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NATURE AND SCOPE OF SYNTHESIS IN FUNCTIONAL ANALYSIS AND TREATMENT OF PROBLEM BEHAVIOR

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Functional analysis (FA) of problem behavior typically includes the contingent delivery of a single reinforcer following problem behavior. However, the FA literature also includes examples of analyses that have delivered multiple reinforcers, arranged multiple establishing operations in one or more test conditions, or both. These analyses have been successfully applied under heterogeneous conditions over several decades and with various synthesized establishing operations and reinforcers, but their qualitative details, outcomes, and contributions to the literature have never been described in a comprehensive manner. The purpose of the current review is to: (a) identify articles that have reported the use of synthesized FAs or treatments; (b) describe the nature and scope of synthesis as it has been applied in the FA literature; (c) analyze outcomes of synthesized FAs and treatments to determine general benefits and disadvantages of synthesis; and (d) offer recommendations for future areas of research.

Key words: functional analysis, problem behavior, synthesized FA, synthesized EOs, treatment

The development of a functional analysis (FA) of problem behavior was a watershed moment in behavior analysis. The methods and results reported by Iwata, Dorsey, Slifer, Bauman, and Richman (1982/1994) provided a seed from which a robust FA literature with many branching lines of research has grown and from which current best practices in the assessment and treatment of problem behavior have been selected. In the thirty-five years since that publication, treatment of problem behavior has shifted from the use of arbitrary reinforcers and punishers (e.g., Corte, Wolf, & Locke, 1971; Dorsey, Iwata, Ong, & McSween, 1980; Repp & Deitz, 1974) to the use of function-based interventions, primarily those that replace problem behavior by identifying its reinforcers and using those same reinforcers to establish a functionally equivalent alternative response (e.g., Carr & Durand, 1985; Hagopian, Fisher, Sullivan, Acquisto, & LeBlanc, 1998; Tiger, Hanley, & Bruzek, 2008). Identifying the reinforcers for problem behavior also allows for extinction to be programmed (Iwata, Pace, Cowdery, & Miltenberger, 1994). Functional analysis is now considered a critical step in assessing and treating problem behavior (Beavers, Iwata, & Lerman, 2013; Hanley, Iwata, & McCord, 2003); treatments based on FAs are more likely to be efficacious and less likely to rely on punishment than treatments that are not function-based (Campbell, 2003; Kahng, Iwata, & Lewin, 2002; Pelios, Morren, Tesch, & Axelrod, 1999).

There are two components common among FAs of problem behavior: a test condition in which at least one putative reinforcer is withheld and then delivered contingent on problem

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behavior, and a control condition in which this contingency is absent (Beavers et al., 2013; Hanley, 2012; Hanley et al., 2003; Iwata & Dozier, 2008). The logic of a test condition is that by withholding a particular reinforcer (e.g., attention), the individual experiences an establishing operation (e.g., deprivation of attention) that evokes problem behavior maintained by that reinforcer. The response that contacts that reinforcer during the test condition presumably continues to occur because it is both evoked by the deprivation of that reinforcer and subsequently strengthened by its contingent delivery. The fundamental components of a test condition in an FA therefore include an establishing operation (EO), the occurrence of some response, and the delivery of reinforcement contingent on that response.

Reviews of FA literature (e.g., Beavers et al., 2013; Hanley et al., 2003) and details from relatively large-*n* studies (e.g., Iwata, Pace, Dorsey et al., 1994) indicate that the majority of FAs provide one reinforcer following problem behavior in any given test condition. For example, Iwata, Pace, Dorsey et al. (1994) reported FAs of self-injurious behavior (SIB) for 152 participants who experienced multiple test conditions with a single reinforcer provided for SIB in each test condition (or with no programmed consequences in the alone condition). Hanley et al. (2003) and Beavers et al. (2013) both noted that approximately 90% of analyses included this same feature of providing a single reinforcer following problem behavior, regardless of other modifications to design or measures (e.g., Bloom, Iwata, Fritz, Roscoe, & Carreau, 2011; Conners et al., 2000; Derby et al., 1992; Iwata, Duncan, Zarcone, Lerman, & Shore, 1994; Northup et al., 1991; Schlichenmeyer, Roscoe, Rooker, Wheeler, & Dube, 2013; Sigafoos & Saggers, 1995; Smith & Churchill, 2002; Thomason-Sassi, Iwata, Neidert, & Roscoe, 2011; Wallace & Iwata, 1999).

Though fewer in number, Beavers et al. (2013) also reported some examples of published FAs in which multiple putative reinforcers were evaluated in the same test condition (e.g., Mueller, Sterling-Turner, & Moore 2005; Sarno et al., 2011). However, Beavers et al. did not provide a comprehensive analysis of this subset of articles beyond noting that arranging multiple consequences in a test condition can be methodologically complicated. That is, the simultaneous provision of multiple reinforcers could obscure a particular functional relation, thereby obfuscating data interpretation. For example, when providing escape and tangible items contingent on problem behavior in an FA test condition, it is unclear whether problem behavior is maintained by each of these reinforcers separately (i.e., multiple control), by only one of the reinforcers (e.g., escape but not tangibles), or by the interaction between the reinforcers (i.e., escape *to* tangibles, and not escape or tangibles in isolation). Despite these potential challenges to interpretation posed by FAs that involve the simultaneous delivery of multiple reinforcers, a number of examples in which multiple reinforcers have been purposely arranged in a test condition have been reported since the review by Beavers et al. (i.e., Call & Lomas Mevers, 2014; Fisher, Greer, Romani, Zangrillo, & Owen, 2016; Ghaemmaghami, Hanley, & Jessel, 2016; Ghaemmaghami, Hanley, Jin, & Vanselow, 2015; Hanley, Jin, Vanselow, & Hanratty, 2014; Jessel, Hanley, & Ghaemmaghami, 2016; Jessel, Ingvarsson, Metras, Kirk, & Whipple, 2018; Lambert et al., 2017; Lloyd et al., 2015; Payne, Dozier, Neidert, Jowett, & Newquist, 2014; Santiago, Hanley, Moore, & Jin, 2016; Slaton, Hanley, & Raftery, 2017; Strohmeier, Murphy, & O'Connor, 2016). Moreover, the literature on FAs that include combined reinforcement contingencies has presented corresponding data on treatment effectiveness, such that interventions based on these types of FAs have also been reported

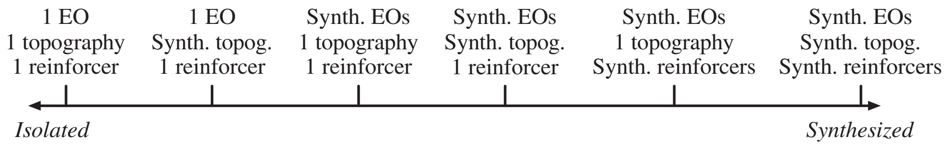

Figure 1. Points along the continuum of FAs from isolated to synthesized. EO = establishing operation; synth. = synthesized; topog. = topographies.

(e.g., Ghaemmaghami et al., 2016; Ghaemmaghami et al., 2015; Hanley et al., 2014; Jessel et al., 2018; Mann & Mueller, 2009; Payne et al., 2014; Santiago et al., 2016; Sarno et al., 2011; Slaton et al., 2017; Strand & Eldevik, 2017; Strohmeier et al., 2016).

