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REVIEW ARTICLE

Variations in Functional Analysis Methodology: A Systematic Review

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Abstract Functional analysis procedures have been revolutionary in the field of applied behavior analysis. Their ability to identify the contingencies maintaining problem behavior has allowed clinicians to develop function-based treatments and minimised the use of aversive procedures to reduce problem behavior. However, limitations including their time consuming nature, the expertise they require, their unsuitability for certain settings and types of behavior, and their reinforcement of the problem behavior, often preclude their use in applied settings. Several alternative types of functional analysis have been developed to compensate for these limitations. This review includes studies that investigated the use of brief functional analysis, latency functional analysis, precursor functional analysis, functional analysis with protective equipment, and trial-based functional analysis. Studies that met the inclusion criteria were evaluated with respect to various aspects including sample and setting characteristics, target behaviors, additional assessments, outcomes of the analyses, and efficacy of function-based treatments applied.

Keywords Brief functional analysis · Latency functional analysis · Precursor functional analysis · Functional analysis with protective equipment · Trial-based functional analysis · Traditional functional analysis

It is long established that all behaviors serve a function for an individual and that behavior is influenced by contingencies in an individual's environment. Determining

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the function of the behavior and its environmental determinants is imperative for creating treatments that will address the issue and remediate problem behavior (Reid and Nelson 2002). The ability to do this was greatly enhanced with the development of functional analysis (FA) methodology by Iwata and colleagues (1982). FA provided behavior analysts with a way of assessing the relationship between behavior and environmental events and of determining behavioral function through the manipulation of establishing operations and observation of problem behavior. The original experimental conditions included (1) social disapproval, designed to assess whether the behavior was maintained by positive reinforcement in the form of attention, (2) academic demand, which assessed whether the behavior was negatively reinforced by escape from aversive situations, (3) unstructured play, which served as a control condition, and (4) an alone condition which sought to determine if the behavior was self-stimulatory.

Functional Analysis procedures were revolutionary in the field of applied behavior analysis. Their ability to identify the underlying reinforcer for problem behavior enabled the development of function-based interventions and lessened the use of default technologies that relied on aversive punishment procedures and artificial reinforcers (Mace 1994). FA techniques became incredibly popular and spawned a great deal of research. For example, Hanley et al. (2003) found 277 empirical studies of FA used to assess the function of problem behavior. Their review showed that FA was most commonly used with children, particularly those diagnosed with a developmental disability. FA was conducted primarily within inpatient facilities, schools, and residential institutions. The problem behaviors most commonly analysed were self-injury, aggression, and disruption. It was found that, among the studies reviewed, 95.9% were successful in identifying the function of the problem behavior and only 4.1% resulted in undifferentiated outcomes. The appeal of FA is enhanced by social validity findings that suggest it is considered an acceptable process by teachers and parents (Langthorne and McGill 2011; Reid and Nelson 2002).

Despite the success and widespread acceptance of FA, several limits and disadvantages of traditional methods have been highlighted. Its applicability to typical service settings has been questioned because of its time consuming nature. A review of over 150 published studies found the average time taken to conduct a FA was six and a half hours which did not include the time required to conduct interviews prior to the analysis, the time between sessions, or the time needed to train staff in the procedures (Iwata et al. 1994; Tincani et al. 1999). The expertise required for successful execution is also considered a disadvantage (Iwata et al. 2000; Northup et al. 1991). Furthermore, it has been claimed that traditional FA conditions may be too limited to accurately address potential maintaining contingencies (Carr 1994). FA may also be unsuitable for use with certain types of problem behaviors such as those that occur at rapid high frequencies, could injure the individual or others, or for behaviors which can only occur once in a session unless further response opportunities are contrived (Borrero and Borrero 2008; Thomason-Sassi et al. 2011). Additionally, FA provides reinforcement for the problem behavior, perhaps strengthening it, and increasing the probability of future rates (Najdowski et al. 2008). Often for these reasons, individuals and treatment providers may rely more on indirect methods of assessment which may be less accurate and less reliable than FA (Northup et al. 1991).

The limitations associated with FA have prompted researchers to alter the technique to make its use more feasible and to reduce the potential risk of injury during the procedures. The purpose of this review is to examine the most common variations of FA that have been developed. It will examine the effectiveness of these methodological variations in identifying behavioral function and the efficacy of treatments based on their results. It will identify the strengths and limitations associated with each type of FA and suggest areas that future research should address.

Methods

Search Procedures

Systematic searches were conducted using the following databases: PsycInfo, Psychology and Behavioral Sciences Collection, ERIC, Medline, and Scopus. The searches were carried out using the terms "brief functional analysis", "single function test AND functional analysis", "latency AND functional analysis", "protective equipment AND functional analysis", "precursor behavior AND functional analysis", "pairwise test design AND functional analysis", and "trial-based functional analysis".

