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FUNCTIONAL ANALYSIS OF PROBLEM BEHAVIOR: A REVIEW

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Functional analysis methodology focuses on the identification of variables that influence the occurrence of problem behavior and has become a hallmark of contemporary approaches to behavioral assessment. In light of the widespread use of pretreatment functional analyses in articles published in this and other journals, we reviewed the literature in an attempt to identify best practices and directions for future research. Studies included in the present review were those in which (a) a pretreatment assessment based on (b) direct observation and measurement of (c) problem behavior was conducted under (d) at least two conditions involving manipulation of an environmental variable in an attempt (e) to demonstrate a relation between the environmental event and behavior. Studies that met the criteria for inclusion were quantified and critically evaluated along a number of dimensions related to subject and setting characteristics, parametric and qualitative characteristics of the methodology, types of assessment conditions, experimental designs, topographies of problem behaviors, and the manner in which data were displayed and analyzed.

DESCRIPTORS: functional analysis, assessment, problem behavior

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Functional analysis methodology identifies variables that influence the occurrence of problem behavior and has become a hallmark of behavioral assessment (see the special issue on functional analysis in the *Journal of Applied Behavior Analysis* [*JABA*], 1994, Vol. 27). Prior to the advent of functional analysis approaches to assessment, problem behavior was typically treated by superimposing powerful arbitrary contingencies of reinforcement or punishment over existing but often unknown sources of reinforcement for problem behavior (Mace, 1994). By contrast, by identifying contingencies that currently maintain problem behavior, relevant consequences and their associated discriminative stimuli (S^Ds) and establishing operations (EOs) may be altered to reduce problem behavior. In essence, functional analysis methodology reemphasized the importance of applied research in contributing to an understanding of the determinants of behavior as the basis for identifying effective treatments that produce generalized results.

Since the development of comprehensive models for conducting functional analyses (i.e., those that examined multiple sources

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of influence; E. G. Carr & Durand, 1985; Iwata, Dorsey, Slifer, Bauman, & Richman, 1982/1994), hundreds of direct and systematic replications, as well as extensions across populations, settings, and topographies of problem behavior, have been reported in the literature. However, the extent of these variations has not yet been systematically evaluated or critically examined. The purpose of this review is to provide a quantitative and qualitative analysis of research on the functional analysis of problem behavior and to identify unanswered questions that may be addressed in future research.

The term *functional analysis* was used by Skinner (1953) to denote empirical demonstrations of "cause-and-effect relations" between environment and behavior; however, the term has been extended by behavior analysts and psychologists in general to describe a wide range of procedures and operations that are different in many important ways (see Haynes & O'Brien, 1990, and Iwata, Kahng, Wallace, & Lindberg, 2000, for two different but comprehensive discussions). In addition, the term evokes different responses through somewhat different uses in other disciplines such as medicine, mathematics, physics, and biology. In the behavior analysis literature, the term *function* has been used in two ways. One use conveys the effect that a behavior has on the environment or, speaking loosely, the purpose the behavior serves for an individual (e.g., the function of behavior is to terminate an ongoing event). The second use describes a relation between two variables (typically between some environmental event and a class of behavior) in which one varies given the presence or absence of the other (e.g., responding as a function of an event). Both uses of the term are relevant to a functional analysis of existing behavior, in that relations between behavior and environmental events are demonstrated in the context of learning about how the behavior operates on the environment.

Although early conceptual analyses (Bachman, 1972; E. G. Carr, 1977; & Smolev, 1971) suggested that self-injurious behavior (SIB) might be the product of reinforcement contingencies that differed across individuals who exhibited these behaviors, methods for identifying various conditions that were correlated with SIB and other problem behaviors prior to intervention were not described until years later. Nevertheless, several noteworthy studies included systematic empirical investigations of environmental influences on problem behavior and laid the groundwork for a comprehensive functional analysis methodology. Lovaas and colleagues (Lovaas, Freitag, Gold, & Kassorla, 1965; Lovaas & Simmons, 1969) were the first to demonstrate the effects of social-positive reinforcement (attention) on the SIB of children who had been diagnosed with autism and mental retardation. Similar studies demonstrated the effects of attention on problem behaviors common to the classroom, such as aggression (Pinkston, Reese, LeBlanc, & Baer, 1973) and disruption (Thomas, Becker, & Armstrong, 1968). Sailor, Guess, Rutherford, and Baer (1968) provided an early demonstration that problem behavior also could be maintained by negative reinforcement (escape from difficult instruction) in a young girl with mental retardation; this work was extended by E. G. Carr, Newsom, and Binkoff (1976, 1980), who showed that aggression and SIB were correlated with the presentation and removal of demands, and by Weeks and Gaylord-Ross (1981), who showed that SIB was positively correlated with task difficulty. In addition to demonstrating the effects of specific contingencies on problem behavior, these studies illustrated the general value of identifying the conditions under which problem behavior may actually worsen: If one could specify which aspects of a procedure led to more problem behavior, one should then be able to change the procedure so as to effect a reduction in problem behavior (a similar notion was presented by Baer, Wolf, & Risley, 1968).

The preceding studies established the basic methodological features of a functional analysis of problem behavior: direct observation and measurement of problem behavior under test and control conditions in which some environmental variable is manipulated. From these strategies, a relation between an environmental event and behavior was demonstrated. However, all of the studies described above focused on single response–reinforcer relations.

The first comprehensive analysis of the determinants of problem behavior was reported by Iwata et al. (1982/1994), who proposed a general model for concurrently assessing the sensitivity of SIB to contingencies of positive, negative, and automatic reinforcement. More specifically, direct observation and repeated measurement of behavior were conducted across four conditions (three tests and one control) arranged in a multielement, single-subject experimental design (Ulman & Sulzer-Azaroff, 1975). Each test condition contained an EO, S^D, and source of reinforcement for a given contingency, whereas these same operations and contingencies were absent from the control condition. This methodology was applied to various forms of SIB (e.g., head banging, biting, eye gouging, face slapping, hair pulling) exhibited by 9 children with developmental disabilities. Results showed that levels of SIB varied widely across participants. More important, they showed that SIB was higher in particular test conditions relative to the control for 8 of the 9 participants.

E. G. Carr and Durand (1985) described another model for conducting a functional analysis of problem behavior. The influences of three assessment conditions were evaluated on varied problem behaviors (aggression, tantrums, SIB, opposition, and out of seat) of 4 children with developmental disabilities in which two antecedent variables, amount of attention and difficulty of instruction, were manipulated. Several patterns of problem behavior were observed, suggesting that influential variables differed across participants.

The functional analysis methods described by Iwata et al. (1982/1994) and E. G. Carr and Durand (1985) marked the beginning of a comprehensive approach to intervention in which control techniques derived from the experimental analysis of behavior were applied, not only to the treatment of problem behavior but to its assessment as well. In addition, both assessment models represented an improvement over arbitrary approaches to the treatment of problem behavior and led to the development of more precise reinforcement-based interventions and an apparent decrease in the use of punishment (Pelios, Morren, Tesch, & Axelrod, 1999). In essence, functional analysis has provided a means to determine in advance which treatments should and should not work, as well as why. What follows is a review of functional analysis methodology, a presentation of guidelines for best practice, and a discussion of areas that warrant further research attention.

METHOD

Functional analysis studies were identified through a search of *Current Contents*, *PsychInfo*, and *ERIC* using the key words *function, analysis,* and *behavioral assessment* through 2000. The reference section of each article so identified was then examined to identify additional functional analysis articles. Finally, all identified studies were reviewed to determine if they met criteria for inclusion in the present review.

Inclusion and Exclusion Criteria

Studies included in the present review were those in which (a) a pretreatment assessment based on (b) direct observation and measurement of problem behavior was conducted under (c) at least two conditions involving manipulation of some environmental variable in an attempt (d) to demonstrate a relation between the environmental event and behavior. The criteria for inclusion (and exclusion) are described more fully below.

Pretreatment Assessment

Pretreatment assessment refers to an attempt by the researcher to identify variables that affected rates of problem behavior (an evaluation of a treatment was not required). This criterion ruled out studies in which a functional relation was established only in the context of treatment (e.g., SIB decreased when a particular intervention was used). That is, studies were excluded if functional relations were not demonstrated independent of treatment.

Direct Observation and Measurement of Problem Behavior

The focus of the current review is on the functional analysis of problem behavior, defined as behavioral excess that is socially significant to the extent that someone complains of its occurrence. These behaviors are typically of sufficient intensity or frequency that the safety of the person or others is threatened, the ability of the person or others to acquire new skills is hindered, or more restrictive living arrangements are warranted.

The requirement for direct observation and measurement specified that the primary data used in the analysis were collected by observers who recorded responses of study participants (either live or from videotape). Thus, reviews, commentaries, and discussion papers were excluded because they did contain data of this type. In addition, studies that relied exclusively on *indirect* means to identify functional variables were excluded. More specifically, studies in which data were based solely on rating scales (e.g., Weiseler, Hanson, Chamberlain, & Thompson, 1985), questionnaires (e.g., Matson, Bamburg, Cherry, & Paclawskyj, 1999), or clinical interviews (e.g., O'Neill, Horner, Albin, Storey, & Sprague, 1990) were not included due to their reliance on anecdotal reports from caregivers in lieu of direct observation of problem behavior.

Manipulation

By limiting the review to studies involving at least two conditions in which some environmental variable was manipulated, all studies that relied exclusively on *descriptive* analysis were not included. Descriptive analysis involves direct observation of behavior under naturally occurring (uncontrolled) conditions in an attempt to identify environmental correlates of problem behavior. Examples of this approach include continuous observation methods (e.g., Bijou, Peterson, & Ault, 1968), antecedent-behavior-consequence (ABC) recording (e.g., Groden, 1989), and scatter-plot recording (e.g., Touchette, MacDonald, & Langer, 1985). Studies that included descriptive analysis in addition to other types of analysis that met the criteria noted above were included in the present review (e.g., Lerman & Iwata, 1993; Mace & Lalli, 1991).

Functional Analysis Methodology

Studies that met the criteria for inclusion in the present review varied along a number of dimensions related to subject and setting characteristics, parametric and qualitative characteristics of the methodology, types of conditions arranged, experimental designs used, types of problem behaviors evaluated, and the manner in which data were displayed and analyzed. Studies that met criteria for inclusion were quantified and critically evaluated along the following dimensions.

Population and Setting Characteristics

Participants. Data were collected on participant age, level of functioning, and diagnosis. Participants were categorized as either child (1 to 18 years) or adult (19 and over). It was noted whether participants fell within a normal range of functioning or if a particular developmental disability (e.g., mental retardation) was noted. Diagnoses of autism also were documented.

Settings. Settings in which assessment occurred were categorized as home, school, outpatient clinic, inpatient hospital unit, institution, or vocational program.

Response Topographies

Data were collected on the specific topographies of problem behavior included in the functional analyses. Based on the authors' description, behaviors were categorized as SIB, aggression, property destruction, pica, motor disruptions, vocalizations (either bizarre or disruptive), elopement, stereotypy, tantrums, aberrant (this was scored if several topographies were combined into one response class), or other.

Type of Functional Analysis

Data were collected on which of the two general types of functional analysis, the AB (antecedent-behavior) model (E. G. Carr & Durand, 1985) or the ABC model (Iwata et al., 1982/1994), characterized the structure of the functional analyses in each study. Data also were collected on whether additional pretreatment assessment data, such as those derived from indirect or descriptive types of functional assessment, were included. Finally, it was noted if a comparison of any of the methodologies (indirect assessment, descriptive analysis, or functional analysis) was conducted.

