problem behavior did not occur actually decreased slightly (from .8042 to .7972). The second positive contingency is indicated by the difference between the probability of access to toys given an occurrence of problem behavior and the probability of access to toys given the nonoccurrence of problem behavior. This difference shows that Amy was more likely to have access to toys following problem behavior than following any other second of the observation during which problem behavior was not observed.

The bottom panel of Figure 5 shows two data paths: the within-EO probability of access to toys following the nonoccurrence of problem behavior and the within-EO probability of access to toys given the occurrence of problem behavior. These data paths indicate that access to toys was more likely to occur within 77 s following periods not containing problem behavior compared to seconds containing problem behavior (a negative contingency). However, that relation flips when depicting the period from 78 s to 120 s (a positive contingency).

Figure 6 shows the results of Amy's lag-sequential analysis for no demands. The top panel shows two data paths: the probability of no demands given the occurrence of problem behavior, and the probability of no demands given the nonoccurrence of problem behavior. The probability of no demands did not increase following behavior compared to before behavior (indicating a neutral contingency). However, the probability of no demands did increase following behavior from 34 s to 85 s and from 96 s to 120 s compared to following seconds without problem behavior (a positive contingency).

The bottom panel of Figure 6 shows two data paths: the within-EO unconditional probability of no demands and the within-EO probability of no demands given the occurrence of problem behavior. These data paths show a negative contingency. The negative contingency is indicated by the difference between the probability of no demands following the nonoccurrence of problem behavior compared to the probability of no demands following the occurrence of problem behavior. This shows that periods of no demands were less likely to be observed following problem behavior that occurred during the presentation of a task compared to seconds without problem behavior (while tasks were still being presented).

Figure 7 shows the results of Jasmine's lag-sequential analysis for no demands. The data show a positive contingency. The positive contingency is indicated by the difference between the probability of no demands given an occurrence of problem behavior and the probability of no demands given the nonoccurrence of problem behavior. This difference shows that periods of no demands were more likely to be observed following problem behavior than following any other second of the observation during which problem behavior was not observed.

DISCUSSION

This study detailed a method of data analysis called lag-sequential analysis to examine the relations between severe problem behavior emitted by adolescents and the behavior of their caregivers. The stimulus functions of common antecedents and consequences (e.g., attention, escape from demands, and delivery of toys) were evaluated for each participant using functional analysis methods similar to those described by Iwata et al. (1982/1994). Lag-sequential analyses were then performed on data collected during interactions between caregivers and adolescents with severe problem behavior. Potential reinforcement contingencies were found to follow one or more of three basic patterns: (a) Conditional probabilities (of putative reinforcing events) were higher following problem behavior than before problem behavior, (b) conditional probabilities were higher following problem behavior than were conditional probabilities given no problem behavior (and unconditional probability), and (c) problem behavior was correlated with a change in the trend of conditional probabilities (e.g., although the conditional probability of no demands for Alice was not initially high following problem behavior, problem behavior was correlated with a change in trend from decreasing to increasing probability). To our knowledge, this is the first demonstration of momentary fluctuations in probability of events after identifying reinforcers via functional analysis. Thus, the present method represents a tentative step forward to examine potential reinforcement contingencies that operate in the natural environment.

It is important to emphasize that the current application of descriptive analysis was not intended to replace the role of a functional analysis. This study did not involve a comparison between functional analysis and descriptive analysis methods. Instead, the approach was designed, in a sense, to take a snapshot of behavior and environmental events and then to evaluate the snapshot after reinforcers had been identified via functional analysis. The idea is that it may be useful to understand how, and in what relation to behavior, events similar to those identified in the functional analysis actually occur during adult–child interactions. Thus, the approach was not presented as a clinical assessment procedure and should not be construed as such. Specifically, we do not recommend that a lag-sequential descriptive analysis be inserted into a functional assessment regimen. Rather, it is hoped that the information obtained from the study might be useful to application and in future applied research.