Inclusion and Exclusion Criteria

Studies were included if they involved the use of any of the following: (a) brief functional analysis, (c) latency functional analysis, (d) precursor functional analysis, (e) functional analysis with protective equipment, and/or (f) trial-based functional analysis. Each study was required to involve the direct measurement and manipulation of the TB or precursor behavior. All studies included were required to involve original research that was written in English and published in a peer-reviewed journal. Studies were excluded if they used a traditional FA (e.g., FA procedures described by Iwata et al. 1982) and no other form. Articles were sourced within the five databases and then filtered according to the inclusion/exclusion criteria. Studies were then sorted based on the type of FA employed.

Brief Functional Analysis

A primary criticism of FA is the length of time taken to complete the assessment which often precludes its use in certain settings (Perrin et al. 2008). Brief functional analysis (BFA) may involve fewer sessions and reduced session duration (MacDonald et al. 2002; Northup et al. 1991). BFA may also incorporate contingency reversals (CR) to determine whether the variables maintaining problem behavior can be used to maintain an appropriate replacement behavior (Northup et al. 1991). The articles in this category are outlined in Table 1.

Latency Functional Analysis

Latency functional analyses (LFA) involve the use of latency to target behavior, rather than frequency measures, to indicate the strength of the target behavior in each

Table 1 Summary of included studies. BFA (brief functional analysis), TFA (traditional functional analysis), LFA (latency functional analysis), PFA (precursor functional analysis), PEFA (protective equipment functional analysis), TBFA (trial-based functional analysis), PB (problem behavior), TB (target behavior)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
Ahearn et al. (2007)	4	3–11 years (7 years)	Autism spectrum disorder	Vocal Stereotypy	BFA	Response interruption and redirection	Treatment reduced TB and increased appropriate behavior. Some maintenance
Boyajian et al. (2001)	3	4–5 years (5 years)	Symptoms of ADHD	Aggression; Noncompliance	BFA	Differential reinforcement of alternative behaviors (DRA)	Treatment reduced TB and increased appropriate behavior
Broussard and Northup (1995)	3	6–8 years (6.7 years)	None; ADHD	Talking out; Hand/arm gestures; Work incompletion; Out of seat behavior; Hitting; Property destruction; Noncompliance; Crying	BFA	DRA; Differential reinforcement of other behaviors (DRO)	Treatments reduced TBs and increased appropriate behaviors
Carr and Britton (1999)	1	32	Intellectual Disability	Problematic speech	BFA	Noncontingent reinforcement (NCR)	Treatment reduced TB
Carr et al. (2002)	1	7	Autism spectrum disorder	Object mouthing	BFA	NCR; response blocking; NCR and response blocking	Treatment reduced TB. Effects generalized to new setting and therapist
Carter et al. (2004)	1	8		Screaming; Hand mouthing	BFA	No	Initial BFA inconclusive.

Table 1 (continued)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
			Developmental disability; Intellectual disability				Follow-up analysis revealed higher levels of TB in presence of tangibles
Casey and Merical (2006)	1	11	Autism spectrum disorder	SIB	BFA	Functional communication training (FCT)	Treatment eliminated TB. Maintained at 2 year follow-up
Cihak et al. (2007)	4	15–21 years (17 years)	Intellectual disability	Outbursts; Inappropriate touching; Vocalisations; Leaving the work area	BFA	Self-operated audio prompts and DRA	Treatment reduced TBs
Derby et al. (1992)	79 cases	1–32 years (14.6 years)	Autism spectrum disorder; Intellectual disability; Seizure disorder; Sensory disability; Fixed motor disorder	SIB; Aggression, Stereotypic behavior; Property destruction	BFA	DRA	BFA identified function for 63% of cases. Treatment during contingency reversal decreased TB in 54% of cases, and increased appropriate behavior in 65% of cases
Derby et al. (1994)	2	12–18 years (15 years)	Intellectual disability; Microencephaly; Down syndrome;	SIB; Stereotypy; Aggression; Other inappropriate behaviors; Manding; Other appropriate behaviors	BFA	DRO; Differential reinforcement of communication	Treatment decreased TB and increased appropriate behaviors
Dufrene et al. (2008)	1	24	None	Nail biting	BFA	Simplified habit reversal	Results of two BFAs were consistent.

Table 1 (continued)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
							Treatment reduced TB to near zero levels
Everett et al. (2007)	4	4–5 years (4.5 years)	None	Noncompliance	BFA	Time-out with escape extinction; Time-out without escape extinction	Both treatments reduced TB and increased appropriate behavior
Ishuin (2010)	1	4	None	Noncompliance	BFA	DRO	Treatment greatly reduced TB
Kahng and Iwata (1999)	50	20–68 years (37.5 years)	Intellectual disability	SIB	TFA & BFA	No	66% correspondence between the results of TFA and BFA, 68% if observed within-session responding patterns.
LaBelle and Charlop-Christy (2002)	3	5–9 years (8.9 years)	Autism spectrum disorder	Disruptive behavior; Inappropriate vocalisations	BFA	No	Condition to assess changing functions revealed multiple control and rapidly changing control of TB within conditions
LeGray et al. (2010)	3	4–6 years (4.7 years)	None	Disruptive classroom behavior	BFA	DRA; DRO	Treatments effectively reduced TB
Luiselli et al. (2004)	1	6	Autism spectrum disorder	Saliva play	BFA	Noncontingent access to alternative stimulation	Treatment eliminated TB