Condition Types

Data were collected on whether single or multiple functions of behavior were assessed. If several conditions were used to evaluate multiple functions, we documented which ones were assessed (e.g., attention, tangible [materials or food], escape, automatic [positive or negative]) and whether a relevant control condition was included. Descriptions of atypical test conditions (e.g., escape from noise) were also noted.

Assessment Duration

Data were collected on the total number of analysis sessions for each participant and were categorized according to the number of observations per condition. An analysis was considered *brief* (e.g., Northup et al., 1991) if two or fewer observations were conducted in each condition, whereas an analysis was considered *full* if three or more observations were conducted in at least two conditions.

Session Duration

Data were collected on the duration of each observation session in the analysis.

Experimental Design

The type of single-subject design used to demonstrate the effects of a variable on problem behavior was noted. Each analysis was categorized as a reversal, multielement (i.e., rapid alternation between two or more conditions), or pairwise (sequential evaluation of each test condition through rapid alternation between a single test and control condition; Iwata, Duncan, Zarcone, Lerman, & Shore, 1994) experimental design, or as sharing features of more than one design (noted as a combination).

Data Display and Analysis

Data were collected on the method used to present data from the functional analyses. All of the data conformed to one of three types of displays. Data were presented as (a) condition means exclusively (typically presented as a bar graph, table, or numerical data in the text), (b) values for each session typically displayed on a graph (i.e., a point per session), or (c) within-session values (i.e., the data binned in sequential time segments during one or more sessions). It was also noted whether data analysis relied exclusively on visual inspection or was aided or replaced by some descriptive or inferential statistical procedures.

Stimulus Parameters

Antecedent variables. Descriptions of antecedent variables that were manipulated were recorded (e.g., instructional types, manner in which attention was diverted).

Consequence variables. If consequences were programmed for the occurrence of problem behavior during test conditions, the specific type of consequence provided (e.g., verbal reprimand or physical interaction), as well as its duration, was noted. Schedules were categorized as either continuous (i.e., consequences delivered following each instance of problem behavior) or intermittent (consequences delivered following a proportion of responses).

Functional Analysis Outcome Summary

To avoid summarizing functional analysis data published in more than one study (Fisher, Piazza, & Hanley, 1998) or small data sets also published as aggregates (e.g., Derby et al., 1992), only functional analysis data that appeared in a line chart format were included in the outcome summary. By so doing, any data that appeared in more than one study were easily identified and included only once in the summary.

General Outcome across Topography

Based on the authors' conclusions presented in each study, the number of differentiated (i.e., those assessments that yielded a determination of behavioral function) and undifferentiated functional analyses was noted for each topography of problem behavior.

Behavioral Function by Topography

For analyses in which the behavior's maintaining reinforcer was identified, the specific behavioral function (as noted by the authors of each study) was catalogued across behavioral topography. Maintaining reinforcer categories included attention, tangible (edible items, toys), escape, automatic, or multiple (two or more behavioral functions).

Interrater Agreement

A second reader independently analyzed 12.6% of the articles as a basis for assessing interrater agreement on the categorization of studies. Agreement was then assessed by an item-by-item comparison of score sheets generated by the two readers in which the number of agreements between the two (i.e., same subcategory scored) was divided by the number of agreements plus disagreements and multiplied by 100%. The mean interrater agreement was 98.0% (range, 92.1% to 100%) across score sheets.

RESULTS

Given the search strategy described above, a total of 790 published works were identified. Of these, 215 articles were excluded from the analysis because they were book chapters, reviews, discussion pieces, or commentaries on functional analysis methodology that did not contain any data. Although data based, an additional 298 studies were excluded because they lacked critical functional analysis elements described above as inclusion criteria. From this, a total of 277 empirical studies were identified and included in the quantitative review.

Journals Publishing Functional Analysis Studies

Table 1 lists the journals in which functional analysis studies have been published. A total of 34 journals have published at least one functional analysis study (as defined in

Table 1
Journals Publishing Functional Analysis Studies

Journal	Number of studies	Percentage of sample
Journal of Applied Behavior Analysis	180	64.9
Research in Developmental Disabilities[a]	21	7.6
Behavior Modification	10	3.6
Journal of Behavior Therapy and Experimental Psychiatry	9	3.2
Journal of the Association for Persons with Severe Handicaps[b]	6	2.2
Behavioral Interventions[c]	5	1.8
Education and Training in Mental Retardation and Developmental Disabilities	5	1.8
Journal of Autism and Developmental Disorders[d]	4	1.4
Journal of Developmental and Physical Disabilities[a]	4	1.4
School Psychology Quarterly	4	1.4
Behavioral Disorders	3	1.1
Behavior Therapy	3	1.1
Journal of Intellectual Disability Research[f]	2	0.7
Number of other journals with one publication	21	7.6
Total number of functional analysis studies[a]	277	

[a] *Applied Research in Mental Retardation* merged with *Analysis and Intervention in Developmental Disabilities* to become *Research in Developmental Disabilities.*
[b] Formerly *Journal of the Association for Education of Persons with Severe and Profound Handicaps.*
[c] Formerly *Journal of Autism and Childhood Schizophrenia.*
[d] Formerly *Behavioral Residential Treatment.*
[e] Formerly *Journal of the Multihandicapped Person.*
[f] Formerly *Journal of Mental Deficiency Research.*
[g] Functional analysis studies as defined in the Method Section.

the present review); 13 journals have published two or more studies. Combined with the fact that numerous discussion and review papers have appeared in still more journals (especially those in the area of education), the data suggest that a large number of readers of psychological literature have come in contact with functional analysis methodology. The number of different journals that published a functional analysis study shows a slight increasing trend across years (see Figure 1); however, the overwhelming majority of functional analysis studies have been published in *JABA* (64.9%). This is not surprising given that the procedures (operant contingencies) and methodology (single-subject designs) on which functional analysis is based are also the cornerstones of applied behavior analysis and the most common characteristics of articles published in *JABA.* Although functional analysis may still be limited to the research and practice of a small number of individuals (Gable, 1996; Gresham, Quinn, & Restori, 1999), the present database shows that over 400 individuals have coauthored data-based functional analysis studies.

Analysis Methodology

Population and Setting Characteristics

Although a substantial proportion of functional analysis studies (37.2%) included adults, the majority of studies included children (70.0%) with some form of developmental disability (91.3%; see Table 2). Given the high prevalence of problem behavior in persons with developmental disabilities, the fact that the majority of functional analysis studies have focused on this population is not surprising. A much lower percentage of studies included functional analyses of problem behaviors exhibited by persons without disabilities (9.0%), showing that this is a relatively underresearched area. However, functional analysis methodology has been applied in 25 studies to evaluate problem behaviors that are more common among typically developing children (some of these studies will be described below).

Most functional analysis studies have been conducted in hospital (inpatient) facilities (32.5%), schools (31.4%), or institutions (25.3%; see Table 2); much less research (17.4%) has been conducted in other settings (e.g., homes, vocational programs, and outpatient clinics). It is unclear whether

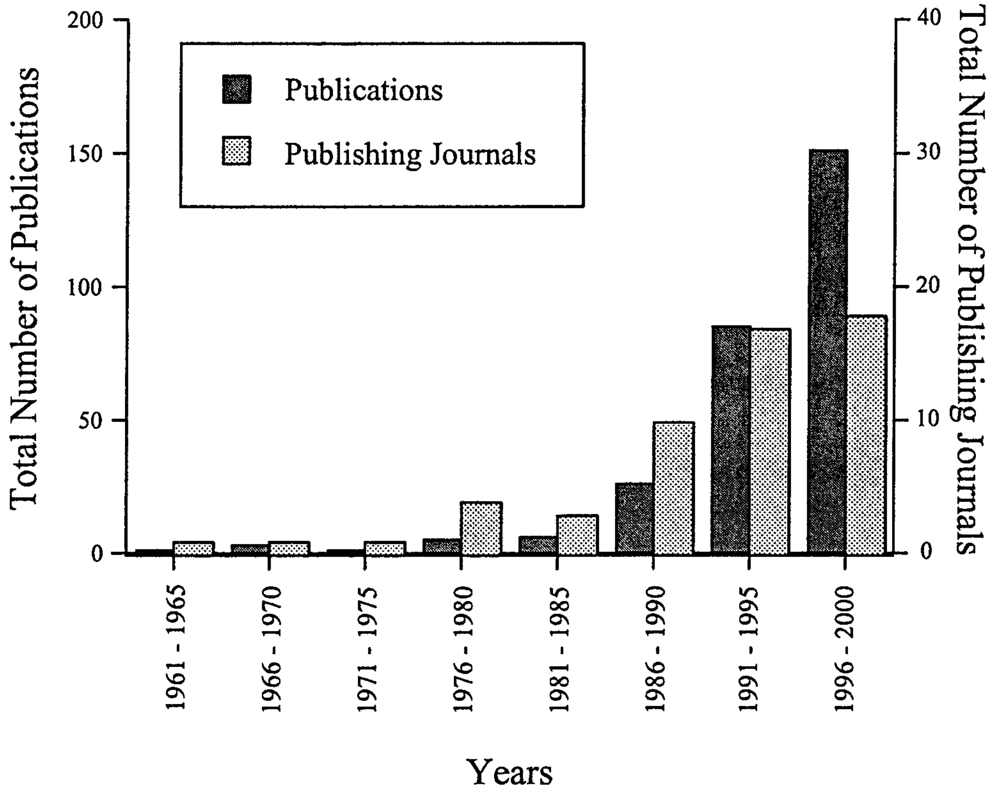

Figure 1. Total number of functional analysis publications (dark bars) and total number of publishing journals (light bars) for 5-year periods between 1961 and 2000.

choice of setting has been due to the greater degree of control afforded by institutional environments or the fact that persons with more severe problem behaviors are more likely to be treated in these settings.

Response Topographies

The majority of functional analysis studies have either included some form of SIB in the cluster of behaviors undergoing assessment or exclusively evaluated the controlling

Table 2
Participant and Setting Characteristics

		Number of studies	Percentage of sample
Participants	Child	194	70.0
	Adult	103	37.2
	Developmental disability	253	91.3
	Autism	58	20.9
	No disability	25	9.0
Setting	Hospital (inpatient)	90	32.5
	School	87	31.4
	Institution	70	25.3
	Home	21	7.6
	Clinic (outpatient)	21	7.6
	Vocational program	6	2.2

Table 3
Prevalence of Behavior Topographies

Topography	Number of studies	Percentage of sample
Self-injury	179 (130)	64.6 (4.6)
Aggression	113 (46)	40.8 (1.6)
Disruption	53 (19)	19.1 (6.9)
Vocalizations	35 (16)	12.6 (5.8)
Property destruction	29 (2)	10.5 (0.7)
Stereotypy	25 (17)	9.0 (6.1)
Noncompliance	12 (1)	4.3 (0.3)
Tantrums	10 (1)	3.6 (0.3)
Elopement	8 (1)	2.9 (0.3)
Pica	7 (3)	2.5 (1.1)
Other	10 (0)	3.6 (0)

Note. The numbers in parentheses indicate studies that included one specific topography in the analysis contingency class.

variables for SIB (179 or 64.6%; see Table 3). Aggression (113 or 40.8%) and disruption (53 or 19.1%) were, respectively, the second and third most common topographies of problem behavior evaluated. A large percentage of studies (85.0%) included only topographically similar responses (e.g., only self-injurious head hitting or only pica) in the class of responses for which consequences were programmed. A fairly large percentage of studies (27.8%) included two or more (typically more) topographies in the target response class in at least one of the functional analyses.