One way the study might influence future application is by emphasizing the complexity of reinforcement contingencies. Although it is perhaps not surprising for behavior analysts, the results suggest that potentially reinforcing events might exert influence over behavior even when they occur in very subtle ways. For example, in Alice's case, the negative contingency present in the first 11 s following problem behavior suggests that her caregivers were implementing something akin to brief differential reinforcement of other behavior. However, the data also show a positive contingency between Seconds 12 and 45. From Alice's perspective, it may be that although problem behavior did not immediately produce a break from demands, her caregivers were more likely to provide escape after a brief delay. Such a pattern could be missed by a casual observation or even the calculation of conditional probabilities 10 s following problem behavior. To address this, specific training could be provided to Alice's caregivers to continue implementing demands for 1 min following problem behavior.

A second way that the study might influence future research is from its emphasis that descriptive research should continue not necessarily for the purpose of identifying methods as suitable replacements for a functional analysis but rather for the purpose of identifying the kinds of potential reinforcement contingencies that should be evaluated in both basic and applied research. For example, although research on descriptive analysis has focused on the identification of positive contingencies between behavior and environmental events, it is possible that in some cases behavior could persist in the presence of a negative or neutral contingency. An individual with an extensive reinforcement history might continue to engage in problem behavior in the face of a treatment involving differential reinforcement of other behavior. It is possible that, under such conditions, the occasional mistake of delivering a reinforcer following problem behavior could serve to maintain behavior, despite the overriding negative contingency in place. We are currently evaluating negative contingencies and history effects in our animal operant laboratory (Samaha, Vollmer, & Osteen, 2005), and we hope to extend that research to severe behavior disorders. For example, how negative does a new contingency need to be in order to suppress behavior previously reinforced by strong positive contingencies?

The specific approach used in this study, lag-sequential analysis, has advantages over other data-summary approaches (e.g., it allows moment-to-moment evaluations of probability), but it also has clear disadvantages. In some cases, the lag-sequential analysis provided a plausible description of behavior and reinforcement in the natural environment. Alice's attention data (Figure 2, top) are perhaps the clearest, reflecting a clear change in the conditional probability of attention before and after problem behavior and following problem behavior compared to following seconds without problem behavior. In other cases, different contingency measures provided contradictory information. Amy's access to materials data (Figure 5, top) reflect hardly any discernible change in the probability of access before and after problem behavior, but a clear difference in the comparison between conditional probabilities given problem behavior and seconds without problem behavior. In other cases, results of the lag-sequential analysis failed to describe any plausible reinforcing relation. Greg's access to materials data (Figure 4) show the largest obtained difference between the probability of a potential reinforcer following problem behavior compared to following seconds without problem behavior, yet in a direction opposite than that expected for the reinforcement of problem behavior. In fact, an examination of the session-by-session data suggested no clear relation between the potential reinforcer and problem behavior. A within-session analysis showed that he had undisrupted access to materials prior to and during problem behavior during the session in which he engaged in the highest rates of problem behavior. One possible explanation for the failure to identify a plausible reinforcing relation is that the reinforcer for Greg's problem behavior was not presented (contingent on behavior) during the descriptive analysis. If so, problem behavior may have been reinforced in some other environment and occurred during the descriptive analysis as a result of generalization or induction. This problem raises a larger question: How much descriptive data are needed to provide a representative sample of events?

In addition to concerns about the lag-sequential approach itself, there are other limitations to the current study that are perhaps inherent to descriptive research. Supposedly similar events were delivered as consequences during the functional and descriptive analyses. For example, the attention delivered by the therapists during functional analysis sessions may have been functionally different than the attention delivered by caregivers during the descriptive analysis. Similarly, it is not known whether periods without demands function similarly to periods of transition from demand to no demand (i.e., a true escape contingency). Attempts were made to incorporate similar forms of attention, preferred materials, and demands into the functional analysis that were observed in the descriptive analysis; however, no claim is made that the events were exactly the same. Future research might attempt to increase the similarities between functional and descriptive analyses by having caregivers serve as therapists during the functional analysis sessions or by attempting to assess the relative reinforcing efficacy of events as delivered by caregivers and therapists.