The combination of reinforcement contingencies has been one of the most prominent developments in the FA literature since the review published by Beavers et al. (2013); however, reinforcement contingencies are not the only component of an FA test condition that can be combined. A number of investigations (e.g., Call, Wacker, Ringdahl, & Boelter, 2005; Dolezal & Kurtz, 2010; O'Reilly, Lacey, & Lancioni, 2000) have examined the effects of combining multiple EOs within the same condition (e.g., diverting attention while presenting demands). Likewise, a number of studies have arranged reinforcement that is delivered contingent upon multiple topographies of problem behavior (e.g., aggression and SIB; see Beavers et al., 2013).

Throughout the remainder of this paper, we use the word *synthesized* to refer to arrangements that involve multiple EOs, multiple potential reinforcers, multiple response topographies, or some combination. In particular, we use *synthesized EOs* to describe the simultaneous presentation of multiple EOs, *synthesized topographies* to describe multiple response topographies scheduled for reinforcement, and *synthesized reinforcers* to describe the simultaneous provision of multiple reinforcers. We describe FAs that explicitly include synthesized EOs, synthesized reinforcers, or both as *synthesized FAs*; we describe their corresponding treatments as *synthesized treatments.* By contrast, we use *isolated FA* to describe an FA in which a single reinforcer is provided in each test condition and *isolated treatment* to describe its corresponding treatment. Finally, throughout this paper, we use the term *analyst* to refer to the person implementing the FA conditions or treatment.

In addition to the individual combination of the above FA components, it is possible that all aspects of an FA contingency might be synthesized. That is, one could synthesize EOs, topographies, and reinforcers to arrange a *synthesized contingency.* Such an arrangement would be in contrast to the FA procedure described by Iwata et al. (1982/1994) in which none of these components is purposely synthesized. We may thus describe all FAs as existing somewhere on a continuum between isolated and synthesized. Figure 1 depicts points along this continuum. Toward the isolated end of the continuum would be FAs in which all components of the contingency are isolated: A single EO is presented and a single topography produces a single reinforcer. For example, demands are presented and spitting produces escape from those demands. Toward the synthesized end of the continuum would be FAs in which all components of the contingency are synthesized: Multiple EOs are simultaneously presented, multiple response topographies are scheduled for reinforcement, and multiple reinforcers are simultaneously provided following problem behavior. For example, demands are presented and tangibles are removed; spitting, hitting, or kicking each produces escape from the demands plus access to the tangible items. In between these points are FAs in which different components are synthesized or isolated to varying degrees.

There are a number of unanswered questions regarding the prevalence of use as well as the features and outcomes of synthesized FAs and synthesized treatments. For example, we do not know the extent to which synthesized FAs and treatments have been reported in the literature, nor do we have information regarding their general features (e.g., settings in which they have been conducted; specific combinations of EOs or reinforcers that have been evaluated). We also do not know the extent to which synthesized FAs produce differentiated outcomes, the overall effectiveness of treatments based on synthesized FAs, or the contexts in which these outcomes have been obtained. Describing examples of synthesis already present in the literature and analyzing their outcomes is an important step in evaluating the benefits and limitations of synthesizing FAs and FA-based treatments. Tacting the use of synthesis in FAs and treatments where applicable is important because it provides a conceptual framework within which to interpret the collective results of studies that may otherwise seem unrelated. In other words, the group of articles that could potentially inform our understanding of the relative merits or limitations of synthesized FA components and synthesized treatments has not yet been identified.

There are also important questions to be answered regarding how synthesized FAs and treatments compare to their isolated counterparts. Such comparisons could be made within the same participant and could examine the relative benefits of synthesized and isolated FAs relative to treatment development, treatment outcomes, programming for generalization, and clinical utility. A comprehensive comparison of the extent to which synthesized and isolated FAs produce differentiated outcomes is beyond the scope of the current paper, but there is information to be gleaned from the small number of cases in which the two types of FAs have been compared. To date, there have been a few studies that have directly compared synthesized and isolated contingencies (e.g., Fisher et al., 2016; Ghaemmaghami et al., 2015; Slaton et al., 2017), and their relative contributions will be discussed herein. Likewise, a range of methods have been reported for determining that a synthesized contingency was necessary to produce a differentiated FA or effective treatment in a particular instance (i.e., such results were obtained only when a synthesized contingency was applied), but these methods have also not been discussed together in terms of their relative value. An integrated discussion might provide some initial guidance for designing FAs and treatments with isolated or synthesized variables.

Given potential problems with data interpretation posed by the use of synthesized reinforcers and the number of unanswered questions regarding the relative contributions of synthesized FAs and treatments, a review of the prevalence of use, methods, and outcomes of synthesized FAs and their corresponding treatments seems timely and warranted. The purpose of this review is to attempt to answer the questions above by describing and analyzing examples of synthesized FAs and treatments, identifying gaps in the literature, and providing recommendations for future lines of research.

METHODS

Article Identification and Selection

We documented the search process using guidelines described in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Liberati et al., 2009). Figure 2 provides a flow chart illustrating this process, including the number of articles identified by each search, the number of articles excluded at various points in the process (and their reason for exclusion), and the final number of articles included. First, we searched