Although the majority of functional analysis studies have examined some form of SIB, aggression, or disruption, the methodology has been extended to a variety of other problem behaviors including reluctant or bizarre vocalizations (e.g., Durand & Crimmins, 1987; Mace & West, 1986), vocal tics (J. E. Carr, Taylor, Wallander, & Reiss, 1996), stereotypy (e.g., Mace, Browder, & Lin, 1987), mouthing (Goh et al., 1995), breath holding (Kern, Mauk, Marder, & Mace, 1995), pica (Mace & Knight, 1986; Piazza, Hanley, & Fisher, 1996), hair pulling (Miltenberger, Long, Rapp, Lumley, & Elliot, 1998), noncompliance (Reimers et al., 1993), tantrums (Vollmer, Northup, Ringdahl, LeBlanc, & Chauvin, 1996), drug ingestion (Chapman, Fisher, Piazza, & Kurtz, 1993), elopement (Piazza, Hanley, et al., 1997), and property destruction (Fisher, Lindauer, Alterson, & Thompson, 1998). In addition, topographies of problem behavior more commonly exhibited by either typically developing children or children with mild disabilities have also been assessed via functional analysis; examples include disruptive behavior of children in regular education classrooms (Broussard & Northup, 1995, 1997), disruptive classroom behavior of students with emotional disabilities (DePaepe, Shores, Jack, & Denny, 1996), finger sucking by children in the home (Ellingson et al., 2000), inappropriate classroom behavior of an elementary student (Lewis & Sugai, 1996), reluctant speech of an elementary school student (Mace & West, 1986), off-task behavior of elementary school children with mild learning disabilities (Meyer, 1999), and classroom disruptive behaviors of children with attention deficit disorder (Northup et al., 1995; Umbreit, 1995b). These studies represent a first step towards extending functional analysis methodology to the problem behavior of typically developing children, and the continued extension and refinement of these methods represents an exciting and important area for future work.

In contrast to recent demonstrations with typically developing children, functional analysis methodology has not yet been extended to behavior problems (e.g., nail biting, complaining, smoking, drug abuse, overeating, or problem behaviors associated with mental illnesses such as depression, bulimia, or anorexia) exhibited by adults without disabilities. This too represents an important area for the systematic extension of functional analysis methodology (see additional discussions by Axelrod, 1991; Haynes

& O'Brien, 1990; McManus & Waller, 1995).

The extension of functional analysis methods to novel topographies of problem behavior has also necessitated procedural variations. For instance, analyses of pica (Piazza et al., 1998), mouthing (Goh et al., 1995), and property destruction (Fisher, Lindauer, Alterson, & Thompson, 1998) required the selection and arrangement of safe materials to consume or destroy; the analysis of elopement (Piazza, Hanley, et al., 1997) required that the participant could be retrieved at least several times so that multiple opportunities to respond were available; analyses of aggression required that a person be within reach and protected; and analyses of noncompliance (Reimers et al., 1993) necessitated the delivery of a consistent number of instructions. Other topographies of problem behavior (e.g., out of seat, crying) have been included in functional analyses; however, these particular responses were part of a larger group of topographically distinct behaviors. Therefore, the utility of functional analysis methods remains undemonstrated for these and other unique, or possibly common, problem behaviors.

Type of Functional Analysis

Functional analysis models. As described earlier, one general model of functional analysis in current use involves the exclusive manipulation of antecedent events (an AB model; see E. G. Carr & Durand, 1985). The second involves manipulation of all aspects of the three-term contingency (i.e., antecedent and consequent events; an ABC model; see Iwata et al., 1982/1994). The ABC model was incorporated in 241 or 87.0% of the functional analysis studies, whereas the AB model was used in 56 or 20.2% of the studies (see Table 4). Most of the 277 studies employed one model to the exclusion of the other; however, 20 studies (7.2%) included both types of assessment either with the same participant or across different participants.

Table 4
Methodological Characteristics of Functional Analysis

	Number of studies	Percentage of sample
Model type		
ABC model	241	87.0
AB model	56	20.2
Both models	20	7.2
Supplementary assessments		
Descriptive or indirect	29	10.5
Descriptive	23	8.3
Indirect	12	4.3
Descriptive and indirect	7	2.5
Condition types		
Social-negative reinforcement	247	89.2
Social-positive reinforcement	237	85.6
Attention	229	82.7
Tangible	96	34.7
Automatic reinforcement	165	59.6
Number of test conditions		
Multiple	248	89.5
Single	51	18.4
Assessment length		
Full	229	82.7
Brief	36	13.0
Unknown	14	5.0
Session duration		
5 min	31	11.1
10 min	144	52.0
15 min	78	28.2
Other	12	4.3
Unknown	22	7.9
Experimental designs		
Multielement	225	81.2
Reversal	43	15.5
Pairwise	7	2.5
Combination	7	2.5
Unknown	16	5.8
Data presentation		
Session values	208	75.1
Condition means	74	26.7
Within-session values	3	1.1

Supplementary functional assessments. Descriptive data (i.e., data collected through direct observation of behavior in the absence of experimental manipulation) were included in 23 studies (8.3%), data generated from indirect means (i.e., questionnaires, rating scales) were included in 12 studies (4.3%), either a descriptive or indirect assessment was included in 29 studies (10.5%), and both descriptive and indirect functional assessment data in addition to that derived from a functional analysis of problem behavior were included in 7 studies (2.5%). Many studies described the use of preliminary assessments as part of the process of identifying variables influencing problem behavior. However, studies in which it was noted that observations, interviews, and so forth were conducted prior to a functional analysis of problem behavior, but in which data from these supplementary assessments were not reported, were not included in these calculations.

Condition Types

The basis for identifying environmental influences in a functional analysis lies in a comparison of behavior under test and control conditions. Test conditions involve some potentially relevant independent variable (e.g., contingency between problem behavior and access to toys), whereas control conditions are generally constructed so that the same independent variable is absent (e.g., toys are not provided following problem behavior).

Social-positive reinforcement. Most functional analysis studies involved tests for behavior maintained by social-positive reinforcement (85.6%), with the majority of these studies (96.6%) specifically assessing the effects of attention on problem behavior. A smaller percentage of studies assessed the effects of other forms of social-positive reinforcement such as foods, toys, or other tangible items (38.3%) on the occurrence of problem behaviors. Assessment of the effect of tangible reinforcement on problem behavior was first reported by Mace and West (1986); however, R. M. Day, Rea, Schussler, Larsen, and Johnson (1988) published the earliest demonstration of behavioral maintenance by access to tangible items. Since then, tests for behavioral sensitivity to tangible forms of reinforcement have often been included in functional analyses (47.0% of functional analyses in the last 5 years included a tangible test condition). The majority of tests for maintenance via social-positive reinforcement arranged a contingency between problem behavior and access to attention or tangible items (94.9%); a smaller percentage of studies (6.7%) exclusively manipulated antecedent events (e.g., altered the percentage of time in which attention or tangible items were available) and inferred behavioral function from the resulting data.

Social-negative reinforcement. Most functional analysis studies involved tests for behavioral maintenance by escape or avoidance contingencies (89.2%) and typically referred to this arrangement as the demand or escape condition. In most cases (88.3% of those testing for a negative reinforcement relation), a brief break from ongoing instructions (or social interaction, e.g., Vollmer et al., 1998) was provided following problem behavior such that a direct test of the effect of a negative reinforcement contingency was evaluated. In a smaller percentage of the studies (18.6%), consequences were not manipulated (and in many instances not specified or controlled); instead, various characteristics of the antecedent environment (e.g., task difficulty) were altered.

Automatic reinforcement. More than half (59.6%) of the functional analysis studies included conditions to test for maintenance by automatic reinforcement. These tests are necessarily indirect because the delivery of automatic reinforcement typically cannot be controlled or directly manipulated by others. Therefore, the test for this sort of relation relies on a strategy in which the influence of social reinforcement is removed by observing behavior under relatively barren conditions (this test is typically referred to as the alone or ignore condition). If problem behavior persists under these conditions, in which no social reinforcement contingencies are programmed and ambient stimulation that may occasion escape-maintained behavior is absent, evidence of maintenance via automatic reinforcement is provided. In an attempt to decrease the possibility that bursts of socially mediated behavior are misdiagnosed as automatically reinforced behavior, several researchers have included either extended (of longer duration) or repeated (consecutive sessions) observations in the alone condition (e.g., Vollmer, Marcus, Ringdahl, & Roane, 1995). Persistence under these conditions provides further support for the nonsocial mediation of problem behaviors.

Control conditions. Of the 56 functional analysis studies employing the AB model, 40 (71.4%) included a control condition to determine the influence of one of two antecedent variables (attention and task difficulty) on problem behavior. The remaining studies in this group simply excluded a relevant antecedent event (i.e., the event present in the test condition) from the control condition. The typical control condition in ABC functional analyses (described originally by Iwata et al., 1982/1994, as the "play" condition) also controls for multiple sources of influence. More specifically, no demands are presented, attention is withheld for problem behavior and is available either freely or for appropriate behavior, and access to alternative forms of stimulation is continuously available (i.e., free access to toys is arranged). Thus, the EOs (deprivation from attention or stimulation, or the presentation of demands) for the three sources of reinforcement, as well as the contingencies for the two sources of social reinforcement, are eliminated or at least minimized in this condition. From this, the effects of several contingencies arranged either directly (attention and escape) or indirectly (automatic reinforcement) are assessed by comparing the relative rates of behavior in these test conditions to those observed in a single control condition. This general type of control condition was used in 91.7% of the 241 functional analysis studies that employed the ABC model. The remaining 8.3% relied on a test condition for one function serving as a control for another test condition (e.g., no demands are presented in the attention condition, and contingent attention is unavailable in the demand condition). This strategy was often employed in brief functional analyses (e.g., Northup, 1991) in which practical constraints limited the number of sessions that could have been conducted. The main limitation of these and other studies that did not arrange a deliberate control condition is the inability to discriminate between multiply controlled and undifferentiated (or exclusively automatically reinforced) responding (see E. G. Carr, Yarbrough, & Langdon, 1997, for examples).

Number of test conditions. Early research on the functional analysis of problem behavior (i.e., studies published prior to 1982) evaluated the effects of a single source of reinforcement. However, the majority of studies in the current review (89.5%) evaluated the effects of multiple sources of influence through the inclusion of two or more test conditions in each functional analysis. In other words, most functional analysis studies included test conditions to delineate control by positive versus negative reinforcement or social versus automatic sources of reinforcement. Clearly, the comprehensive approach represents a refinement in assessment strategy because it (a) identifies important controlling relations, (b) rules out competing relations, (c) allows one to select a treatment matched to the function of behavior, and (d) avoids programming changes that will not affect the occurrence of problem behavior (or will be contraindicated). In addition, comprehensive functional analyses may identify (or rule out) multiple sources of control (H. M. Day, Horner, & O'Neill, 1994).

Session Duration

Data from published studies indicate that most functional analysis sessions are 10 min (52.0%), 15 min (28.2%), or 5 min (11.1%) in duration. However, a few studies have programmed sessions as brief as 1 min (Sigafoos & Meikle, 1996; Sigafoos & Saggers, 1995) or as long as 30 min (e.g., Arndorfer, Miltenberger, Woster, Rortvedt, & Gaffaney, 1994; Reese, 1997).