In conclusion, a method for identifying possible reinforcement contingencies was evaluated. It was necessary to conduct a functional analysis to identify the stimulus functions of possible reinforcers. In future work, functional analyses could be conducted using contingency arrangements similar to those found in the descriptive analysis. Perhaps these analyses will allow more to be learned about the nature of reinforcement.

REFERENCES

Borrero, J. C., & Vollmer, T. R. (2002). An application of the matching law to severe problem behavior. *Journal of Applied Behavior Analysis*, *35*, 13–27.

Catania, A. C. (1998). *Learning*. Englewood Cliffs, NJ: Prentice Hall.

Emerson, E., Thompson, S., Reeves, D., Henderson, D., & Robertson, J. (1995). Descriptive analysis of multiple response topographies of challenging behavior across two settings. *Research of Developmental Disabilities*, *16*, 301–329.

Horner, R. D., & Keilitz, I. (1975). Training mentally retarded adolescents to brush their teeth. *Journal of Applied Behavior Analysis*, *8*, 301–309.

Iwata, B. A., Dorsey, M. F., Slifer, K. J., Bauman, K. E., & Richman, G. S. (1982). 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., Pace, G. M., Cowdery, G. E., & Miltenberger, R. G. (1994). What makes extinction work: An analysis of procedural form and function. *Journal of Applied Behavior Analysis*, *27*, 131–144.

Lerman, D. C., & Iwata, B. A. (1993). Descriptive and experimental analyses of variables maintaining self-injurious behavior. *Journal of Applied Behavior Analysis*, *26*, 293–319.

Roane, H. S., Vollmer, T. R., Ringdahl, J. E., & Marcus, B. A. (1998). Evaluation of a brief stimulus preference assessment. *Journal of Applied Behavior Analysis*, *31*, 605–620.

Sackett, G. P. (1979). The lag sequential analysis of contingency and cyclicity in behavioral interaction research. In J. D. Osofsky (Ed.), *Handbook of infant development* (pp. 623–649). New York: Wiley.

Samaha, A. L., Vollmer, T. R., & O'Steen, L. E. (2005, May). *Some effects of contingency manipulations on responding with rats*. Presentation at the annual meeting of the Association for Behavior Analysis, Chicago.

Skinner, B. F. (1956). A case history in the scientific method. *American Psychologist*, *11*, 221–233.

Sloman, K. N., Vollmer, T. R., Cotnoir, N. C., Borrero, C. S. W., Borrero, J. C., Samaha, A. L., et al. (2005). Descriptive analyses of parent reprimands. *Journal of Applied Behavior Analysis*, *38*, 373–383.

St. Peter, C. C., Vollmer, T. R., Bourret, J. C., Borrero, C. S. W., Sloman, K. N., & Rapp, J. T. (2005). On the role of attention in naturally occurring matching relations. *Journal of Applied Behavior Analysis*, *38*, 429–443.

Thompson, R. H., & Iwata, B. A. (2001). A descriptive analysis of social consequences following problem behavior. *Journal of Applied Behavior Analysis*, *34*, 169–178.

Thompson, R. H., & Iwata, B. A. (2007). A comparison of outcomes from descriptive and functional analyses of problem behavior. *Journal of Applied Behavior Analysis*, *40*, 333–338.

Vollmer, T. R., Borrero, J. C., Wright, C. S., Van Camp, C., & Lalli, J. S. (2001). Identifying possible contingencies during descriptive analyses of severe behavior disorders. *Journal of Applied Behavior Analysis*, *34*, 269–278.

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