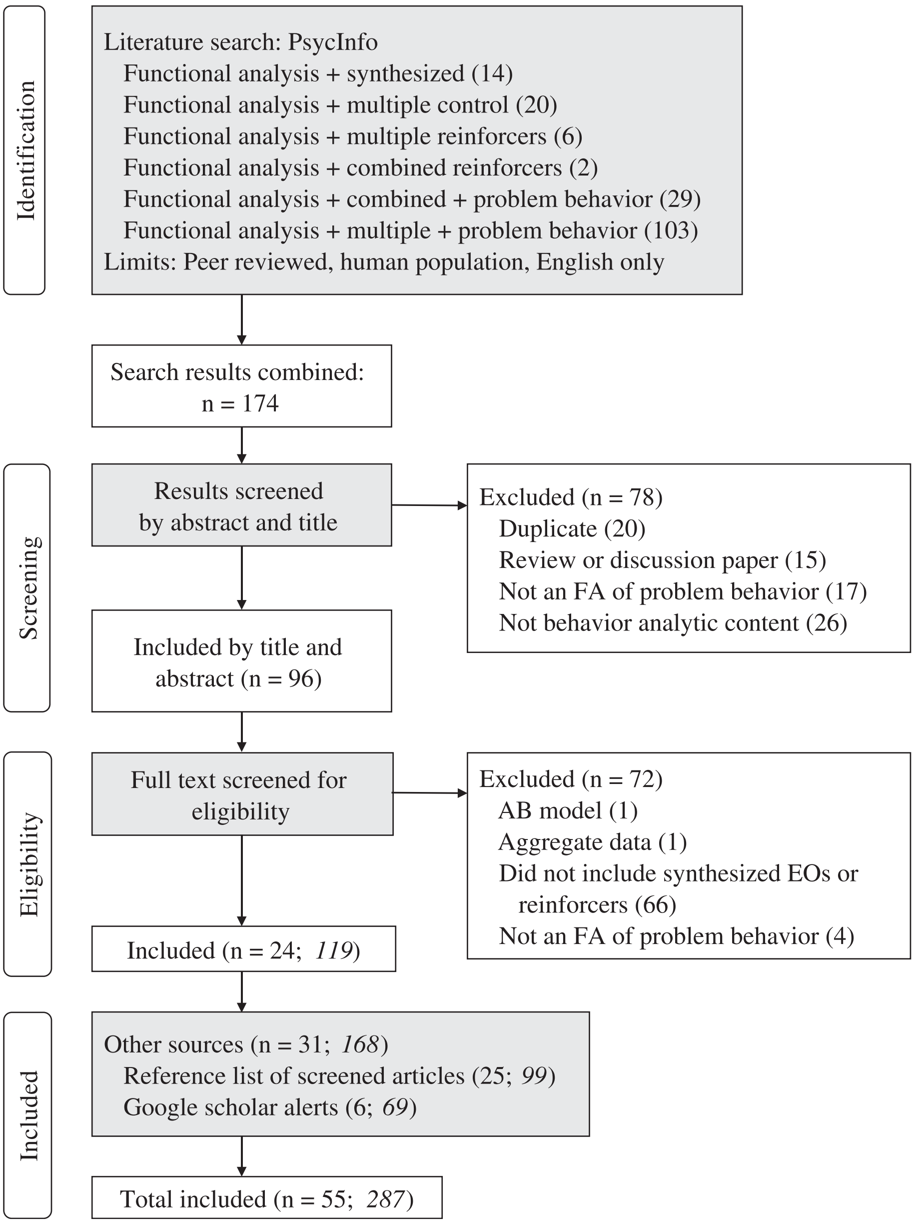

Figure 2. PRISMA flow chart describing article identification and inclusion process. Numbers in regular font indicate the number of articles in that category; numbers in italics indicate the total number of applications in that category.

PsycInfo for the keyword *functional analysis* in combination with each of the following: *synthesized, multiple control, multiple reinforcers, combined reinforcers, combined + problem behavior, multiple + problem behavior.* All articles returned by these searches were screened by title and abstract to determine whether the study included an FA of problem behavior. Articles that appeared to meet inclusion criteria were then screened by reviewing the methods section and figures in the article to determine final eligibility (i.e., determine whether synthesized EOs, synthesized reinforcers, or both were arranged in at least one test condition for at least one participant). Second, we created a Google Scholar alert for any articles with the following key words and screened these alerts as they were received: *functional analysis, functional analysis + autism, functional analysis + aggression, functional analysis + SIB.* Third, we identified additional articles from the reference lists of the articles detected through *PsycInfo* and Google Scholar.

We included articles that reported FAs of problem behavior in which consequences were provided following problem behavior (i.e., the A-B-C model) and which also met at least one of the following criteria: (a) the FA included synthesized EOs in at least one test condition; or (b) the FA included synthesized EOs *and* synthesized reinforcers in at least one test condition; or (c) the treatment included synthesized EOs, synthesized reinforcers, or both regardless of whether the FA had included these variables. We excluded studies in which FA differentiation and treatment effects could not be determined for each individual participant (e.g., large *n* studies reporting aggregated data or samples of participant data).

Interobserver agreement (IOA) for inclusion of articles was obtained by having a second person independently screen 20% of all articles returned by each search. IOA across all search terms averaged 88% (range, 83% - 100%).

Variables Coded

We used details from the Method section of each article to code the following variables for each application of a synthesized FA or treatment: setting; which components of the FA or treatment were synthesized (EOs only or EOs + reinforcers); which EOs or reinforcers were synthesized (e.g., attention + tangibles); how those EOs or reinforcers were selected for synthesis; which topographies of problem behavior were reinforced; how those topographies were selected. We used visual inspection of figures to code whether the FA was differentiated (our interpretation was always consistent with the authors' interpretation), whether an undifferentiated FA or ineffective treatment occurred first,[1] whether treatment data were included, and whether the experimenters directly compared synthesized and isolated conditions. We defined an application as each distinct setting, analyst, set of stimuli, or contingency evaluated during FA or treatment. For example, a synthesized FA in which a clinician and a parent both served as analysts and which was then followed by a synthesized treatment would be scored as three applications (2 FAs and 1 treatment; e.g., participant Gail in Hanley et al., 2014). We did not score replications of the same application. For example, if a synthesized treatment was compared to an isolated treatment in a reversal design, we did not score each reversal as a new application. IOA was obtained by having a second person independently score 20% of articles. An agreement was scored if both observers coded the same response for a particular variable in the same article (e.g., both observers coded "home" as the setting for the FA, or both observers coded "attention, tangibles" as the reinforcers that were synthesized). IOA was calculated by dividing the total number of agreements by the total number of agreements plus disagreements (i.e., the total number of articles for which IOA was scored) and multiplying by 100. IOA across all variables averaged 97% (range, 80 – 100%). Specific IOA for each variable is as follows: setting, 100%; which components of the FA or treatment were synthesized (EOs only or EOs + reinforcers), 100%; which EOs or

[1]In cases in which no visual display of previous FA iterations was included, we relied on the Method section in which authors stated that a previous FA had occurred and was undifferentiated. This occurred in two FA applications (1.5% of all synthesized FAs).

reinforcers were synthesized (e.g., attention + tangibles), 89%; how those EOs or reinforcers were selected for synthesis, 100%; which topographies of problem behavior were reinforced, 100%; how those topographies were selected, 100%; number of differentiated FA applications, 100%; whether an undifferentiated FA or ineffective treatment occurred first, 100%; number of treatment applications, 100%; number of FA applications, 80%; whether isolated and synthesized conditions were directly compared, 100%.

Evaluating Treatment Effects

We used the program WebPlot Digitizer (https://automeris.io/WebPlotDigitizer/) to extract the value of individual baseline and treatment data points depicted on treatment graphs. WebPlot Digitizer is a free program that allows users to load an image of a graph and click on individual data points to calculate their X and Y values. We then calculated mean baseline reduction (MBLR) and percentage of nonoverlapping data (PND) for each treatment application using the same methods reported by Campbell (2003): MBLR was calculated by subtracting the mean of all data points in the final treatment phase from the mean of all baseline points in the first baseline phase, dividing by the mean baseline, and multiplying by 100; PND was calculated by counting the number of data points in the final treatment phase that fell below the lowest data point in the first baseline phase, dividing by the total number of data points in the final treatment phase, and multiplying by 100. For cases in which data were reported for both a synthesized and an isolated treatment, MBLR and PND were also calculated for the isolated treatment. After obtaining MBLR and PND across all synthesized and isolated treatment applications, we conducted an independent samples *t*-test to determine whether the difference between the two was statistically significant.

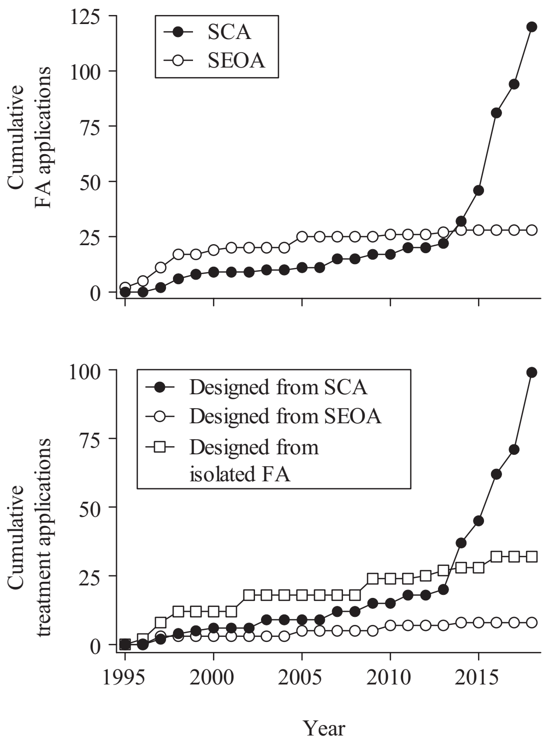

Figure 3. Cumulative applications of synthesized FAs and treatments between 1993 and January of 2018.