Table 1 (continued)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
Lyons et al. (2007)	2	11–14 years (12.5 years)	Global developmental delay; Autism spectrum disorder; Intellectual disability	Post meal rumination	BFA	NCR	Treatment substantially reduced TB
MacDonald et al. (2002)	1	5	Cortical visual impairment	Eye poking	BFA	Response blocking	Treatment eliminated TB
Normand et al. (2008)	1	7	Autism spectrum disorder	Sign for "soda pop"	BFA	No	Identified multiple functions of TB; Both mand and mimetic functions
Northup et al. (1991)	3	13–24 years (19.3 years)	Intellectual disability; Cerebral palsy	Aggression	BFA	DRA	Treatments evaluated during contingency reversal reduced level of TB and increased appropriate behaviors
O' Reilly et al. (2000)	2	9–22 years (15.5 years)	Intellectual disability; Fragile x syndrome	Pushing; Pinching; Property destruction; SIB	BFA	NCR	Treatment effective in reducing TB. Maintained at 24 weeks
Oikawa et al. (2011)	1	24	Intellectual disability	Pseudo Seizures	BFA	No	Identified automatic reinforcement as function of low frequency, high intensity behavior.

Table 1 (continued)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
Perrin et al. (2008)	2	3 (3 years)	Autism spectrum disorder	Elopement	BFA	NCR and extinction; FCT	Treatments reduced behavior to near zero levels
Pitman (2007)	1	52	Intellectual disability	Upright walking (incompatible behavior)	BFA	Differential reinforcement of incompatible behavior (DRI)	Treatment based on incompatible behavior led to increases in appropriate incompatible behavior but PB was not reduced
Rapp et al. (1999)	2	5 years 7 months (5.6 years)	None	Thumb sucking	BFA	Simplified habit reversal	BFA did not identify function for one participant. Treatment moderately effective for both but booster sessions required
Reimers et al. (1993)	6	4–5 years (5.1 years)	None; Intellectual disability	Noncompliance	BFA	No	BFA identified functions for two participants, results indicated multiple control for four participants.
Tincani et al. (1999)	3	26–30 years (28.7 years)	Autism spectrum disorder; Intellectual disability	Aggression; SIB	TFA & BFA	FCT	TFA and BFA identified the same TB function for all participants.

Table 1 (continued)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
							Treatment evaluated within BFA led to reductions in TB and increases in appropriate behavior
Umbreit (1995)	1	5	Intellectual disability	Disruptive behavior	BFA	Curriculum changes; FCT	Treatment eliminated TB.
Vollmer et al. (1995)	20	3–18 years	Cerebral palsy; Intellectual disability; Autism spectrum disorder; Pervasive developmental disorder; Rett syndrome; Visual Impairment; Down syndrome	SIB	BFA	No	Results suggest that BFA will only work for 30% of cases
Vollmer et al. (1996)	3	2–4 years (3.5 years)	Language delays	Tantrums; Appropriate behavior	BFA	Differential reinforcement & FCT	Treatment evaluated within the BFA led to decreases in TB and increases in appropriate behavior
Ward and Higbee (2008)	1	1 year 4 months	None	Tub-standing	BFA	NCR	Treatment reduced TB to zero levels
Watson and Sterling (1998)	1	4	None	Vocal tic	BFA	DRO and extinction	Treatment reduced TB to zero levels
Watson et al. (2005)	2	11–14 years (12.5 years)	Tourettes syndrome	Vocal tics; Motor tics	BFA	Simplified habit reversal	Identification of antecedent for TB

Table 1 (continued)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
							and implementation of treatment in those situations led to decrease in TB
Wilder et al. (2006)	2	2 years 10 months-3 years 4 months (3.1 years)	None	Tantrums	BFA	Advance notice of a transition; DRO and extinction	Treatment led to elimination of TB
Wilder et al. (2001)	1	43	Schizophrenia; Personality disorder not otherwise specified	Bizarre vocalisations	BFA	DRA and extinction	Treatment reduced TB and increased appropriate behavior. Effects generalized to another setting.
Wilder et al. (2005)	1	3 years 4 months	Autism spectrum disorder; Food allergies; Gastroesophageal	SIB; Food refusal	BFA	NCR	Treatment decreased TB and increased appropriate behavior
Call et al. (2009)	2	6–14 years (10 years)	Autism spectrum disorder; Cerebral palsy and Intellectual disability	Aggression; SIB; Disruptive Behavior	LFA	No	Use of latency as measure revealed function of behavior.
Thomason-Sassi et al. (2011) (i)	38 data sets	Not given	Not given	SIB; Aggression; Property destruction	LFA	No	High degree of correspondence between LFA outcomes and TFA outcomes. Correspondence for 33/38 datasets.