Assessment Duration

Assessment duration refers to the number of sessions that comprise a functional analysis. Most functional analyses are conducted until stability is achieved (i.e., no a priori criteria are used for terminating the analysis; rather, the analysis is concluded when useful information has been obtained). This is consistent with the general strategies of single-subject research (Sidman, 1960). However, the exigencies of clinical practice (e.g., time limitations) often compromise attempts at thorough assessment, thus necessitating the use of either alternative functional assessment tools (e.g., indirect methods) or modifications to functional analysis methodology. In a significant contribution to the literature, Northup et al. (1991) illustrated the latter strategy through development of what has come to be called the *brief* functional analysis. It was designed to accommodate a 90-min outpatient evaluation, thereby circumventing limitations posed by the use of indirect assessment while addressing the practical limitations posed by more lengthy functional analysis. Basically, one or two sessions were conducted under various test conditions to determine the function of the target behavior. The current review identified 36 studies (13.0%) that employed brief functional analyses (i.e., two or fewer observations in each test condition). The length of assessment was not described and is therefore unknown in 14 studies (5.0%), and full analyses (three of more observations per condition) were included in the majority of studies (229 or 82.7%).

Experimental Design

Most single-subject experimental designs involve observation of several features of behavior (i.e., level, trend, and stability) across two or more conditions in which relevant stimuli are either present (test conditions) or absent (control conditions). The design most commonly used in functional analysis studies was the multielement (225 studies or 81.2%), which is characterized by the rapid alternation of the experimental conditions. This design is attractive for functional analyses because it is an efficient way to examine the effects of several independent variables (e.g., social-positive, social-negative, or automatic reinforcement). In addition, organismic or other extraneous variables (e.g., allergies, medication changes) should affect behavior similarly across all conditions because the individual is exposed to the alternating conditions within a relatively short period.

The second most common experimental design was the reversal or ABAB design characterized by repeated observations of behavior under a single condition, followed by the introduction, withdrawal, and reintroduction of an experimental variable. The reversal design was used in 43 functional analysis studies (15.5%) and was more common in studies evaluating a single source of influence on behavior or in those employing an AB model. Although the reversal design is a time-consuming strategy for evaluating multiple sources of behavioral control, Vollmer, Iwata, Duncan, and Lerman (1993) provided evidence that reversal designs may be helpful if the rapidly alternating conditions of the multielement designs produce interaction effects (Higgins Hains & Baer, 1989).

Iwata, Duncan, Zarcone, Lerman, and Shore (1994) described a method for conducting functional analyses that combined features of the reversal and multielement designs. Test conditions were implemented sequentially (as in a reversal design); however, each test condition was alternated with a control condition in a multielement format. The sequential test–control (or pairwise) design was intended to minimize interaction effects while decreasing the number of reversals required to demonstrate a functional relation and was shown to result in differentiated outcomes for 2 participants whose prior multielement analyses yielded unclear results.

The pairwise design has appeared in six subsequent functional analysis studies. Three studies used the design from the outset of the assessment (Fisher, Kuhn, & Thompson, 1998; Lalli, Casey, & Kates, 1995; Shirley, Iwata, Kahng, Mazaleski, & Lerman, 1997), and all analyses yielded a clear behavioral function. Two studies provided systematic replications of the strategy described by Iwata, Duncan, Zarcone, Lerman, and Shore (1994), in which pairwise analyses yielded clear results following initially unclear multielement outcomes (Piazza, Fisher, et al., 1997; Piazza, Hanley, et al., 1997).

Data Display and Analysis

Researchers in behavior analysis have long relied on visual inspection of data for drawing conclusions about the effects of experimental variables. Visual analysis of data is an attractive tool because it allows researchers (a) to view much of the raw data, (b) to detect interesting changes in behavior (e.g., extinction bursts), (c) to analyze data on a continual basis (as opposed to waiting until all of the data have been collected), and (d) to assess effects of experimental variables without relying on inferential statistics (Hopkins, Cole, & Mason, 1998; Huitema, 1986; Michael, 1974). Thus, it is not surprising that most functional analysis data have been depicted in line charts displaying individual session values (208 studies or 75.1%). However, 74 functional analysis studies (26.7%) reported condition means only (in text or bar charts), which is somewhat troublesome because it eliminates access to aspects of the data (changes in level, trend, or stability) that could influence conclusions about behavioral function.

In contrast to displaying data as whole-session values, some authors have binned data within smaller time intervals (e.g., 1 min) from each session to view more fine-grained trends (Kahng & Iwata, 1999; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993a, 1993b; Vollmer et al., 1995). It is possible that differences in responding across conditions may go undetected if data are collapsed as session means (Roane, Lerman, Kelley, & Van Camp, 1999); however, the utility of viewing within-session patterns has not been established because the same conclusions typically can be drawn regardless of whether data are portrayed as sessions means or within-session patterns. A notable exception was reported by Vollmer et al. (1993b), who showed that 1 participant's SIB, which was high and undifferentiated across six functional analysis sessions, revealed extinction effects in the play and alone conditions and maintenance of SIB in the attention condition. These effects were apparent only when within-session data were examined.

Stimulus Parameters

Researchers typically arrange similar antecedent conditions (i.e., low levels of attention, presentation of instructions) and, if incorporated, similar consequent events (i.e., attention, escape from instructions) during the conditions of a functional analysis. However, some researchers have evaluated specific aspects of these antecedent and consequent events or have incorporated unusual variations of these events in their functional analyses. These methodological variations, categorized as either antecedent or consequent variables, are described below.

Variations in Antecedent Events

Most of the antecedent events manipulated in functional analyses (e.g., amount of attention) may best be conceptualized as EOs that influence behavior by altering the reinforcing effectiveness of some consequence (Michael, 1982). This is in contrast to S^Ds, which influence behavior through their correlation with the differential availability of reinforcement. Both can be contrasted with other descriptive labels for antecedent variables (setting events, contextual variables) that do not specify a particular source of influence in any response–reinforcer relation (see Iwata, 1994, and Smith & Iwata, 1997, for discussions). Although procedural labels have often been used in the literature, antecedent manipulations can be discussed in the context of particular types of reinforcement relations (e.g., social-positive, social-negative, automatic). The evocative effects of low levels of attention for attention-maintained problem behavior, low levels of ambient stimulation for automatically reinforced behavior, and the presentation of instructions for escape-maintained behavior have been repeatedly demonstrated in the functional analysis literature. However, some authors have suggested strategies for either increasing the influence exerted by these typical antecedent events or demonstrating functional control of qualitatively different antecedent events.

Variations for social-positive reinforcement relations. Responding in a particular test condition may be influenced by the extent to which the putative reinforcer is available prior to the actual test session. Taking advantage of the establishing (and abolishing) effects of functional analysis sessions, Iwata, Pace, et al. (1994) described a fixed cycle of condition presentation (alone, attention, play, demand) that maximized EOs during assessment. For example, if problem behavior were maintained by attention, the alone condition would provide presession deprivation from attention, whereas the noncontingent attention delivered during the play condition should eliminate attention deprivation (or at least minimize carryover from the preceding attention session). Presession variables other than assessment sessions per se that may exist immediately prior to assessment observation also have been demonstrated to influence responding during functional analyses (Berg et al., 2000; O'Reilly, 1999; O'Reilly & Carey, 1996). More specifically, O'Reilly showed that levels of SIB were higher during a contingent attention test condition when presession attention was withheld compared to when presession attention was available on a rich schedule. These results suggest that certain condition sequences may facilitate rapid response differentiation, especially during outpatient evaluations in which sessions are conducted with little time between sessions. However, this strategy may exert little influence if extended periods of time expire between sessions, in which case researchers should consider the establishing effects of specific presession variables and program conditions that maximize the effects of assessment contingencies.

During the attention test condition in ABC functional analyses, the antecedent event typically involves having the therapist engage in a solitary activity. Mace, Page, Ivancic, and O'Brien (1986) introduced an interesting variation of the attention condition, referred to as *divided attention,* in which the therapist attends to another person in the room, and the utility of this novel arrangement was demonstrated in subsequent studies (Fisher, Kuhn, & Thompson, 1998; O'Reilly, Lancioni, King, Lally, &

Dhomhnaill, 2000; J. C. Taylor, Sisson, McKelvey, & Trefelner, 1993). For example, Taylor et al. showed that the functional relation between problem behavior and contingent attention was dependent on the therapist attending to another person by showing zero or near-zero rates of problem behavior during a typical attention condition and high rates of problem behavior during a divided-attention condition. Other interesting antecedent variations that have been shown to influence responding include arranging for the therapist to leave the room following the delivery of reinforcement (Vollmer et al., 1998) or situating the client in particular positions (sitting in a wheelchair as opposed to sitting on a mat; Adelinis, Piazza, Fisher, & Hanley, 1997). Although these variations and their results may seem idiosyncratic, they illustrate the general strategy described by Smith, Iwata, Goh, and Shore (1995) of assessing antecedent influences by holding a reinforcement contingency constant while manipulating the antecedent event of interest. These studies also show that the influence of antecedent events may be best understood in the context of contingencies and indicate that the influence of idiosyncratic antecedent events should be considered when typical analyses fail to uncover functional relations.

Variations for social-negative reinforcement relations. In most tests for social-negative reinforcement relations, some form of task demand is presented as a means of establishing the reinforcing efficacy of escape and, consequently, of evoking escape-maintained problem behavior. The identification of idiosyncratic antecedent events (i.e., task difficulty, lack of choice among tasks, curricular influences, social interaction) has been prominent in studies employing an AB functional analysis model (e.g., DePaepe et al., 1996; Dunlap, Kern-Dunlap, Clarke, & Robbins, 1991; E. G. Durand & Carr, 1991; Kennedy, 1994; Kennedy & Itkonen, 1993; Lee, Sugai, & Horner, 1999; J. T. Taylor, Ekdahl, Romanczyk, & Miller, 1994; Vaughn & Horner, 1997; Weeks & Gaylord-Ross, 1981); however, the functional basis for these influences has been difficult to specify in the absence of reinforcement contingencies (Smith & Iwata, 1997).

By contrast, Smith et al. (1995) evaluated EOs in the presence of an escape contingency for problem behavior and showed that several aspects of the demand situation (task novelty, duration of instructional session, and rate of task presentation) altered the effects of negative reinforcement in different ways across individuals. The strategy of maintaining a negative reinforcement contingency while manipulating aspects of the antecedent condition to identify idiosyncratic EOs was used in several studies in which otitis media (O'Reilly, 1997), sleep deprivation (O'Reilly, 1995), amount of attention or instruction during prior classroom conditions (O'Reilly & Carey, 1996), or various instructional procedures (McComas, Hoch, Paone, & El-Roy, 2000) were shown to affect levels of problem behavior in demand conditions. Collectively, these studies are exemplary in demonstrating the effects of antecedent events (temporally proximate or distant) on the occurrence of negatively reinforced problem behavior.

Although task instructions are typically programmed in tests for negatively reinforced problem behavior, researchers have demonstrated the evocative effects of other types of EOs such as medical examinations (Iwata, Pace, Kalsher, Cowdery, & Cataldo, 1990), noise or other auditory stimulation (Derby et al., 1994; O'Reilly, 1997; Smith et al., 1995), and social interaction (Frea & Hughes, 1997; Vollmer et al., 1998). Continued improvements in the assessment and treatment of negatively reinforced problem behavior may be realized by additional research that documents the influence of (a) different classes of EOs (e.g., loud noises),

(b) temporally proximate events that occur within demand conditions (e.g., pace of instruction), and (c) temporally distant events (e.g., illness) that culminate in establishing the value of escape.