RESULTS

As depicted in Figure 2, we identified 55 articles for inclusion. This sample yielded 287 applications of synthesized FAs or treatments across 149 participants, published between 1995 and January 2018. Figure 3 shows cumulative number of FA and treatment applications across publication year. The majority of applications (66.9%) were published since 2014, indicating that the use of synthesized EOs or synthesized reinforcers has become increasingly more common in the last several years. About half of the 287 applications were FAs (n = 148; 51.6%); the remaining 139 applications (48.4%) were synthesized treatment applications. We found applications at three points along the synthesis continuum (see Figure 1): FAs and treatments in which EOs were synthesized but reinforcers were not

Table 1
Types of Synthesized FAs and Treatments

Type of Synthesized Application	Number of Applications	Earliest Example	Most Recent Example
FA (n = 148)			
SEOA	28	O'Reilly (1995)	Call (2014)
SCA	120	Bowman (1997)	Jessel (2018)
Treatment (n = 139)			
Designed from SEOAs	8	Horner (1997)	Call (2014)
Designed from SCAs	99	Bowman (1997)	Jessel (2018)
Designed from isolated FAs	32	Lalli (1996)	Zangrillo (2016)

Note. Examples of earliest and most recent articles are listed by first author and publication year.
SEOA = synthesized establishing operation analysis; SCA = synthesized contingency analysis.

(28 FAs and 8 treatments)[2]; FAs and treatments in which EOs, topographies, and reinforcers were all synthesized (i.e., a synthesized contingency; 120 FAs and 131 treatments). Of those 131 treatments with synthesized contingencies, 99 were designed from an FA with synthesized contingencies and 32 were designed from an isolated FA. We did not find any examples in which EOs and reinforcers were synthesized but topographies were not. Table 1 presents a summary of these different categories. The sections below present descriptions of these types of applications, followed by analysis of their methods, features, and outcomes.

Types of Synthesized FAs and Treatments

Synthesized EOs. We offer the term *synthesized EO analysis* (SEOA) to describe applications in which two or more EOs are simultaneously presented, but only one reinforcer was delivered following problem behavior (in an FA) or an alternative response (in treatment). For example, demands might have been presented while attention was also diverted from the individual, thus combining EOs for escape and attention; problem behavior may produce only the attention of the adult, while the demand continues to be presented (e.g., Call et al., 2005). Table 2 lists each SEOA we reviewed and the combinations of EOs evaluated. Most of the 36 SEOA applications we reviewed were FAs (77.8%); the remaining were treatment applications following those FAs.

We noted two distinct types of synthesized EOs: those that evaluated external variables (i.e., socially-mediated events that occur outside the individual's body, such as the delivery of attention or escape; e.g., Dolezal & Kurtz, 2010) and those that evaluated internal variables (i.e., physiological events that occur inside the individual's body, such as sleep deprivation or illness; e.g., Kennedy & Meyer, 1996). SEOAs have evaluated the interaction between external variables (e.g., attention + escape EO) or between external and internal variables (e.g., escape EO + sleep deprivation). Carr and Smith (1995) noted that internal EOs can interact with external EOs to produce problem behavior. For example, SEOAs have demonstrated that the evocative effects of demands can depend on the presence of sleep deprivation (O'Reilly, 1995), allergy symptoms (Kennedy & Meyer, 1996), or ear infections (O'Reilly, 1997), such that the presentation of demands evokes problem behavior only when these internal EOs are also present.

In two applications, an SEOA demonstrated that SIB maintained by automatic reinforcement occurred at high rates across all conditions only when the child also had a sinus infection and not when the child was healthy

[2] 25 of these 28 applications also included synthesized topographies (i.e., points three and four along the continuum).

Table 2
Details and References for Synthesized Establishing Operation Analyses

Synthesized EOs	First Author (Year)	Participants
Noise + ear infection	O'Reilly (1997)	Mary
Sinus infection + all isolated FA conditions	Carter (2005)	Gagan
	Lohrmann (2001)	Jamie
Escape + allergy symptoms	Kennedy (1996)	Rudolfo
Escape + sleep deprivation	O'Reilly (1995)	Shawn
	Kennedy (1996)	Marcello, Mimi
Tangibles + sleep deprivation	Horner (1997)	Karl
Escape + tangibles	Call (2005)	Kevin
	Call (2014)	Jett
Attention + escape	Call (2005)	Richard
	Dolezal (2010)	Kyle
Attention + tangible	Lalli (1998)	Dave, Carter, Dan
Attention + client location	Adelinis (1997)	Andy
Escape + schedule change	Horner (1997)	Clay, Pat
Escape + noise	O'Reilly (2000)	Eilis
Attention + noise	Bowman (2013)	Phillip

Note. EO = establishing operation.

(Carter, 2005). Psychotropic medications are another variable that can interact with external EOs to produce changes in function of problem behavior (see Cox and Virués-Ortega, 2016, for a recent review). The correlation between internal events and problem behavior can be demonstrated by initiating sessions on days when these EOs are present and on days when these EOs are absent, allowing for a direct comparison between isolated EOs (e.g., escape only) and synthesized EOs (e.g., escape + sleep deprivation). The impact of these internal events is correlational because the events cannot be directly manipulated by the analyst during the FA; this poses some challenges in that the analyst must wait for these events to occur and then implement the SEOA conditions.

In contrast to difficulties with manipulating internal EOs, a number of studies have directly manipulated external EOs. As an example, Call et al. (2005) evaluated a condition in which demands were presented while access to tangible items was restricted (participant Kevin; escape + tangible EO) and a condition in which demands were presented while attention was diverted (participant Richard; escape + attention EO). Contingent on problem behavior, only one of these reinforcers was provided (escape but not tangibles for Kevin; attention but not escape for Richard). Problem behavior for both participants was elevated during their synthesized EO condition relative to isolated EO conditions, indicating that their problem behavior depended on the interaction between two EOs and was not sensitive to either EO in isolation. These procedures were replicated by Dolezal and Kurtz (2010), who compared a synthesized EO condition to isolated EO conditions and demonstrated that problem behavior for a child with traumatic brain injury depended on the interaction between EOs for escape and attention.

Synthesized contingencies. We offer the term *synthesized contingency analysis* (SCA) to describe applications in which multiple EOs are simultaneously presented and all corresponding reinforcers are delivered following problem behavior (in an FA) or for some alternative response (in treatment). For example, tangible items may be removed and demands may be presented (combining EOs for escape and tangible items; e.g., Slaton et al., 2017; Strohmeier et al., 2016); problem behavior may then produce escape from the demand and simultaneous access to the tangible items.

Table 3 lists each SCA we reviewed, including the synthesized contingency evaluated in each application. Of the 219 SCA applications we reviewed, 120 were FAs (54.8%) and 99 were treatments. We found two qualitatively different types of synthesized contingencies: those that combined the typical reinforcers evaluated in isolated FAs (e.g., escape + attention; Iwata et al. 1982/1994), and those that combined idiosyncratic reinforcers that do not easily fit into any of the typical isolated categories.