Table 1 (continued)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
Bergen et al. (2002)	1	28	Lesch-nyhan syndrome	One or both hands over shoulder level (PCB to eye gouging)	PFA	No	PFA determined that frequency of PCB was related to attention delivery. Attention acted as reinforcer and discriminative stimulus for SIB.
Borrero and Borrero (2008)	2	11–12 years (11.5 years)	Autism spectrum disorder	Vocalisations (PCB to SIB; Aggression; Property destruction)	TFA & PFA	No	Same function for PCBs and more severe problem behaviors were identified for both participants
Deaver et al. (2001)	1	2.5	None	Hair Twirling (PCB to hair pulling)	PFA	Noncontingent application of mittens	Treatment based on function of PCB reduced PB to near zero levels. Effects generalized to another setting and were maintained at 10 months
Herscovitch et al. (2009)	1	10	Autism spectrum disorder	Finger biting (PCB to SIB)	PFA	No	Same function identified for PCB and PB.
Langdon et al. (2008)	3	6–18 years (10.3 years)	Autism spectrum disorder; Intellectual	Hand posturing; Jerky body movements;	PFA	FCT	Treatment of PCB led to reductions in both PCB and PB

Table 1 (continued)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
			disability; Characteristics of autism	Vocalisations (PCBs to SIB and Aggression)			
Najdowski et al. (2008)	3	5–45 years (19.3 years)	Emotional handicap; Traumatic brain injury; Development disability; intellectual disability	Whining; Threatening to hurt self/others; Crying; Statements of toy possession; Statements about genitalia (PCBs to aggression and inappropriate sexual behavior)	PFA	FCT	Treatments based on PFA led to large decreases in PCBs and the more serious PB
Smith and Churchill (2002)	4	35–53 years (45.3 years)	Developmental disabilities; Intellectual disabilities	Screaming; Grabbing, Vocalisations; Crying; Reaching; Foot stomping (PCBs to SIB and aggression)	PFA	No	Same function identified for PCB and PB for each participant
Borrero et al. (2002)	2	8–35 years (21.5 years)	Intellectual disability; Down syndrome	Head banging; Trichotillomania	PEFA	No	The function of the behaviors identified in a FA without PE was suppressed and impossible to identify when PE was used

Table 1 (continued)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
Contrucci Kuhn and Triggs (2009)	1	7	Intellectual disability; Stereotypic movement disorder; Disruptive behavior disorder; Cerebral palsy; Dysphasia; Kyphoscolio; Visual Impairment	SIB	PEFA	No	Addition of protective equipment allowed further analysis and identification of a social function of SIB following initially inconclusive FA results.
Le and Smith (2002)	3	35–40 years (37.3 years)	Intellectual disability	SIB	PEFA	No	PE suppressed TB during PEFA. Function only identified when PE was removed
Moore et al. (2004)	1	12	Autism spectrum disorder	SIB	PEFA	No	When PE was applied TB occurred at near zero levels and only increased when padding removed. PE obscured function of behavior
Bloom et al. (2011)	10	6–18 years (11.9 years)	Autism spectrum disorder; Speech and language delay; Hearing impairment; Down syndrome; Intellectual disability	Aggression; SIB; Bizarre vocalizations; Inappropriate touching	TFA & TBFA	No	Correspondence between the functions of TB identified by TFA and TBFA was observed in 60% of cases

Table 1 (continued)

Study	*n*	Age range (Mean)	Diagnosis	Target behavior	Type of functional analysis	Function-based treatment	Outcome
LaRue et al. (2010)	5	4–29 years (14 years)	Autism spectrum disorder; Intellectual disability	Aggression; SIB; Disruption; Spitting; Inappropriate vocalizations; Hand stereotypy	TFA & TBFA	No	High correspondence between outcomes of TFA and TBFA. Functions for four participants matched, and there was a partial match for the fifth participant.
Sigafoos & Saggers (1995)	2	10–12 years (11 years)	Autism spectrum disorder; Intellectual disability	Aggression	TBFA	No	Clear functions were identified for the TB of both participants
Wallace and Knights (2003)	3	Adults (Not available)	Developmental disabilites	Disruptive behavior	TFA; TBFA	No	Identified same function for two participants. For third participant, TFA identified two functions TB while TBFA only identified one

condition (Thomason-Sassi et al. 2011). Thomason-Sassi and colleagues (2011) suggest that using latency as a measure should result in fewer instances of problem behavior which is advantageous when the behavior can result in harm to the individual or others. The two studies in this category are presented in Table 1.

Precursor Functional Analysis

Precursor functional analysis (PFA) involves the identification of behaviors that commonly occur before the problem behavior and signal that it is about to be emitted (Smith and Churchill 2002). The concept is that precursor behaviors (PCB) are a different, but functionally equivalent, topography of the problem behavior and thus are suitable replacements for the more severe or dangerous behavior during FA (Langdon et al. 2008). Using PCB should reduce the chance of injury to all involved (Herscovitch et al. 2009). The seven articles in this category are described in Table 1.

Protective Equipment and Functional Analysis

Research has also investigated the use of protective equipment (PE) within FA. The identification of behavioral function is reliant on the emergence of elevated levels of the problem behavior relative to the control condition. However, when the target behavior for reduction involves self-injury or aggression this could result in injury to individuals (Borrero et al. 2002). For this reason, if PE did not influence the results of a FA it could be used to protect individuals from harm during the assessment. The four articles in this category are outlined in Table 1.