Variations for automatic reinforcement relations. The influence of antecedent events on problem behavior maintained by automatic reinforcement (beyond those typically manipulated, such as low levels of ambient stimulation during the alone condition) has not often been examined in the functional analysis literature. Several studies (e.g., Fisher, Lindauer, Alterson, & Thompson, 1998; Goh et al., 1995; Piazza, Adelinis, Hanley, Goh, & Delia, 2000) have shown that access to certain leisure materials may compete with the stimulation produced by problem behavior, thereby diminishing its reinforcing effects. Manipulations of this sort are typically involved in functional analyses. For instance, a variety of toys are included in the control (i.e., play) and the attention conditions but typically are absent in the test condition for automatic reinforcement. Although antecedent events are not typically altered prior to or during test conditions for automatically reinforced problem behaviors, Van Camp et al. (2000) showed that unusual antecedent events (a specific toy, social interaction) evoked 2 children's stereotypic behavior that persisted in the absence of social contingencies.

O'Reilly (1996) described another notable exception in which an individual's SIB did not occur during a functional analysis for 35 out of 40 days; however, SIB persisted across all conditions (including an alone condition) during the 5 days that were preceded by nights spent at a respite care facility. The effect of spending a night at the respite facility was then systematically manipulated, and the results showed that high rates of SIB were observed only following nights at the respite facility (as opposed to nights spent at home). This study is exemplary in that it illustrates a method for assessing the influence of temporally distant antecedent events on the occurrence of behavior (in this case, automatically reinforced SIB) during functional analyses. Caution should be taken (as O'Reilly suggested) in concluding that respite care was an EO for this individual's behavior because, although respite care and the occurrence of SIB were correlated, the functional relation was unknown. The next step to be taken in such analyses is to identify the critical events that are correlated with respite care (deprivation from stimulation in this case?) that may have greater functional significance to the maintenance of SIB. From these extended analyses, treatments of greater scope and effectiveness may be derived.

Variations in Consequent Events

Consequence manipulations in functional analysis research are organized and discussed according to their properties of quality, type, duration, and schedule.

Quality or type. The qualitative aspects of attention, delivered as positive reinforcement, often are described only briefly: Researchers typically note that reprimands (e.g., "don't do that, you might hurt yourself") and brief physical contact such as a pat on the back or a touch to the shoulder are provided by adults on a contingent basis. However, several studies have shown that the source of attention may be an important factor. For instance, the problem behavior of some students has been shown to be sensitive to attention provided by peers but not by adults (Broussard & Northup, 1997; Lewis & Sugai, 1996; Northup et al., 1995, 1997). Although the critical variables responsible for observed differences were presumably qualitative (e.g., form or intensity of attention) or historical (e.g., children may have customarily attended to the problem behavior of the participants), these factors were not directly evaluated and therefore represent an interesting area of future research.

Fisher, Ninness, Piazza, and Owen-DeSchryver (1996) published the initial study showing some forms of attention (reprimands) functioned as reinforcement for problem behavior, whereas others (statements unrelated to the problem behavior) did not. Richman and Hagopian (1999) and Piazza et al. (1999) also demonstrated important qualitative differences in the reinforcing effectiveness of attention. Initial functional analyses in the Richman and Hagopian study showed undifferentiated patterns of responding. Parental interview and informal observation suggested that the form of the attention used in the initial analyses (i.e., verbal reprimands) was different than that provided by caregivers who either delivered exaggerated vocal (high level of voice intonation and dramatic description of the problem behavior) or physical attention (being picked up and held) following problem behaviors. Incorporation of these idiosyncratic types of attention into subsequent functional analyses yielded differentiated results.

Tests for behavioral maintenance by attention as well as by food, toys, and particular activities have been demonstrated often within functional analyses (e.g., Durand & Crimmins, 1988; Vollmer et al., 1995). A unique form of social-positive reinforcement that has been shown to support SIB is that of restraint. Smith, Lerman, and Iwata (1996) showed that access to self-restraint (self-initiated confinement) functioned as reinforcement for SIB in a woman with profound mental retardation, and Vollmer and Vorndran (1998) replicated these findings. Although SIB and self-restraint may be related in several different ways (see Fisher & Iwata, 1996), these studies demonstrate that idiosyncratic and mundane materials (e.g., particular clothing types) may serve as positive reinforcers for severe problem behavior.

It may be difficult to determine behavioral function if the reinforcing value of events presented during assessment varies across time. An example of this phenomenon was described by Bowman, Fisher, Thompson, and Piazza (1997), whose initial functional analyses yielded unclear results for 2 participants. Informal observations suggested that problem behavior was occasioned by parental noncompliance with each child's mands (i.e., when the parent did not deliver or remove something the child had requested, the child engaged in problem behavior). During assessment, problem behavior was observed at its highest rates when the therapist complied with the child's mands following occurrences of problem behavior. Subsequent analyses showed that when mands were immediately reinforced, zero or near-zero rates of problem behavior occurred. Two things were unique about the relations described by Bowman et al. First, problem behavior did not appear to be maintained by access to any one particular type of reinforcement. Second, the event that evoked problem behavior was specified by the participant prior to its occurrence (via manding). The generality of this relation between mands and multiple reinforcement contingencies for problem behavior has yet to be determined, but the strategy described by Bowman et al. could be a promising way to identify variables that influence problem behaviors exhibited by persons with verbal repertoires. A second example of problem behavior that appeared to be motivated by different events across time was described by Fisher, Adelinis, Thompson, Worsdell, and Zarcone (1998). Following initial undifferentiated functional analyses, several subsequent analyses showed that problem behavior was evoked by instructions to engage in behavior that interfered with an individual's current ongoing activity, and that problem behavior was maintained by resumption of that activity. These results suggest that, although instructions may evoke problem behavior, it is possible that the target response could be maintained by positive reinforcement (resumption of a preferred activity) rather than by negative reinforcement (termination of an aversive event).

By contrast, Adelinis and Hagopian (1999) found that the type of instruction that interrupted the preferred activity ("do" vs. "don't" requests) was influential in evoking problem behavior. Specifically, they found that "don't" requests that interrupted an activity (e.g., "don't lie on the floor") evoked problem behavior, whereas symmetrical "do" requests (e.g., "sit in a chair") did not. These results suggest that the form of the instruction, in addition to the context in which it is delivered, may contribute to the control of problem behavior for some individuals. Additional studies in this area may help to clarify the respective roles of particular forms of instructions and the type of relations involved. Nevertheless, these studies provide sound experimental evidence of complex behavior relations that, once discovered, lead to effective interventions.

Duration. Consequences used in functional analysis conditions are typically delivered briefly, which permits repeated contact between problem behavior and the programmed contingency within a session. Although the duration of reinforcement has varied across conditions within a study and within the same condition across studies, attention typically is delivered for 5 to 10 s, tangible items are delivered for 30 s, and escape is provided for either 30 s or the remainder the intertrial interval (ranging from 1 to 29 s).

The influence of reinforcer (and related EO) duration on the outcomes of functional analyses was examined by Fisher, Piazza, and Chiang (1996) in an ABAB design. During the first and third phases, which typified most ABC multielement functional analyses, the relative durations of reinforcement were unequal across the tests for attention, tangible, and escape conditions, with attention delivery being brief and tangible and escape consequences lasting for 30 s. Durations of reinforcement were equal (escape, tangible, and attention consequences were all 30 s) in the second and fourth phases. Rates of problem behavior were higher in the three test conditions relative to the play (control) condition in all phases. However, markedly higher rates of responding were observed in the attention condition when relative reinforcer durations were unequal, whereas similar levels of responding across the three test conditions were observed when reinforcer durations were equal. These data suggest that the relative duration of reinforcement (and related EOs) should be considered when designing or interpreting functional analyses. In other words, responding was higher in the attention condition of the typical functional analysis, not because attention was a more potent reinforcer or that problem behavior was primarily sensitive to attention as reinforcement, but, rather, because there was simply more opportunity to respond under relevant deprivation (i.e., absence of the reinforcing event). One may wish to equate reinforcement duration (and the length of exposure to the EOs) during functional analyses to avoid interpretative difficulties. Alternatively, it may be best (a) to include a condition that controls for the effects of the contingencies in the test conditions and (b) always to compare rates of problem behavior in each test condition to that of the control (as opposed to rates of responding in other test conditions) when determining behavioral function.

Schedule. Most studies arrange consequences on a continuous reinforcement (CRF) schedule during functional analyses such that each occurrence of problem behavior results in a programmed reinforcer (216 of the 241 studies [89.6%] employing an ABC model incorporated CRF schedules

Table 5
Functional Analysis Outcome Summary

Topography	Undifferentiated	Differentiated	Escape	Attention	Tangible	Automatic	Multiple
Self-injury	13	222	65	59	28	55	15
Aggression	2	50	24	9	6	1	10
Property destruction	0	2	0	0	2	0	0
Pica	0	6	0	1	0	3	2
Disruption	0	16	11	3	1	1	0
Vocalizations	1	14	6	3	1	0	4
Noncompliance	0	8	1	2	1	0	4
Elopement	0	3	0	0	0	0	3
Stereotypy	1	30	6	0	0	19	5
Tantrums	0	6	2	1	1	0	2
Other	0	13	4	5	0	1	3
Aberrant	5	144	57	47	12	1	27
Total number	22	514	176	130	52	81	75
Percentage of sample	4.1	95.9	34.2	25.3	10.1	15.8	14.6

in the analysis). Intermittent schedules were used in 10 studies (4.1%), and the type of schedule was not clear in 15 studies. Studies that incorporated intermittent schedules (e.g., Kern, Carberry, & Haidara, 1997; Lalli & Casey, 1996; Mace et al., 1986; Paisey, Whitney, & Hislop, 1991; Sturmey, Carlsen, Crisp, & Newton, 1988) typically based the schedule on data generated from a descriptive assessment in which a caregiver was observed to deliver the putative reinforcers intermittently. The ecological validity of the functional analysis may be enhanced through such an approach, and the potential of problem behavior entering into novel response–reinforcer relations may be decreased with the use of leaner schedules. However, the use of intermittent schedules in functional analyses may pose certain problems: (a) Lengthy descriptive assessments would be required to identify the parameters of the intermittent schedule. (b) Intermittent schedules, although derived from descriptive assessment, do not represent the actual schedule that generated or maintains the problem behavior outside the environment in which specific interactions were observed. (c) Problem behavior may not contact the reinforcing contingency on a sufficient number of occasions early in the functional analysis and thus may necessitate more lengthy analyses. (d) Higher rates or intense bursts of behavior may be engendered by intermittent reinforcement relative to a CRF schedule. A direct comparison of the types of performances and outcomes generated by CRF and intermittent schedules in functional analyses is an interesting and necessary future area of research.

Summary of Functional Analysis Outcomes

Through 2000, 536 graphed individual data sets (with at least one data point per observation session) have been published depicting the results of functional analyses (see Table 5). The majority of these graphs (514 or 95.9%) were interpreted by their authors as representing differentiated outcomes. Large proportions of differentiated functional analyses showed behavioral maintenance through social-negative (34.2%) and social-positive reinforcement (35.4%). More specifically, 25.3% showed maintenance via attention and 10.1% via access to tangible items. Automatic reinforcement was implicated in 15.8% of cases. Finally, multiple reinforcement contingencies were identified in 14.6% of cases. A small proportion of cases (4.1%) were interpreted as undifferentiated by their authors.

Conclusions regarding the multiple control of aberrant behavior are somewhat troublesome given that the aberrant behavior category is comprised of multiple response topographies. Therefore, the data beg the question as to whether each topography of problem behavior was sensitive to multiple reinforcers or whether different behavioral topographies served single (but different) behavioral functions. The studies in which one response topography was analyzed may provide a more accurate estimate of the prevalence of multiply controlled behavior. In addition, more analyses such as those conducted by Smith, Iwata, Vollmer, and Zarcone (1993), in which different function-based treatments are assessed as a means of supporting conclusions of multiple control, may provide more rigorous demonstrations of multiply controlled behavioral phenomena.