As an example of the latter type of synthesized contingency, several authors have reported examples of problem behavior evoked by the denial of the participant's mands (e.g., Bowman, Fisher, Thompson, and Piazza, 1997; Eluri, Andrade, Trevino, & Mahmoud, 2016; Roscoe, Schlichenmeyer, & Dube, 2015). Bowman et al. (1997) were the first to describe this contingency type. These experimenters began each test session by occasioning and then denying the child's mands. The authors describe this denial as "deviat[ing] from the activity specified by the child ... For example, if the child requested that the analyst sing a specific song while walking in a circle, the analyst might continue to walk in a circle but discontinued the song or altered the words or melody of the song" (p. 255). In other words, the analyst denied the mand *and* engaged in a specific incompatible activity related to the request. Contingent on problem behavior, the analyst terminated the incompatible activity and granted the child's request. We consider this an example of a synthesized contingency because two EOs were present in the test condition: (a) the child's mands were denied, and (b) the analyst engaged in an incompatible activity related to the mand. Problem behavior produced both corresponding reinforcers: (a) the analyst terminated the incompatible activity (i.e., provided negative reinforcement), and (b) the analyst provided access to the activities requested by the child (i.e., provided positive reinforcement). Several authors have reported similar arrangements in which a seemingly preferred ongoing activity was interrupted with another activity, and problem behavior produced termination of the new activity and access to the previous activity (Adelinis & Hagopian, 1999; Fisher, Adelinis, Thompson, Worsdell, & Zarcone, 1998; Hagopian, Bruzek, Bowman, & Jennett, 2007; Hanley et al., 2014). Hagopian et al. (2007) noted that problem behavior in this type of "interruption analysis" could be a function either of negative or positive reinforcement, in that some activity is terminated and some other activity is initiated. The synthesized reinforcers in these FAs could be evaluated in isolation (e.g., a mand compliance test condition in which the adult terminates the nonrequested activity without initiating the requested activity); however, we found no instances in which experimenters attempted to do so.

In other cases, contingencies have been synthesized even though their constituent parts could easily be evaluated separately. For example, Payne et al. (2014) reported SCAs in which escape and attention (participant Andrew) or attention and tangibles (participant Samantha) were evaluated as reinforcers for problem behavior. These reinforcers were synthesized based on observations during a previously ineffective treatment (i.e., problem behavior was not reduced to clinically acceptable levels during the treatment based on the initial isolated FA). Mann and Mueller (2009) reported an SCA in which contingent access to attention and tangibles was presented based on parental report that the child often experienced attention from parents and access to TV following problem behavior. As a third example, Hanley et al. (2014) reported SCAs in which multiple reinforcers were combined for three children with autism spectrum disorder (attention + tangibles for Gail; escape + tangibles for Bob[3]; escape, attention, tangibles, and mand compliance for Dale). These reinforcers could

[3]Based on the description of Bob's test condition provided in Hanley et al. (2014), we have categorized his contingency as escape to previous activity (see Table 3).

Table 3
Details and References for Synthesized Contingency Analyses

Synthesized Contingency	First Author (Year)	Participants
Escape to mand compliance	Bowman (1997)	Ben, Jerry
	O'Connor (2003)	Pete
	Roscoe, Schlichenmeyer (2015)	Daniel, Nate
	Eluri (2016)	Pablo
	Jessel (2016)	Allen, Mike, Jesse, Jian
	Schmidt (2017)	Daryl, Larry
	Torres-Viso (2018)	Amy
Escape to previous activity	Adelinis (1999)	Raffie
	Fisher (1998)	Ike, Tina
	Hanley (2014)	Bob
	Hagopian (2007)	Perry, Maxwell, Kelly
Escape to rituals / stereotypy	Leon (2013)	Laura
	Rispoli (2014)	Timmy, John, Diego
	Jessel (2016)	Sam
	Slaton (2017)	Chloe
Attention + tangibles	Brown (2000)	Jim
	Ghaemmaghami (2016)	Jack, Nico
	Hanley (2014)	Gail
	Mann (2009)	Madison
	Payne (2014)	Samantha
	Santiago (2016)	Karen
	Strand (2017)	John
Escape + tangibles	Fisher (2016)	Cameron
	Jessel (2016)	Kristy, Jim, Carson, Chris, Mitch
	Jessel (2018)	Joe, Stan, Matt, Ken, Tim, Zane, Mike, Dace, Larry
	Lambert (2017)	S-2
	Lloyd (2015)	Abhi, Sid
	Roscoe, Schlichenmeyer (2015)	Jim
	Slaton (2017)	Riley, Dylan, Jeff,
	Strohmeier (2016)	S-1
Escape + attention	Mueller (2005)	Bob
	Filter (2009)	Dylan
	May (2013)	Jaylin
	Payne (2014)	Andrew
	Sarno (2011)	Brandon, Franklin, J'Marcus
Escape + attention + tangibles	Fisher (2016)	Alan, Allie, Sylvia, Tina
	Ghaemmaghami (2015)	Dan
	Jessel (2016)	Jeff, Gary, Wayne, Earl, Keo, Lee, Paul
	Jessel (2018)	Aaron, Kane, John, Alex, Sarah, Annie, Dan
	Santiago (2016)	Zeke
	Slaton (2017)	Diego, Emily, Kyle, Jonah
Escape + attention + tangibles + mand compliance	Ghaemmaghami (2016)	Alex
	Hanley (2014)	Dale
	Jessel (2016)	Jian
Escape + preferred conversation topics	Jessel (2016)	Sid, Beck, Steve
	Santiago (2016)	Karen
	Slaton (2017)	Mason

have been evaluated in isolation (and were for Gail), but were combined based on parent reports of how they typically responded to problem behavior. For instance, Dale's parents reported that when Dale aggressed towards them or it appeared that Dale was about to have a "meltdown," they relented with their instructions, redirected him to a preferred

Table 4
Details and References for Treatment-only Applications

First Author (Year)	Isolated FA Outcome[a]	Isolated Treatment[b]	Synthesized Treatment[c]
Lalli (1996)	Escape, attention	Escape	Escape to attention
Piazza (1996)	Escape, attention, tangibles	–	Escape to tangibles and attention
Piazza (1997)	Andy: esc, att Carly: esc, att, tang Ben: esc, att, tang	Attention Escape	Andy: esc. to tang. Carly: esc. to tang. Ben: esc. to tang.
Piazza (1998)	Escape, attention, tangibles	Attention Escape	Tom: esc. to tang, att Jerry: esc. to att.
Harding (2002)	Escape, tangibles	Escape Tangibles	Escape to tangibles
Hoch (2002)	Mickey: escape Emily: escape Sean: escape, tang.	Mickey: N/A Emily: escape Sean: escape	Escape to tangibles
McComas (2002)	Escape	–	Escape to tangibles
Bachmeyer (2009)	Attention, escape	Attention Escape	Escape extinction + attention extinction
Falcomata (2012)	Escape, attention, tangible	–	Escape to tangibles and attention
Falcomata (2013)	Escape, attention, tangibles	–	Escape to tangibles and attention
Falcomata (2014)	Escape, attention, tangibles	Attention	Attention + tangibles
Zangrillo (2016)	Escape	Escape	Escape to tangibles

Note. Esc = escape; Att = attention; Tang = tangibles. In cases where participants are not listed separately, this means the information in that cell applies to all participants in the study.
[a] Denotes the reinforcers identified separately during an isolated FA.
[b] The contingency applied for appropriate behavior during treatment conditions with one reinforcer.
[c] The contingency applied for appropriate behavior during treatment conditions with synthesized reinforcer.

activity in an attempt to calm him, and made their attention available to prevent any further escalation of problem behavior.