Trial-Based Functional Analysis

Trial-based functional analysis (TBFA) involves the use of discrete trials to present each FA condition (Sigafoos and Saggers 1995). Trial sessions are often divided into test periods, where the establishing operation is present, and control periods, where the establishing operation is absent, and the effect of the contingencies on behavior is analysed (LaRue et al. 2010). There were four studies in this category as shown in Table 1.

Results

The search procedures and the application of the inclusion and exclusion criteria led to a total of 54 studies in this review. Table 1 summarises sample characteristics, target behaviors, type of functional analysis used, function-based treatments implemented, and intervention outcomes.

Sample and Setting Characteristics

With the exception of seven studies (Bloom et al. 2011; Derby et al. 1992; Kahng and Iwata 1999; Reimers et al. 1993; Smith and Churchill 2002; Thomason-Sassi et al. 2011; Vollmer et al. 1995), all other studies had a sample size of five or less

participants. It was found that, of the studies that provided age of participants, 66% used samples of children (<18 years), 20.8% had adult samples, and 13.2% included both children and adults. An intellectual disability was the most common diagnosis among participants with 47.2% of studies including at least one participant identified as having some level of intellectual disability. Autism spectrum disorder was the next most common diagnosis in studies, 37.7%, followed by other developmental disabilities, 9.4%. A fifth of studies, 20.6%, involved typically developing children or adults. Other diagnoses included were: traumatic brain injury (Najdowski et al. 2008), lesch-nyhan syndrome (Bergen et al. 2002), Down Syndrome (Bloom et al. 2011; Borrero et al. 2002; Derby et al. 1994; Vollmer et al. 1995), visual and hearing impairments (Bloom et al. 2011; Contrucci Kuhn and Triggs 2009; MacDonald et al. 2002; Vollmer et al. 1995), schizophrenia (Wilder et al. 2001), tourettes syndrome (Watson et al. 2005), ADHD/symptoms of ADHD (Boyajian et al. 2001; Broussard and Northup 1995), and Rett Syndrome (Vollmer et al. 1995).

The setting in which assessments were conducted was also analysed. It was found that FAs were most commonly conducted in schools or classrooms, 38.9%. Other settings including outpatient facilities or day programs, 20.4%, residential or inpatient settings, 18.5%, university clinics, 18.5%, homes, 11.1%, and vocational programs, 7.4%, were also common. A considerable number, 14.8%, of FAs were conducted in more than one setting.

Target Behaviors

Self-injurious behavior (SIB) was the most commonly analysed behavior, as either the sole target behavior or one of several target behaviors, in 35.2% of studies reviewed. Other target behaviors for reduction included: aggression, 22.2%, vocalizations including bizarre speech, tics, crying, screaming and whining, 24.1%, property destruction, 7.4%, noncompliance, 9.3%, and stereotypy, 7.4%. Additional behaviors included in functional analyses were: habits (e.g., nail biting and thumb sucking; Dufrene et al. 2008; Rapp et al. 1999), disruptive behavior (LaBelle and Charlop-Christy 2002; LeGray et al. 2010; Wallace and Knights 2003; Umbreit 1995), saliva play (Luiselli et al. 2004), rumination (Lyons et al. 2007), pseudo seizures (Oikawa et al. 2011), elopement (Perrin et al. 2008), trichotillomania (Borrero et al. 2002), and tantrums (Vollmer et al. 1996; Wilder et al. 2006). FA has also been used in atypical ways to facilitate the examination of behaviors incompatible with the primary problem behavior (Pitman 2007) and the function of language (Normand et al. 2008).

Additional Assessments

It was found that less than half of the studies reviewed, 42.6%, used no form of supplemental assessment tools prior to conducting a FA. A third of studies, 33.3%, reported the use of interviews with individuals such as home staff, parents, principles, teachers, school psychologists, and the individual themselves, to gather information about the target behavior. A number of studies, 16.7%, made use of stimulus preference assessments. Several studies, 13%, included a social validity measure to assess the acceptability of either the assessment or subsequent treatment. The social validity assessment tools used to determine the acceptability of the treatment

implemented were: the Intervention Rating Profile (Broussard and Northup 1995; Cihak et al. 2007; LeGray et al. 2010), the Treatment Acceptability Rating Form-Revised (Everett et al. 2007; Umbreit 1995), the Treatment Evaluation Inventory-Short Form (Rapp et al. 1999), and one study developed their own social validity of treatment measure (Carr et al. 2002). One study used the Assessment Rating Profile-Revised to examine how acceptable the FA procedures used were considered to be (LeGray et al. 2010). One article reported the use of ABC recording to gather descriptive information about the problem behavior (Watson and Sterling 1998). A small number of studies, 13%, used another assessment instrument prior to the FA. These included: The Negative Reinforcement Rating Scale (Call et al. 2009), the Motivation Assessment Scale (Carr and Britton 1999; Pitman 2007), the Conners' Teacher Rating Scale- Revised (Boyajian et al. 2001), the Conners Parent Rating Scale-Revised (Boyajian et al. 2001), Problem Identification Interview (Boyajian et al. 2001), Problem Analysis Interview (Boyajian et al. 2001), the State Trait Anxiety Inventory (Dufrene et al. 2008), the Beck Depression Inventory (Dufrene et al. 2008), the Functional Assessment Informant Record for Teachers Pre-School Version (LeGray et al. 2010), and The Functional Assessment Informant Record- Parent Form (Everett et al. 2007).