As evident in the epidemiological study conducted by Iwata, Pace, et al. (1994) and the present analysis, the function of SIB varies across individuals and necessitates individualized assessment. Other topographies show trends that may suggest a particular function for a given topography of problem behavior. For instance, an overwhelming majority of functional analyses identified escape as the reinforcer for aggression and automatic reinforcement as supporting stereotypy. However, there have been exceptions to the predominant function for both topographies, and a relatively small number of functional analyses have been conducted exclusively for each topography. Even considering the trends in the summary of function across topography, it appears that behavioral function and topography remain independent, such that function cannot be predicted by the topography of problem behavior.

Less than 5% of the studies have included undifferentiated functional analysis results such that an assessment-based course of treatment could not be identified. Given that publication contingencies generally favor positive findings, this low percentage of undifferentiated results may not be representative of the actual failure rate in clinical settings. Although publication of only assessment failures is rare, many studies included in the present review described initially unclear results that were clarified by one of several strategies: (a) inclusion of idiosyncratic antecedent and consequent variables during subsequent functional analyses (Bowman et al., 1997; Fisher, Lindauer, Alterson, & Thompson, 1998; Thompson, Fisher, Piazza, & Kuhn, 1998), (b) altering the experimental design (e.g., Iwata, Duncan, Zarcone, Lerman, & Shore, 1994; Piazza, Fisher, et al., 1997) or aspects of the experimental arrangement (Conners et al., 2000) to facilitate discrimination across conditions, or (c) including assessments of the efficacy of the putative reinforcers for problem behavior to strengthen alternative behaviors (e.g., Steege, Wacker, Berg, Cigrand, & Cooper, 1989). In addition, Vollmer et al. (1995) described a methodology that progressed from relatively brief assessments to more extended analyses that resulted in clear and replicable response patterns for 85% of participants.

DISCUSSION

In considering historical and current functional analysis research, two final areas of discussion seem warranted: (a) experimental integrity and (b) the ecological validity of functional analysis. The importance of specific issues related to these broad topics will be presented, as will future directions for research and suggestions for best practices.

Experimental Integrity

Functional Analysis Models

Both general models of functional analysis attempt to identify behavioral function so as to facilitate development of an effective, function-based treatment; however, the ABC model provides a more rigorous demonstration of causation. The AB model is considered a functional analysis in that a functional relation is demonstrated between an environmental event and problem behavior, and from this, situations in which problem behavior is more likely are clearly identified. However, because putative reinforcers are not manipulated in the AB analysis, the source of reinforcement for problem behavior must be inferred on the basis of the correlation between behavior and the antecedent conditions under which a contingency is likely to operate.

However, patterns of responding observed in AB analyses may sometimes lead to erroneous conclusions about behavioral function. For example, demands may occasion problem behavior not because they establish escape as negative reinforcement but because the prompting may signal that attention (positive reinforcement) is available for problem behavior (Vollmer, Iwata, Smith, & Rodgers, 1992). Alternatively, high levels of problem behavior observed when low levels of antecedent attention are arranged may be indicative of an attention function or may reflect the evocative effects of a relatively barren environment on automatically reinforced behavior. However, it should be noted that this could also be a limitation of ABC assessments when the quality of attention delivered contingent on problem behavior does not compete effectively with the putative automatic reinforcer.

Because AB assessments do not arrange social reinforcement for problem behavior, it is somewhat counterintuitive that target behaviors (other than those maintained by automatic reinforcement) would persist in these assessments. One possible explanation is that observed rates of problem behavior may simply reflect an early stage of extinction (i.e., elevated rates of responding). Because the majority of studies employing the AB model also conduct few observations per condition in a reversal design, the latter stage of the extinction process (i.e., near-zero rates of responding) may not be readily apparent in the data. An alternative possibility is that AB assessments involve responding during extinction that culminates in reinforcement (e.g., problem behavior may be followed by attention that is provided in every third interval) and therefore the problem behavior is maintained even though reinforcement is not programmed for problem behavior. In essence, the processes responsible for behavioral persistence during the AB functional analysis model may be related to by-products of extinction processes (Goh & Iwata, 1994) or adventitious reinforcement (Vollmer, Ringdahl, Roane, & Marcus, 1997).

By contrast, the ABC model of functional analysis involves a strong contingency between problem behavior and putative reinforcers (typically, every response results in the programmed consequence of a given condition) in the presence of strong EOs (putative reinforcement is available only following the emission of problem behavior). Whereas AB assessments rely on inference, probabilistic contingencies, or indirect effects of extinction in determining behavioral function, an ABC model demonstrates functional relations between antecedent events and behavior (e.g., low levels of antecedent attention are associated with high levels of problem behavior) as well as the adaptive function of problem behavior (e.g., the level of problem behavior is high when and only when attention is arranged as a consequence).

Given the apparent advantages of conducting ABC analyses, it is difficult to determine why AB analyses continue to be conducted as a method for assessing behavioral function. It cannot be because AB analyses are more efficient—the delivery of consequences takes hardly any time. It may be argued that ABC analyses are less attractive because they contain explicit reinforcement contingencies for problem behavior (i.e., increased risk to the client), whereas AB analyses do not. However, both assessments are designed to produce occurrences of problem behavior; therefore, both assessments place the client at a similar risk of harm from engaging in problem behavior.

Finally, some authors (e.g., Martin, Gaffan, & Williams, 1999; Sturmey, 1995) have suggested that arranging explicit contingencies may result in new learning during assessment. However, the contingent events manipulated in functional analyses are either mundane events (e.g., attention or escape) that are typically delivered for problem behaviors (Thompson & Iwata, 2001) or are derived from clinical interview or observation (Fisher, Kuhn, & Thompson, 1998), so the likelihood of establishing new response–reinforcer relations seems low. Incidental maintenance of problem behavior has been observed rarely during a functional analysis and only when highly preferred tangible items were presented following problem behavior in the absence of information suggesting that a contingency may have existed (Shirley, Iwata, & Kahng, 1999). But, this finding underscores the importance of clinical interview or observation prior to arranging contingencies between problem behavior and atypical and potentially potent *tangible* reinforcers during functional analyses. In addition, identifying new contingencies that support problem behavior is not necessarily unimportant. It may lead to measures that prevent the development of new reinforcement contingencies in the natural environment (i.e., redirection to preferred items may be strongly discouraged). In sum, ABC analyses do not appear to be associated with greater risk or less efficiency than do AB analyses. Moreover, given the greater precision of the ABC analysis, the best practice recommendation is to include the manipulation of consequences in functional analyses.

Number of Topographies in the Contingency Class

When several topographies of problem behavior are included in the same functional analysis, interpretation based on examination of aggregate data may obscure important findings. For instance, Derby et al. (1994, 2000) showed that different forms of problem behavior (e.g., aggression and stereotypy) appeared to have different functions when graphed separately. A more rigorous strategy for determining if multiple topographies belong to the same response class (i.e., are maintained by the same reinforcement) is to arrange extinction contingencies for the predominant responses and then to observe reinforcement effects in the remaining responses (e.g., Lalli, Mace, Wohn, & Livezey, 1995; Richman, Wacker, Asmus, Casey, & Andelman, 1999). Magee and Ellis (2000) arranged contingencies for multiple topographies of behavior (out of seat, yelling, inappropriate language, and destruction for 1 participant; object mouthing, destructive and aggressive behavior for a 2nd participant), and only one of the topographies was observed consistently in a single test condition for each participant. The authors then implemented extinction for the most frequent response and observed a decrease in those responses and increases in other responses. This procedure was continued across the remaining topographies, and similar effects were observed, thereby demonstrating functional relations for each distinct topography.

If additional graphing solutions (e.g., Derby et al., 1994, 2000) or extinction assessments (Magee & Ellis, 2000) are not employed, some functional relations may go unnoticed when multiple topographies of behavior are included in the same contingency class. In such cases, separate analyses for single topographies may increase the likelihood of developing effective treatments (see Thompson et al., 1998, for an example of this phenomenon). Practical considerations are probably the strongest justification for including more than one topography in a functional analysis. This approach may not be deleterious if the multiple topographies of behavior do indeed serve the same function; however, this cannot be known prior to conducting a functional analysis. In addition, as the number of different topographies of behavior included in the contingency class increases, so does the likelihood that some target behaviors will serve different functions (resulting in an undifferentiated assessment outcome). From this, the recommendation for best practice is to minimize the number of different topographies of problem behavior included in a single functional analysis. If multiple topographies are included in the analysis, then each topographical class of behavior should be subjected to extinction or separate topographies of behavior should be graphically analyzed to verify membership in the reinforced class.

Parameters of Control Conditions

A distinguishing feature of applied behavior analysis is its emphasis on single-subject experimental designs, in which each participant serves as his or her own control in evaluating the effects of independent variables. Control conditions are based on the general strategy of retaining all features of the experimental condition with the exception of the contingency of interest (Barlow & Hersen, 1984; Rescorla, 1967). All of the functional analysis studies included some type of control condition; however, the specific type and rigor of some of the control conditions varied.

Although the play condition described by Iwata et al. (1982/1994) has functioned as an effective control condition for the majority of functional analyses, several variations have been described. The first involves the manner in which attention is delivered: (a) according to a fixed-time 30-s schedule, (b) in conjunction with a brief omission contingency, or (c) continuously available. These arrangements differ in the extent to which the EO or contingency involving attention is removed. The second variation involves the type of leisure materials provided. Most studies do not specify the manner in which items were selected for inclusion, but several strategies are available: (a) Toys are selected that are thought to be sufficiently stimulating to compete with automatically reinforced behavior, (b) the most highly preferred items based on a systematic preference assessment are selected, (c) toys are selected from those that caregivers report can be found in the natural environment, or, if a test for behavioral sensitivity to tangible reinforcement is arranged, (d) the same items as used in the tangible test condition are selected. To date, no systematic evaluation of these strategies has been undertaken, yet this is an important area of future research because without effective control conditions, determination of behavioral function is unlikely.

In contrast to the various ways of controlling for the effects of positive reinforcement during functional analyses, the effects of negative reinforcement are typically controlled by providing continuous escape (i.e., absence of instructions) in the play condition. However, Kahng and Iwata (1998) suggested that the alone condition might be a better control for the evaluation of negative reinforcement on problem behavior (that does not require the presence of another person), because the S^D (a person who may have a history of delivering instructions) as well as the EO (instructions) and contingency (escape following problem behavior) are absent from the alone condition. The authors provided supporting data, in that greater differences between alone and demand conditions were observed for most participants relative to the differences observed between play and demand conditions.