Synthesized variables in treatment only. We found 32 applications across 12 articles in which the pretreatment FA was conducted with isolated reinforcers, but the subsequent treatment included synthesized reinforcers. Table 4 lists the treatment-only applications we reviewed, including which reinforcers were identified in the isolated FA and what type of treatment was experienced. These examples represented 23% of all treatment applications. In other words, approximately one-fourth of all synthesized treatments were based on the results of FAs that included isolated EOs or reinforcement contingencies.

For example, Lalli and Casey (1996), Piazza et al. (1997), and Piazza, Hanley, Fisher, Ruyter, and Gulotta (1998) reported cases in which an isolated FA indicated control by multiple reinforcers (e.g., attention, escape), but separate treatments based on each isolated reinforcer were not effective in reducing problem behavior to acceptable levels. These experimenters combined the reinforcers detected by the isolated FA into an effective treatment consisting of a single synthesized contingency. In each case, the synthesized treatment was directly compared to the isolated treatment in a multielement or reversal design, and treatment effects were observed only during the application of treatments that involved synthesized reinforcers. As another example, Bachmeyer et al. (2009) reported synthesized treatment applications in which multiple reinforcers as well as multiple forms of extinction were evaluated. These experimenters conducted an isolated FA of inappropriate mealtime behavior and found that problem behavior was sensitive to escape and attention separately. Escape extinction only, attention extinction only, and combined escape/attention extinction conditions were then compared in a multielement and reversal design (participants Tyler, Savannah, Ella) or a multielement within a multiple baseline design (participant Matthew). During the escape extinction condition, attention was provided as a reinforcer for problem behavior and escape was withheld; during the attention extinction condition, escape was provided as a reinforcer for problem behavior while attention was withheld; during the combined extinction condition, both reinforcers were provided for appropriate behavior. Problem behavior was reduced to clinically acceptable levels for all participants only when both reinforcers and both forms of extinction were synthesized.

In a more recent example, Zangrillo, Fisher, Greer, Owen, and DeSouza (2016) conducted an isolated FA and then compared isolated and synthesized treatments (escape-only vs. escape to tangibles). The pretreatment (isolated) FA for both participants was differentiated for escape; problem behavior was not differentiated for tangibles for either participant in their isolated tangible conditions. However, the treatment comparison for both participants indicated that providing escape to tangibles was more effective in eliminating problem behavior during FCT and subsequent reinforcement schedule thinning. Problem behavior persisted during treatments that were based on the escape-only contingency and schedule thinning was not successful in this context, suggesting that tangible reinforcers were relevant to the problem behavior, even though the isolated FA did not identify contingent access to tangibles as a reinforcer for problem behavior.

Analysis of Synthesized FA and Treatment Features

Settings. Synthesized FAs (i.e., SEOAs and SCAs) and their resultant treatments have been conducted across a variety of settings, ranging from natural environments to highly specialized settings. Over one third (35.9%) of all applications were conducted in natural environments where the individual typically spends his or her time; these included at home, at school, or at adult day placements (e.g., vocational or day habilitation facilities). Outpatient clinics accounted for 39.7% of applications; the remaining 19.9% of applications were conducted on inpatient units.

Topographies. Topographies of problem behavior reinforced in synthesized FAs included aggression, SIB, disruption (including motor and vocal disruptions, flopping, climbing on furniture), spitting, elopement, crying, mouthing, and inappropriate sexual behavior. Most synthesized FAs evaluated multiple response topographies; 81% did so by reinforcing dissimilar responses (e.g., aggression and SIB), and 17% did so by reinforcing similar responses within the same general category (e.g., aggression in the form of hitting and kicking). There were three applications (2%) that evaluated a single topography only (crying in Bowman, Hardesty, & Mendres-Smith, 2013; self-biting for participant Rudolfo in Kennedy & Meyer, 1996; mouthing in Lohrmann-O'Rourke & Yurman, 2001), and three applications in which authors did not specify whether multiple topographies were reinforced (Lambert et al., 2017; O'Reilly et al., 2000). In approximately half of applications (49%), it appears that the topographies reinforced in the FA were selected because they were the specific behaviors for which the individual was referred (i.e., the authors provided no additional information regarding interviews, observation, or other methods that were used to cull response topographies for analysis). The Method sections of most articles reported that the participant had a history of or was referred for specific problem behaviors; we may infer that these were the behaviors reinforced during the FA. Topography selection based on record review was not reported. Topographies were selected through an open-ended interview in which teachers or caregivers answered questions regarding the individual's problem behavior in

46.7% of articles; 7.2% of articles also reported reinforcing precursor responses as well as problem behavior.

Conditions under which synthesis is applied. We identified two distinct conditions under which researchers have conducted synthesized FAs. In 17.1% of all applications, the use of synthesis was preceded by an isolated FA that was not differentiated (e.g., Bowman et al., 1997; Fisher et al., 1998). Synthesis was applied in these cases in an attempt to obtain more conclusive results. For the remainder of the FA applications, the use of synthesis was based on an interview or observations that suggested certain variables were operating together to influence problem behavior. In other words, a large majority of experimenters who conducted synthesized FAs did so as the first iteration, rather than designing these test conditions only after other methods were unsuccessful. This finding may be somewhat counterintuitive because the majority of published FAs include isolated rather than synthesized reinforcers (Beavers et al., 2013); one may therefore assume that in most applications of synthesis, analysts attempted to use isolated reinforcers first, and only resorted to synthesis when those methods were inconclusive. Examining these data by publication year provides some additional context. Most synthesized FAs have been published since 2014; 12% of those FAs were preceded by an initial isolated FA. Of the 33.1% of synthesized FAs that were published before 2014, 22% were preceded by an initial isolated FA. In other words, experimenters were almost twice as likely to conduct an isolated FA first before attempting a synthesized FA prior to 2014; the tendency for a synthesized FA to be the first iteration of an FA (when they are reported) is fairly new and is possibly associated with the publication of Hanley et al. (2014), in which a comprehensive FA and treatment process relying on synthesis was initially reported. It is important to note, however, that the majority (73%) of synthesized FAs published since 2014 have been conducted by current or former researchers from the Hanley lab.

Likelihood of differentiation. A high percentage of all synthesized FAs were differentiated (139 out of 148; 94%). There were six SCA applications that were undifferentiated (participant Sylvia in Fisher et al., 2016; participants Jim and Daniel in Roscoe, Schlichenmeyer et al., 2015; participant Gail [with analyst] in Hanley et al., 2014; Participant 2 in Lambert et al., 2017). For Sylvia, Jim, and Daniel, an isolated FA was also undifferentiated; the isolated FA occurred after the SCA for Sylvia and before the SCA for Jim and Dave. For Gail, a second SCA application with her mother was differentiated. There were three SEOA applications that were undifferentiated and interpreted as indicating an automatic function because responding persisted across all conditions (Carter, 2005). Beavers et al. (2013) also reported that 94% of published FAs (including those reviewed by Hanley et al., 2003) were differentiated; thus, the likelihood of differentiation for synthesized FAs is comparable to the data reported by those authors, though the number of applications is from a considerably smaller sample size (148 in the present review, compared to 981 combined across Beavers et al. and Hanley et al.). It is also important to note that most synthesized FAs detected socially mediated reinforcers; there were only four applications (2.7%) in which an automatic function was implicated.