Outcomes of Brief Functional Analysis

It is notable that BFAs differ in the ways the duration of analysis is shortened. Many studies reduced the duration of sessions with studies most commonly using 5 min (Ahearn et al. 2007; Carter et al. 2004; Casey and Merical 2006; Dufrene et al. 2008; Ishuin 2010; Lyons et al. 2007; MacDonald et al. 2002; Najdowski et al. 2008; Perrin et al. 2008; Reimers et al. 1993) or 10 min (Cihak et al. 2007; Normand et al. 2008; LaBelle and Charlop-Christy 2002; Luiselli et al. 2004; O' Reilly et al. 2000; Rapp et al. 1999; Tincani et al. 1999; Vollmer et al. 1995; Wilder et al. 2001; Wilder et al. 2005; Umbreit 1995) session durations . Others reduced the number of sessions of each condition conducted (Carr et al. 2002; Carr and Britton 1999; Cihak et al. 2007; Ishuin 2010; MacDonald et al. 2002; Northup et al. 1991; Tincani et al. 1999; Umbreit 1995). Finally, some studies used fewer conditions to reduce the duration of analysis (Broussard and Northup 1995; Everett et al. 2007; Ward and Higbee 2008; Watson and Sterling 1998).

Two studies examined the correspondence between the outcomes of BFA and traditional functional analysis (TFA). Tincani and colleagues (1999) compared the behavioral functions identified by BFA and TFA for three participants. They found complete correspondence for all. The BFA had a much reduced total duration of between 85 and 110 min, while the TFA took between 450 and 540 min to conduct. Kahng and Iwata (1999) compared the outcomes of BFA and TFA for 50 individuals and found 66% correspondence. The correspondence rose to 68% when within-session responding patterns during BFA were analysed. Correspondence was found to be higher when results of the TFA were clearly differentiated (77.1%) than when they were less clear (40%).

A number of BFAs, 27%, included a CR in their analysis. The majority of CRs demonstrated that the variable maintaining the problem behavior could also be used to maintain an appropriate alternative behavior (Boyajian et al. 2001; Broussard and

Northup 1995; Derby et al. 1992; Derby et al. 1994; Ishuin 2010; LeGray et al. 2010; Northup et al. 1991; Tincani et al. 1999; Umbreit 1995; Vollmer et al. 1996). However, MacDonald et al. (2002) conducted a CR to evaluate the effects of attention, a hypothesized maintaining variable, contingent on any behavior other than the problem behavior. The rate of problem behavior during both conditions of the CR led authors to conclude that attention was not the maintaining variable.

Of the 37 BFA studies included in this review, five studies, 13.5%, contained at least one BFA that produced either initially inconclusive or completely inconclusive results (Carter et al. 2004; Derby et al. 1992; Perrin et al. 2008; Rapp et al. 1999; Vollmer et al. 1995). All other BFAs successfully identified behavioral function. Seven studies, 18.9%, did not include any form of treatment evaluation (Carter et al. 2004; Kahng and Iwata 1999; LaBelle and Charlop-Christy 2002; Normand et al. 2008; Oikawa et al. 2011; Reimers et al. 1993; Vollmer et al. 1995). Of the studies that did incorporate a treatment, 96.7% reported that the treatment led to decreases in problem behavior, 50% reported treatment led to increases in appropriate behavior, 13.3% reported some evidence of generalization of treatment effects, and 10% demonstrated maintenance of treatment effects over a period of time.

Outcomes of Latency Functional Analysis

It has been suggested that the use of a latency measure during FA would lessen the risk of strengthening problem behaviors and the possible risk of injury to individuals (Thomason-Sassi et al. 2011). Thomason-Sassi and colleagues (2011) compared the behavioral functions identified by previous FAs when response rates were used as the measure and when latency to first response was used as the measure. Complete correspondence was found in 33 of 38 datasets. They conducted and compared a further 10 FAs and observed correspondence in nine. The only discrepancy observed was for problem behavior identified as multiply controlled by the TFA. Call and colleagues (2009) used a latency measure to evaluate the hypothesis that problem behavior was correlated with aversiveness of demands. Both participants showed greatest levels of problem behavior during the demand condition of a TFA and the shortest latency to problem behavior with highly aversive demands.