A strength of the control conditions (whether play or alone) in ABC functional analyses is the efficiency with which information regarding behavioral function can be obtained—multiple sources of influence can be assessed through comparison with a single condition. In addition, large discrepancies between test and control conditions are arranged (i.e., strong contingencies and EOs are present in the test conditions, whereas these same events are typically absent from the control condition), which presumably result in more rapid differentiation between rates of problem behavior across test and control conditions. However, these same aspects may compromise the experimental integrity of the analysis in that multiple features of the environment are altered across test and control conditions (i.e., specification of the primary sources of behavioral influence may be difficult given the multiple differences between test and control conditions). The extent to which this may be a problem has not been clearly demonstrated. Nevertheless, examples of analyses that exclusively controlled for a contingency arranged in test conditions were provided by Fisher, Kuhn, and Thompson (1998), Sigafoos and Meikle (1996), and Sigafoos and Saggers (1995); these authors arranged for the reinforcer used as a consequence in the test condition to be available continuously and noncontingently in the control condition while all other features of the environment remained unchanged across test and control conditions. Future research could be directed towards evaluating the relative merits and limitations of using a single control condition to assess the effects of several test conditions versus arranging a specific control condition (with only one altered variable) for each test condition. Best practice recommendations regarding the selection of control conditions are highly dependent on time constraints. If efficiency is required, designing a single control condition that provides high levels of noncontingent access to all reinforcers to be tested while eliminating the contingency between reinforcers and problem behavior is recommended. If the situation calls for the most thorough analysis, designing individual control conditions matched to each test condition is recommended.

Tests for Automatic Reinforcement

Slightly more than 40% of the functional analysis studies did not include a test for behavioral persistence in the absence of social contingencies. Unfortunately, the omission of conditions controlling for the effect of social events may lead to erroneous conclusions about behavioral function. For example, high rates of behavior observed in a condition in which low levels of attention are scheduled may reflect the effects of deprivation from attention (social reinforcement); alternatively, the behavior could be automatically reinforced and observed only under conditions of low stimulation (Davenport & Berkson, 1963).

The type of problem behavior examined (e.g., aggression) in many studies may imply maintenance through social reinforcement, suggesting that a test for automatic reinforcement may not be warranted. This also may be problematic. For example, Thompson et al. (1998) showed that some forms of a young boy's aggression (e.g., hitting, kicking) were socially mediated; whereas another (chin grinding) was automatically reinforced by the stimulation directly produced by the response. The authors provided further support for these conclusions by demonstrating the effectiveness of separate treatments matched to the specific function of each form of aggression.

Although the test for automatically reinforced problem behavior typically consists of observing the persistence of responding in a condition in which the individual is alone, some authors have used an ignore condition in which a person is present but does not provide social consequences for responding. This modification is included in analyses because some behavior cannot occur in the absence of another person (e.g., aggression), particularly intense SIB may require blocking if it exceeds a particular frequency, or the assessment environment does not allow unobtrusive observation. A potential problem with the ignore condition as a test for automatically reinforced behavior is that an S^D for socially mediated behavior is present. Because social reinforcement is not delivered following occurrences of problem behavior during ignore conditions, socially mediated problem behavior should be extinguished. However, Hanley, Piazza, Fisher, and Adelinis (1997) showed that the presence of another person might exert powerful stimulus control over responding to the extent that their participant's attention-maintained problem behavior persisted under extinction (when the person was present) for 50 consecutive sessions (problem behavior was rapidly extinguished in the absence of the person). These data suggest that elevated response rates across all assessment conditions (suggestive of automatically maintained responding or of undifferentiated responding) may be under the discriminative control of the presence of a person. Conducting true alone sessions in which the S^D (a person) for social reinforcement is absent or creating novel discriminative control by correlating conditions with different cues (Conners et al., 2000) may help to clarify undifferentiated analyses that result from control exerted by stimuli common across assessment conditions (e.g., people).

Because interventions for problem behaviors maintained by either social or automatic reinforcement involve the manipulation of very different contingencies and environmental events, it is important to be able to distinguish between the two types of maintaining contingencies. Therefore, it is recommended that functional analyses include tests for automatic reinforcement that minimize all features of the environment that may occasion socially mediated responding. Consistent with strategies described by Goh et al. (1995) and Piazza et al. (1998), future research should proceed beyond demonstrating behavioral persistence in the absence of social consequences and continue analyses to identify the specific features of the environment that serve to maintain automatically reinforced problem behavior.

Alternative Methods of Data Analysis

Interpretation of results from functional analyses typically is done through visual inspection of graphed data, a process that is somewhat informal. Several authors have suggested using either explicit, structured criteria during visual inspection (Hagopian et al., 1997; Toogood & Timlin, 1996) or more formal statistical analysis of the data (Martin et al., 1999). Hagopian et al. developed a set of formal criteria for visual inspection of multielement functional analysis data based on consensus by experts, which resulted in higher interrater agreement than that resulting from unstructured visual inspection. These results suggested that (a) determinations of behavioral function may be less reliable than generally assumed, (b) rules used by experts to determine behavioral function can be operationalized, and (c) individuals with a limited history of interpreting functional analysis data can be trained to apply these rules to improve accuracy and consistency. A strength of the interpretative strategy described by Hagopian et al. is that it established a consistent basis for evaluating complex data arrays (e.g., the relation between trends and levels of responding in particular test and control conditions) that typically requires a more extensive history with functional analysis data.

Martin et al. (1999) compared a modified version of the structured criteria described by Hagopian et al. (1997; 50% or more sessions in the highest condition had to be 1 *SD* above the mean rates in the control condition for a determination of behavioral function) with another set of criteria proposed by Toogood and Timlin (1996; 50% or more sessions in the highest condition had to be at least 50% higher than the overall assessment mean to ascribe behavioral function) and with a probability-based statistical procedure (modified *z* score) for interpreting functional analysis results. The authors found generally low agreement across the three interpretive strategies. They also evaluated the validity of each strategy by examining the number of assessments for which each interpretive strategy yielded a behavioral function, and found that the probability-based procedure resulted in the largest number of identified functions. However, the fact that an analytic strategy yields a determination of behavior function does not imply that it would be the basis for effective therapeutic action because the behavioral functions identified via the probability-based statistical procedure may have represented false-positive outcomes.

This same difficulty is present in other studies that compared outcomes of various functional assessments (indirect assessments, descriptive or functional analyses) by comparing the number of assessments for which a determination of behavioral function was achieved (e.g., Toogood & Timlin, 1996). In other words, simply guessing will always yield a behavioral function. The main difficulty in determining which method of data analysis (or which functional assessment strategy) is more accurate is that there is no universal standard for comparison. Comparing the efficacy of different courses of action (e.g., treatments) suggested by either different interpretative methods or different types of assessment may be helpful on a practical level, but this would not directly address the issue of accuracy. Although an apparent need for more studies on the interrater agreement and accuracy of visual inspection or statistical strategies for interpreting functional analysis data is suggested by the Hagopian et al. (1997), Martin et al. (1999), and Toogood and Timlin (1996) studies, an alternative line of research might attempt to identify the historical and methodological variables that give rise to "noisy" and difficult-to-interpret functional analysis outcomes, thereby reducing the need for more subtle (statistical) interpretive strategies. That is, tighter control over influential variables would lead to more easily interpretable, differentiated functional analyses. Therefore, a best practice recommendation is to continue to refine and individualize the various components of functional analysis methodology until a clear (visual) determination of behavioral function can be made.

Ecological Validity

Assessment Settings and Therapists

Although the settings in which functional analyses are conducted may vary (e.g., school, hospital, etc.), most are conducted under well-controlled conditions that may not closely resemble the settings in which the problem behavior of interest typically occurs. For example, a functional analysis in the school may be conducted in the corner of the classroom away from the other students (e.g., J. Taylor & Miller, 1997). Thus, functional analyses usually are conducted in settings that are neutral with respect to behavioral history. The advantage of arranging controlled conditions away from the natural environment is that changes in rates of behavior across conditions can be attributed to the variables explicitly manipulated by the experimenter; thus, conclusions regarding behavioral function can be derived with confidence.

Nevertheless, several authors have questioned the ecological validity of functional analysis methodology based on the fact that assessment takes place outside the natural environment (these authors typically refer to functional analyses as analogue assessments), therefore rendering conclusions about the function of behavior somewhat questionable (e.g., Conroy, Fox, Crain, Jenkins, & Belcher, 1996; Martin et al., 1999; Sturmey, 1995). *Ecological validity* is used here to indicate the extent to which functional relations tested in the analysis are consistent with those that operate in the natural environment. In other words, the functional analysis may identify a response–reinforcer relation that is not necessarily the same as the one that maintains problem behavior either at home or at school. Several researchers have seemingly circumvented this issue by (a) conducting sessions during a child's typical routine in the home (e.g., Arndorfer et al., 1994; H. M. Day et al., 1994; Ellingson et al., 2000), (b) embedding sessions in a child's normal mealtime routine (Paisey et al., 1991), or (c) conducting sessions during typical classroom activities (e.g., Lalli, Browder, Mace, & Brown, 1993; Northup et al., 1995, 1997; Sasso et al., 1992; Umbreit, 1995a, 1995b).

An interesting approach to conducting functional analyses under naturalistic conditions was described by Sigafoos and Saggers (1995), who assessed the effects of contingent attention, tangible items, or escape from task-related instructions during 20 2-min trials distributed at various times across the child's school day. Each trial consisted of two parts. In the first minute, the reinforcer was available only following aggression; in the second minute, the same reinforcer was available continuously. Using these brief and intermittent test-control trials, the authors observed differential responding for both participants. This approach was replicated (Sigafoos & Meikle, 1996) with 2 boys with autism who engaged in multiple problem behaviors, and successful function-based treatments were again prescribed. Just as the brief functional analysis (Northup et al., 1991) serves as a practical and effective substitute when more thorough analyses cannot be conducted, the approach described by Sigafoos and colleagues may be an attractive option for enhancing the ecological validity of behavioral assessment. Strategies such as these may lead to an understanding of the natural conditions under which problem behaviors occur more readily than indirect or descriptive assessment methods, which omit methodological requirements (e.g., direct observation and manipulation) for isolating behavioral phenomena. However, a potential limitation of this approach is that the complex nature of naturally occurring events may compromise procedural integrity (i.e., lack of control over the type, quality, schedule, and duration of the programmed consequences). This may lead to extended assessment durations or may prohibit entirely the accurate identification of specific variables that influence problem behavior.

Another strategy for increasing the ecological validity of functional analyses involves incorporating into assessment sessions individuals who have a previous history of interaction with the person exhibiting problem behavior, such as parents or other family members (e.g., Reimers et al., 1993; Umbreit, 1996; Vollmer et al., 1996), teachers (e.g., Mace, Yankanich, & West, 1989; Watson, Ray, Turner, & Logan, 1999), or classroom peers (e.g., Broussard & Northup, 1995; J. E. Carr et al., 1996). Results of a preliminary study by Ringdahl and Sellers

(2000) suggest that having caregivers deliver programmed consequences during functional analyses may facilitate clearer outcomes; however, additional research is needed to determine the utility of this practice. In other words, the extent to which conducting sessions in the natural environment during typical routines or having caregivers or teachers conduct assessment sessions will improve the efficiency or accuracy of a functional analysis is still not well known. Large-scale direct comparisons of ecologically valid and more tightly controlled analyses are needed to identify both the benefits and limitations of incorporating natural features of the client's environment into analysis conditions. With respect to best practice, it seems reasonable to incorporate as many features of the client's natural environment into the assessment conditions as possible, as long as the integrity of the experimental arrangements is monitored to insure that procedures are implemented as specified.

Supplemental Assessments

Many studies described the use of preliminary assessments (indirect or descriptive procedures) to facilitate the functional analysis process. Although these types of assessment may be helpful in structuring more precise functional analyses of problem behavior, the data derived from these supplementary assessments have been presented rarely, and the relevance of the supplementary assessment data in the studies that did include them is not well known (Iwata, 1994). In other words, it is possible that analysis outcomes would be the same whether or not results from additional assessments were used as a basis for structuring the functional analysis. The definitive study yet to be conducted would involve conducting two simultaneous but procedurally different functional analyses, one of which would be based on results of a supplementary assessment and the other would be structured typically and without supplementary information.