Reinforcer combinations. Most SCAs (91.7%) included escape to some other reinforcer(s): escape to different combinations of tangibles and attention (25%); escape to some type of tangibles, including preferred activities (24%); escape to mand compliance, including access to attention or preferred activities (16.7%); escape to a previous ongoing activity (7.3%); escape to some form of attention, including preferred conversations (12.5%); escape to ritualistic or stereotypic behavior (6.3%). The remaining 8.3% of SCA applications included a combination of attention and tangibles. It is possible that escape was reported so frequently because the presentation of demands in the context of an ongoing preferred activity may further establish the value of that activity. It is also possible that parents and teachers are more likely to report that problem behavior tends to occur in the context of demands because lack of compliance with typical daily demands is their most pressing concern.

Demonstrating necessity of synthesis. We considered experimenters to have demonstrated that synthesis was necessary in a particular case if they conducted a direct comparison of synthesized and isolated conditions (e.g., via a multielement or reversal design) and found that differentiation occurred or treatment was effective when and only when EOs or whole contingencies were synthesized. Such direct comparisons occurred in 8% of all synthesized FAs and 22% of all synthesized treatments. For the subset of applications in which synthesized and isolated conditions were directly compared (n = 53), 80% found that the synthesis of variables was necessary to produce a differentiated FA or efficacious treatment.

As an example, Mueller et al. (2005) conducted a multielement SCA that included an escape-to-attention condition, an escape-only condition, and a control condition. Problem behavior reliably occurred in the escape-to-attention condition but was not differentiated in the escape-only condition. We may therefore conclude that a synthesis of escape and attention was necessary to obtain a differentiated FA, given the conditions selected by these experimenters. As another example, Sarno et al. (2011) conducted SCAs with the same three conditions with three participants, and although problem behavior occurred at the highest rates in the escape-to-attention condition for each participant, the escape-only condition was differentiated as well. This indicates that the synthesis of escape and attention was *not* necessary to obtain a differentiated FA. However, Sarno et al. also used a reversal design to compare treatment conditions with escape-to- attention and escape-only and found that problem behavior was reduced and appropriate engagement was increased only when both reinforcers were synthesized.

Slaton et al. (2017) reported similar results for two participants (Emily and Jeff): both an SCA and an isolated FA were differentiated for these participants, suggesting that a synthesis of reinforcers was not necessary to obtain differentiation. A multielement treatment comparison, however, indicated that FCT was effective only with the synthesized contingency and not with the isolated reinforcer. The data reported by Sarno et al. and Slaton et al. are noteworthy because they illustrate the fact that synthesis may still be critical even when the FA suggests it is not (i.e., a differentiated FA with isolated reinforcers might still require a treatment with synthesized reinforcers). As a fourth example, Fisher et al. (2016) compared SCAs and isolated FAs for five participants, similar to Slaton et al. Problem behavior was differentiated in both FAs for four out of five participants, suggesting that synthesis was not necessary to obtain differentiation. However, unlike Sarno et al. and Slaton et al., Fisher et al. did not include a comparative treatment analysis, which means we cannot determine whether synthesis would have been a necessary component of effective treatment in those cases.

There were several ways in which experimenters arranged conditions to compare the influence of isolated and synthesized components. The examples of Mueller et al. (2005) and Sarno et al. (2011) described above demonstrate the most common arrangement: A synthesized test condition was compared to one in which a single reinforcer was provided (e.g., escape + attention vs. escape only vs. attention only) in a multielement design. Most synthesized FAs that included direct comparisons of isolated and synthesized variables used this arrangement (91%), but there are some methodological variations worth noting. Several authors reported FAs in which a synthesized test condition was compared to conditions in which *all but one* of the reinforcers were present. For example, participant Gail in Hanley et al. (2014) experienced a SCA with a combination of attention and tangibles. To evaluate these reinforcers separately, experimenters arranged a multielement FAs with a test condition in which toys were withheld but attention was continuously available and a second test condition in which attention was withheld but toys were continuously available. This created a context in which only one of the two EOs was operating at any given time. This type of isolated EO condition has also been reported in at least four other studies (Call et al., 2005; Dolezal & Kurtz, 2010; Ghaemmaghami et al., 2015; Santiago et al., 2016). In each of these cases, the isolated EO condition produced zero or near-zero rates of problem behavior, indicating one of two things: either none of the EOs by themselves were sufficiently evocative, or the presence of reinforcers associated with other EOs effectively competed with the single EO presented. In addition to demonstrating that problem behavior depended on the interaction between EOs, these experimenters also demonstrated some of the boundary conditions under which stimuli did and did not function as reinforcers (e.g., Hanley et al. demonstrated that attention did not function as a reinforcer for Gail in the context of preferred toys).

As another methodological variation, two studies reported conditions in which a single reinforcer was delivered following problem behavior or an appropriate mand, and other reinforcers were then delivered if problem behavior persisted during that reinforcement interval (Ghaemmaghami et al., 2015; Payne et al., 2014). For example, Payne et al. (2014) conducted an SCA (with participant Samantha) in which tangible reinforcement was provided, and if problem behavior persisted during the tangible interval, attention was then provided as well. They compared this to a control condition in which noncontingent attention was provided during the tangible reinforcement interval. Ghaemmaghami et al. (2015) reported an SCA in which attention, tangibles, and escape were combined; treatment began by teaching a mand for only one of these reinforcers (escape). If problem behavior occurred during the escape interval, the other reinforcers (attention, tangibles) were provided. Both experimenters demonstrated that problem behavior persisted in the presence of a single reinforcer and was eliminated only when subsequent reinforcers were also provided. The logic is that if problem behavior persists in the presence of a putative reinforcer, it may not be maintained by that single reinforcer (e.g., Roane, Lerman, Kelley, & Van Camp, 1999).

Falcomata, Muething, Gainey, Hoffman, and Fragale (2013) described a way of evaluating individual reinforcers in a synthesized contingency during treatment (rather than during the FA). These experimenters initially taught an omnibus mand that produced access to multiple reinforcers that were each detected individually in an isolated FA. Following acquisition of the omnibus mand, they taught specific mands for each individual reinforcer, and found that mands for some reinforcers (e.g., escape, tangible items) were consistently emitted, but mands for other reinforcers (e.g., attention) were rarely emitted. A plausible interpretation of these results is that escape and tangible items were functional reinforcers for problem behavior, but attention was not. This example is important as a model for evaluating the role of individual reinforcers because conducting this evaluation during treatment (instead of during the FA) allows for treatment to begin immediately once the FA is concluded. In some cases, this may be preferable to delaying treatment while additional analyses are conducted to tease out the role of each reinforcer.

A final example of comparative analyses between synthesized and isolated reinforcers worth noting is found in Call and Lomas Mevers (2014). These experimenters directly compared an SEOA condition, SCA condition, and isolated reinforcer condition in a multielement design. In the SEOA condition, demands were presented while tangible items were restricted; problem behavior produced escape only. In the SCA condition, the same synthesized EOs were programmed, but problem behavior produced both reinforcers (escape to tangibles). In the isolated escape condition, demands were presented and problem behavior produced escape. All three conditions were differentiated; however, these authors also evaluated within-session patterns of responding to determine whether problem behavior persisted during the reinforcer interval (see also Jessel et al., 2016; Roane et al., 1999). Within-session analyses showed that problem behavior persisted during the reinforcer interval of the SEOA condition (when escape was provided but the tangible EO remained in place) and the isolated escape condition (in which tangibles were never provided). By contrast, problem behavior immediately ceased and did not occur during the reinforcer interval of the SCA condition in which both reinforcers were provided, suggesting that tangible items were relevant to problem behavior. Treatment data confirmed this interpretation.