Outcomes of Precursor Functional Analysis

The key element of PFA is the identification of PCB that is highly correlated with the more severe problem behaviors. Studies differ in the method used to do this. Some authors identified PCBs through observation and discussions with caregivers (Najdowski et al. 2008; Smith and Churchill 2002). Bergen et al. (2002) selected the raising of one or both hands above shoulder level as the PCB to eye gouging because logic dictated that the behavior had to occur for the problem behavior to occur. Langdon and colleagues (2008) used interviews with staff and direct observations to identify PCBs and subsequently calculated transitional probabilities that indicated how likely it was that they would occur along with the problem behavior. Both Herscovitch et al. (2009) and Borrero and Borrero (2008) conducted interviews and observations to develop hypotheses about PCBs and employed conditional and unconditional probability analyses to determine the likelihood that the problem behavior

would occur if the PCB occurred. One study did not provide detail on how PCBs were chosen (Deaver et al. 2001)

Several studies examined whether PCBs and problem behavior were functionally equivalent by measuring both behaviors during a FA. Langdon et al. (2008) demonstrated results from a FA suggesting that PCBs and problem behavior were functionally equivalent. Herscovitch and colleagues (2009) identified that both PCBs and problem behavior were maintained by negative reinforcement. Smith and Churchill (2002) observed completed correspondence between the behavioral functions of the PCBs and problem behavior. Similarly, Borrero and Borrero (2008) found that PCBs and problem behavior were functionally equivalent.

Three studies also evaluated the effects of a function-based treatment on both PCBs and problem behavior. Langdon et al. (2008) used FCT to teach participants a communication response that was functionally equivalent to both PCBs and problem behavior. During conditions where reinforcement was available for the problem behavior, PCBs, and the communication response, levels of communication were high while other behaviors remained low suggesting the intervention was successful. Najdowski et al. (2008) also applied FCT based on the functions of PCB and found that treatment resulted in low levels of the PCB and elimination of problem behavior. Deaver et al. (2001) evaluated the noncontingent application of mittens after a PFA revealed the PCB (hair twirling) to be maintained by automatic reinforcement, and found the treatment eliminated both hair twirling and the problem behavior (hair pulling) and that results were maintained at a 10 month follow-up.

Outcomes of Functional Analysis with Protective Equipment

Iwata et al. (1982, p. 199) recommended that individuals "be allowed to engage in self-injurious behavior while free from mechanical, physical, or chemical restraint". However, the risk of serious injury to the individual has led researchers to evaluate the effects PE may have on the outcomes of FA.

Le and Smith (2002) compared the outcomes of FA conducted with and without PE. The FA without PE identified clear maintaining variables for two participants while the behavior was completely suppressed, and the function unidentifiable, once PE was applied. Undifferentiated results were obtained for the third participant during both types of analysis. Borrero et al. (2002) replicated this study and observed similar findings. While a function was identified for both participants during initial analyses without PE, application of PE reduced levels of the behavior and made it impossible to identify the function. Moore et al. (2004) evaluated the effects of PE on three topographies of SIB during FA. SIB decreased to near zero levels when PE was in place and as PE was removed from different body parts the topography related to that body part increased. Once again, it was impossible to determine the function of the behavior when PE was applied.

However, Contrucci Kuhn and Triggs (2009) demonstrated that PE can be used to enhance the utility of FA. The results of their initial analyses of the SIB of a young girl were undifferentiated and suggested that the behavior was maintained by automatic reinforcement. However, an additional FA conducted using PE revealed elevated levels of SIB in the attention condition suggesting that SIB was, at least in part, maintained by positive reinforcement.

Outcomes of Trial-Based Functional Analysis

Three studies have evaluated the use of discrete trials as a way of presenting FA conditions. Sigafoos and Saggers (1995) used a TBFA to determine the function of aggression displayed by two young boys. Each discrete trial consisted of two conditions, each lasting for up to 60 s. The first half of each trial was the test condition while the second half acted as a control condition. Twenty trials were integrated into typical school routines over 5 days. A clear behavioral function was identified for both participants based on their responding during the first half of each trial while, as would be expected, few instances of problem behavior occurred during the second half of trials. The same methodology was used by Wallace and Knights (2003) and LaRue et al. (2010). However, Bloom et al. (2011) extended the duration of each condition to 2 min and changed the order so that a control condition preceded and followed the test condition meaning that each trial could last for up to 6 min.

The results of TBFA have been compared to the results of TFA by several studies. Wallace and Knights (2003) compared outcomes from both and found correspondence between the functions identified for two participants and partial correspondence for the third participant whose problem behavior was multiply controlled. LaRue et al. (2010) and Bloom et al. (2011) conducted similar comparisons. LaRue et al. (2010) identified complete correspondence for 4 participants and partial correspondence for a fifth participant whose problem behavior was multiply controlled. Bloom et al. (2011) identified complete correspondence for six participants, partial correspondence for one, and no correspondence for three.

Discussion

Brief Functional Analysis

The research in support of BFA is quite convincing with over 85% of BFAs identifying a clear behavioral function. More than 96% of function-based treatments within the studies led to reductions in problem behavior, and 50% led to increases in appropriate behavior. These studies demonstrate strong support for the use of BFA to evaluate problem behavior. BFA increases the applicability of FA procedures and make them more feasible in typical treatment settings while also reducing the financial cost and human resources required (Northup et al. 1991; Tincani et al. 1999)

However, there are some limitations to the research. There is as yet no standardized format for conducting BFAs and future research should attempt to determine optimal procedures. Research should consider whether the addition of discriminative stimuli to conditions would be of benefit (Cihak et al. 2007). Future studies should also examine BFAs that do not show correspondence with TFAs and attempt to explain the differences observed. It would also be worthwhile examining if the reduced duration or reduced number of sessions involved in BFA improves social validity ratings of caregivers. Future research could compare social validity measures of TFA and BFA.