One general criticism found in several commentaries on functional analysis methodology that appeared in the 1994 special issue of *JABA* was that functional analyses do not adequately sample all relevant aspects of the controlling environment. Some of these aspects include (a) physiological or internal states related to illness or drugs (E. G. Carr, 1994), (b) structural aspects of reinforcers (Carr) or EOs (Horner, 1994), or (c) temporally distant events that may influence the occurrence of problem behavior (Repp, 1994). The authors referred to these potentially important antecedent events as either setting events (Carr; Repp) or contextual variables (Carr; Horner) and lamented their lack of consideration in functional analysis methodology. They also suggested that the identification of these contextual variables would result in more accurate behavioral assessment and ultimately more effective and durable treatments. Relevant to the present discussion, several authors suggested that a greater emphasis on either indirect or descriptive assessments might resolve this particular limitation of functional analysis methodology (Carr; Horner; Mace, 1994; Repp).

Mace (1994) suggested that descriptive assessments might be useful in identifying idiosyncratic reinforcers or schedules, which could be programmed subsequently in a functional analysis. However, the extent to which complex descriptive analyses would improve the efficiency or accuracy of a functional analysis has not been demonstrated empirically. In fact, indirect and descriptive assessment strategies (e.g., Durand & Crimmins, 1988; Mace & Lalli, 1991) do not necessarily sample a wider range of EOs or reinforcers. Instead, they seem to represent a different way of gathering information about the same variables manipulated in a functional analysis, and, as a result, would not enhance the accuracy or ecological validity of the functional analysis.

By contrast, results from several studies have suggested that unstructured observations conducted outside the assessment context sometimes have been helpful in identifying unusual events that, once incorporated into a functional analysis, resulted in the identification of functional relations (see Bowman et al., 1997; Fisher, Adelinis, Thompson, Worsdell, & Zarcone, 1998; Fisher, Kuhn, & Thompson, 1998; Fisher, Lindauer, Alterson, & Thompson, 1998; Richman & Hagopian, 1999; Thompson et al., 1998). The authors of these studies did not use formal descriptive analysis techniques, questionnaires, or rating scales; instead, they merely had observers document unusual aspects of caregiver–child interactions or environmental conditions that were present when problem behavior occurred. This process may be best characterized as an open-ended descriptive assessment in which the antecedent and consequent events are not specified prior to the observation. It is a process that is more akin to the narrative recording technique described by Bijou et al. (1968), which permits the identification of idiosyncratic types of EOs (e.g., talking to another person) and consequences (e.g., specific type of attention) that typically would not be included in a functional analysis and also would not be captured via questionnaire or descriptive analysis. As illustrated in the studies cited, these events, once identified, may be incorporated into a functional analysis when initial analyses yield uninformative results.

If idiosyncratic events that may influence behavior are identified via supplemental assessment, their functional role as EOs or reinforcers still requires demonstration by way of a functional analysis. For instance, if the hypothesis derived from clinical observation is that SIB is maintained by escape from instructions but only when the individual is tired or ill, the impact of these EOs can be observed by conducting functional analysis conditions before and following exercise, nights of disturbed sleep, or bouts of illness. Unique and temporally proximal or distant EOs may exert control over behavior maintained by a given contingency (e.g., negative reinforcement); however, these effects can only be verified in the context of experimental manipulation. In other words, progress from general classes of maintaining contingencies (e.g., positive vs. negative reinforcement or social vs. automatic reinforcement) to more individualized environment–behavior relations (i.e., increased precision) might be best accomplished through more careful experimental manipulation (e.g., Smith et al., 1995; Thompson et al., 1998) rather than through more extensive indirect or descriptive strategies.

To summarize, all forms of functional assessment are limited in that potentially important, idiosyncratic reinforcers and EOs may go unnoticed. Identifying idiosyncratic events prior to conducting a functional analysis is not always essential for determining behavioral function and designing effective intervention (e.g., sleep deprivation may act as an EO and increase escape-reinforced problem behavior, but escape extinction should be effective even if the relation between sleep and problem behavior goes undetected). However, observing idiosyncratic features of the natural environment when functional analyses yield undifferentiated results is highly recommended. Future research should establish guidelines for examining natural environments for idiosyncratic features that may be relevant to the maintenance of problem behavior.

Practical Enhancements

Tests for Single Sources of Influence

Although most functional analysis research includes tests for multiple sources of control, assessment of single response–reinforcer relations continues to a lesser extent (at least two studies each year since 1990 have tested for single sources of control). Assessment strategies that focus on single response–reinforcer relations may be beneficial under some conditions. For example, if anecdotal information or descriptive assessment data are strongly suggestive of a particular source of influence, that variable can be evaluated quickly, and treatment matched to that function can be initiated prior to or concurrent with tests of other sources of influence.

Brief Session Duration

Wallace and Iwata (1999) examined the extent to which variations in session duration (5, 10, or 15 min) affected the outcomes of functional analyses. All of the 10-min data sets yielded interpretations identical to those based on the 15-min data sets (i.e., 100% agreement), whereas three of the 5-min data sets yielded interpretations different than those based on the 15-min data sets (i.e., 93.5% agreement). Their results suggested that assessment efficiency could be improved with little or no loss in clarity by conducting brief (5- or 10-min) sessions.

Brief Assessment Duration

Kahng and Iwata (1999) compared data sets from 50 full functional analyses (35 of which showed clear response patterns and 15 of which were undifferentiated) with those from brief assessments that were constructed by isolating the first session of each condition from the full analyses. The outcomes of the brief assessments corresponded with those of the full analyses in 66% of cases. The results of this study, along with numerous replications of the procedures described by Northup et al. (1991), suggest that the brief functional analysis may be adequate when circumstances do not permit repeated observation of problem behavior under multiple test and control conditions.

Discriminative Stimuli

Conners et al. (2000) attempted to minimize interaction effects within functional analyses by increasing the discriminability of assessment conditions. Multielement functional analyses were conducted on the SIB or aggression of 8 adults with mental retardation in which each condition initially was correlated with a specific therapist and room color. In subsequent analyses, the programmed S^Ds were removed (i.e., all conditions were conducted by the same therapist in the same room). Results indicated that the inclusion of distinctive visual S^Ds facilitated differential responding during multielement functional analyses in half of the participants. Strengthening the stimulus control exerted in each analysis condition may be especially helpful when conducting (a) brief assessments (e.g., Northup et al., 1991), (b) sessions of short duration (e.g., 5 min), or (c) assessments in the same setting (e.g., classroom). Future research could identify a range of stimuli that facilitate discrimination under different situations (e.g., particular seating positions in the classroom) or by different individuals (e.g., scents with persons who are blind), so that therapists can construct efficient assessment procedures in spite of practical constraints imposed by time, setting, or personnel.

Proceeding from Undifferentiated Analyses

Although not commonly reported, undifferentiated analysis outcomes occur, most often when problem behavior occurs sporadically or at very low rates. As noted previously, the inclusion of information gathered through other sources (e.g., about idiosyncratic EOs, qualitative aspects of reinforcement) in functional analyses may clarify initially undifferentiated results (see E. G. Carr et al., 1997, for an example). Including stimuli from the client's natural environment or conducting the analysis in the environment in which the problem behavior occurs (e.g., Sigafoos & Saggers, 1995) also may increase the likelihood of a differentiated assessment outcome (although this has not been empirically demonstrated). Minimizing the number of response topographies in the contingency class (e.g., Thompson et al., 1998) or graphing response topographies separately (Derby et al., 1994, 2000) may also yield clear assessment outcomes. When functional analyses based on brief session duration (5 to 15 min) yield undifferentiated results, observing the effects of contingencies over longer periods (hours, days, or weeks) may allow relevant EOs to operate for a sufficient amount of time to evoke problem behavior and yield clear assessment results (e.g., Arndorfer et al., 1994; Reese, 1997). Finally, arranging contingencies to follow reported precursors to the target responses or even arbitrary responses (see Piazza, Hanley, et al., 1997, Grace, Thompson, & Fisher, 1996) may demonstrate behavioral sensitivity to particular forms of reinforcement that can then be incorporated into treatments for problem behavior (this strategy may be an improvement over arbitrarily selecting an intervention, but it does not determine the actual function of problem behavior).

CONCLUSION

Several researchers have suggested that there has been a lack of systematic extension of functional analysis methodology (e.g., Gable, 1996; Gresham et al., 1999; Sturmey, 1995). However, it is apparent from the present review that comprehensive functional analysis models (E. G. Carr & Durand, 1985; Iwata et al., 1982/1994) have generated a voluminous database of extensions as well as replications across a wide range of client populations, target behaviors, and settings. Systematic growth in the use of functional analysis methodology as a primary method of behavioral assessment and, more generally, as a means of studying environment–behavior relations is evident in the sharply increasing trend in the publication rates of functional analysis research (see Figure 1).

At the present time, functional analysis research has not yielded an established set of rules for conducting an assessment; however, best practices are beginning to emerge. As noted in the Discussion, these practices include (a) limiting response classes to one or a few behavior topographies, (b) programming consequences for the occurrence of target behaviors, (c) incorporating EO influences before and during assessment, (d) including S^Ds to facilitate discrimination of test conditions, (e) conducting relatively brief (e.g., 10-min) sessions, (f) including tests to identify behavior maintained by automatic reinforcement, (g) considering relative reinforcement durations when interpreting analysis results, (h) testing for functional relations between problem behavior and tangible reinforcement only when preliminary assessment information suggests a relation might exist, (i) starting brief and simple (i.e., arranging common test conditions) and progressing to more lengthy or complex assessments as needed, and (j) using other sources of information (e.g., open-ended interviews and observations) as adjuncts to structure the more complex analyses.

Although functional analysis has been repeatedly shown to be a powerful behavioral assessment tool for prescribing effective treatments, concerns have been raised about the feasibility of conducting functional analyses in typical service settings (e.g., classrooms) due to either time requirements (Applegate, Matson, & Cherry, 1999; Pyles, Riordan, & Bailey, 1997) or the level of training and clinical expertise needed to insure procedural fidelity (Crawford, Brockel, Schauss, & Miltenberger, 1992; Sturmey, 1994). However, as noted earlier, over 80 functional analysis studies have been conducted in school settings. In addition, Iwata et al. (2000) noted that the time commitment appears no greater than that required by a descriptive assessment and presented a 2-hr strategy for teaching the basic skills necessary for conducting a functional analysis. Combining these instructional procedures with information regarding best practice in conducting functional analyses and analyzing their results should produce a set of basic competencies in clinicians and educators who are charged with assessing and treating problem behaviors.

As with all behavioral assessment strategies, it is important to consider ethical issues when implementing functional analysis methodology. Questions arise concerning the necessity of a rigorous functional analysis and the potential harm to the individual that may be incurred during assessment. Whether a problem behavior necessitates such rigorous analysis may be partially addressed by considering the short- and long-term cost (or danger) of ineffective treatment versus the potential harm that may be engendered during the course of a functional analysis. Consideration of brief assessments, careful structuring of analyses, and evaluations of within-session patterns may be appropriate measures to avoid lengthy behavioral assessment.

Although a number of permutations of functional analysis procedures have been described, further refinements are still needed to improve the efficiency and generality of functional analysis methodology while its precision is maintained. Developing practical yet precise assessment strategies may be an elusive goal, but its realization can be achieved only through systematic refinement based on sound research. Experimental methods have led to a greater understanding of a wide range of phenomena, and their extension to the evaluation of environment–behavior relations that influence clinical phenomena constitutes a clear improvement over alternative strategies.

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