Latency Functional Analysis

There has been little research examining the use of LFA. The results of Thomason-Sassi et al. (2011) are promising given the high degree of correspondence between the results of LFAs and TFAs. The findings of Call et al. (2009) suggest that latency to problem behavior might be a useful way of differentiating between aversive demands if differential levels of problem behavior are observed with various types of demand. However, it is inadvisable to draw conclusions based on two studies. Further research is needed to determine the correspondence between behavioral functions identified by LFA and TFA, the importance of programming discriminative stimuli during LFA, and whether treatments based on behavioral functions identified by LFA effectively reduce problem behavior.

Precursor Functional Analysis

The studies reviewed appear to support the use of PFA. There is as yet no standardized methodology for identifying and selecting PCBs for inclusion. While the evidence appears stronger with statistical confirmation of the relation between both behaviors there are no apparent differences in the results of analyses and treatments between these studies and those that use less sophisticated, indirect methods of identifying PCBs. Conclusions must be tentative at this point as there are few studies available and even fewer that compare the functions identified by TFA and PFA, or that implement function-based treatments and evaluate their effects on PCBs and problem behavior. Future research should focus on replicating these studies and addressing whether treatments based on PFA have long-term effects on the more severe problem behaviors. However, it appears that PFA may be a viable alternative to TFA and reduce the risk of injury inherent in analyses of severe SIB or aggression.

Functional Analysis and Protective Equipment

Although the use of PE would have obvious benefits, the current body of research suggests that clinicians should ensure PE is not in place during FA as its use appears to alter the outcome. Authors have suggested that PE may reduce levels of behavior through sensory extinction, response cost, stimulus control, or punishment (Le and Smith 2002; Moore et al. 2004). There are some situations where the use of PE to conduct additional sessions for FA with inconclusive results might prove useful and aid with identification of behavioral function (e.g., xx). It has been hypothesized that PE may extinguish the automatic reinforcement the individual obtains from the behavior and thus elevated levels in other conditions may help clinicians identify positive or negative reinforcement contingencies that are also maintaining problem behaviors.

The studies included within this review have several limitations worth noting. None evaluated the effects of a function- based treatment so it is difficult to evaluate their success in identifying the function of problem behaviors. There was little variety in the behavioral functions identified for participants in each study, with four of the six participants displaying behavior that was automatically reinforced. Thus, it is difficult to determine how the use of PE might differentially affect behavior that was maintained

by positive or negative reinforcement. Finally, the exact mechanisms through which PE suppresses behavior are as yet unknown and warrant further research.

Trial-Based Functional Analysis

The research on TBFA seems encouraging thus far. Once again, the limited number of studies available prevents any concrete conclusions from being drawn. Each study that compared the outcomes of TBFA and TFA produced at least 60% correspondence while partial correspondence was observed for some of the remaining participants. The applicability of TBFA appears promising given that all studies reviewed were conducted in classroom settings and all trials were integrated into ongoing activities and instruction. However, future research must evaluate the utility of TBFA in other settings (Lang et al. 2010). The short trial length should also make it suitable for use in typical service settings (Sigafoos and Saggers 1995). The short duration of sessions and the termination of test conditions following problem behavior also reduce the risk of harm to individuals which is another benefit (Sigafoos and Saggers 1995).

However, several limitations are worth noting. It may be that procedural refinements are necessary as Bloom et al. (2011) note that although their trial duration was lengthier than that used in any of the other studies it was still insufficient to identify behavioral function for one participant. Claims that TBFA reduces the length of the analysis needed to identify behavioral function making it more applicable for use in typical settings were not uniformly supported with Bloom et al. (2011) noting that the TBFA was lengthier than the TFA. Bloom et al. (2011) also noted that their results were influenced by the stimulus control of a teacher along with a possible confound of the implementation of the two approaches in different settings (TBFA in the classroom and TFA in the clinic). Lang et al. (2010) suggest that future research on TBFAs in the classroom should investigate the role such factors play in the analysis.

Conclusion

Hanley and colleagues (2003, p. 179) wrote that "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". Many of the studies included in this review came after their article was completed and it seems that research using these FA variations is increasing. While the body of research is still comparatively small, the evidence to support the use of each type, excepting PEFA, is promising thus far. All offer advantages over the TFA methodology whether it be reducing duration of assessments, decreasing the risk of harm to individuals, easier integration into natural routines, or less reinforcement of the problem behavior. The applicability of FA seems as evident with these variations as it is with traditional procedures and a similar variety of populations, settings, and target behaviors have been examined in the studies included in this review to those in Hanley et al. (2003). As the efficacy and practicality of these forms of FA come to be established, future research must attempt to refine these procedures further in order to create and implement treatments based on their results. This will allow further evaluation of the maintenance and generality

of any treatment effects found, identification of whether supplemental preliminary assessments strengthen these procedures, and an examination of whether certain variations are more suited for particular behaviors, populations, or settings. For now, it seems that the evolution of FA methodology is underway and that behavior analysts currently have access to a number of valuable resources for examining and treating any serious problem behavior despite any constraints particular to their situation.

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