Treatment efficacy. Identifying the controlling variables for problem behavior is a desirable outcome not for the sake of differentiation in and of itself, but because differentiation provides information from which to design treatment. Treatment effect size is thus an important criterion by which to evaluate the merits of synthesized FAs, and perhaps a more pragmatic criterion than that of differentiation (i.e., a differentiated FA has practical value if it produces an effective treatment, and much less value if that treatment fails). Table 5 reports a summary of two different measures of treatment effect size (MBLR and PND) for the final phase of all synthesized treatments and any

Table 5
Treatment Efficacy

Type of Treatment	PND[a]	MBLR[b]
Synthesized (n = 109)	M = 88.6	M = 90.2
Isolated (n = 27)	M = 43.3	M = -0.3

Note. PND = percentage of non-overlapping data points; MBLR = mean baseline reduction.
[a] PND was calculated by dividing the number of treatment points that fell below the lowest baseline point by the total number of treatment points and multiplying by 100.
[b] MBLR was calculated by subtracting that mean treatment score from the mean baseline score, dividing that number by the mean baseline score, and multiplying by 100.

comparative isolated treatments. Average MBLR across all synthesized treatment applications was 90.2%, compared to -0.3% across all isolated treatment comparisons. An independent samples *t*-test found this difference to be statistically significant ($p < 0.01$; t (26) = 7.7). Measuring treatment effects using PND revealed a similar pattern. Average PND across all synthesized treatment applications was 88.6%, compared to 43.3% for isolated treatment applications; an independent samples *t*-test found this difference to be significant as well ($p < .01$; t (32) = 8).

Figure 4 presents MBLR values for each individual application, organized first by within-subject comparisons and then by synthesized applications without an isolated comparison.[4] Most synthesized treatment applications (89%) achieved a MBLR of 80% or higher; over half (57%) achieved a reduction of 95% or higher. By contrast, 11% of isolated treatment applications achieved a MBLR of 80% or higher; 7% achieved a reduction of

[4]The number of applications evaluated for MBLR and PND is less than the total number of treatment applications reviewed because we evaluated treatment effects using only the final phase of each treatment (e.g., a treatment that was conducted in a clinic and then extended to the home environment would be counted as two applications; only the latter was evaluated for MBLR and PND).

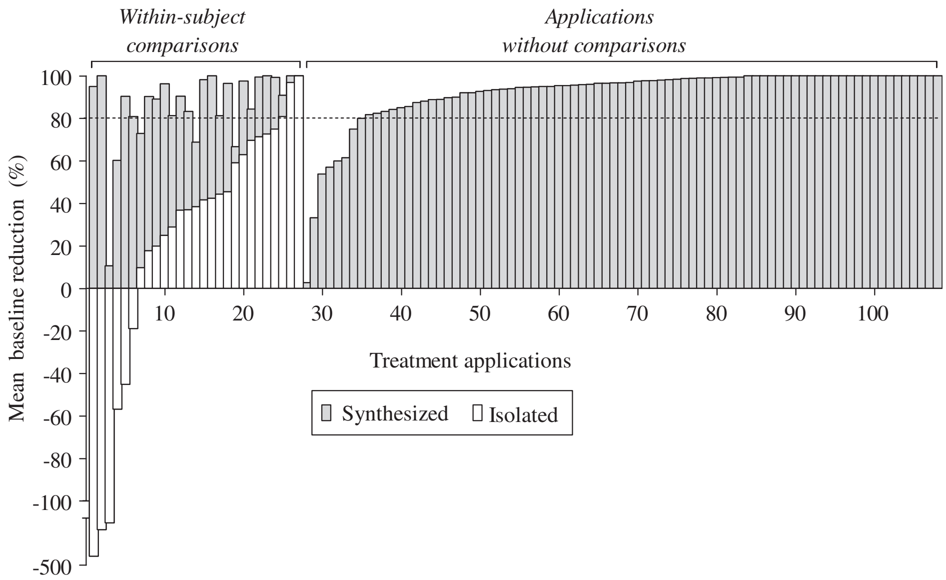

Figure 4. MBLR for all synthesized treatment applications and comparative isolated applications.

95% or higher. Of the 97 synthesized treatment applications that achieved 80% MBLR or higher, the majority of them (n = 61; 63%) also included schedule thinning (e.g., Ghaemmaghami et al., 2016; Strohmeier et al., 2016) or schedule thinning plus social validity measures (e.g., Jessel et al., 2018). For example, Ghaemmaghami et al. (2016) gradually increased the number of demands that participant Alex was required to complete before accessing the functional reinforcers for his problem behavior, until he was regularly complying with up to 50 demands over a period of approximately 10 min). There were three treatment applications that compared synthesized versus isolated contingencies during schedule thinning beyond the initial stages of FCT; each of them demonstrated that schedule thinning was only successful in the synthesized treatment condition (one application in Lalli & Casey, 1996; two applications in Zangrillo et al., 2016).

Several treatment applications are worth noting because of the extended effects of synthesized contingencies (e.g., Hagopian et al., 2007; Hanley et al., 2014; Jessel et al., 2018; Santiago et al., 2016). The synthesized treatments described by Hanley et al. (2014) and Santiago et al. (2016) all eliminated problem behavior, were generalized to other settings, and were socially validated by the parents of the children. Jessel et al. (2018) recently reported 25 synthesized FA and treatment applications in a consecutive controlled case series (similar to Hagopian, Rooker, Jessel, & DeLeon, 2013); these authors reported a mean MBLR of 99% across the final three treatment data points for these 25 consecutive cases.

There were three instances in which an isolated treatment comparison achieved MBLR of at least 80% (two for participant Dylan and one for participant Chloe in Slaton et al., 2017), indicating that isolated and synthesized treatments were both effective in these cases. The fact that both treatments were effective suggests that the synthesized contingency was not necessary to obtain initial treatment effects for either participant; these applications represent the only examples to date in which the inclusion of possibly unnecessary reinforcers in an SCA has been demonstrated.

"Unplanned" synthesis. We identified a number of articles (not included in the samples) in which the authors did not describe their conditions as including synthesis, but it was clear from carefully reading the Method sections that the test conditions in these FAs actually included synthesized reinforcers. For example, a number of studies reported providing tangibles or attention during the escape period of the escape condition (Asmus et al., 1999; Berg, Wacker, Harding, Ganzer, & Barretto, 2007; Harding, Wacker, Berg, Lee, & Dolezal, 2009; Schieltz et al., 2010). In other cases, demands were presented during tangible or attention conditions, indicating that multiple EOs were likely salient and that problem behavior may have produced escape and attention or tangibles simultaneously (Day, Horner, & O'Neill, 1994; Jones, Drew, & Weber, 2000). These conditions were described as isolated reinforcer conditions (e.g., escape or attention), but the details reported in the Methods indicated that synthesized contingencies were operating. It is important to note that these papers were identified outside of the search terms we described above; it is likely that there are more examples of studies that have included synthesis without clearly labeling it.

All of the studies with what might be referred to as an "unplanned" synthesis were conducted in homes or classrooms where it is likely that multiple events occurred together following problem behavior. For example, the analysis reported by Harding et al. (2009) was conducted with a toddler in his bedroom with his mother serving as the analyst. It is reasonable to assume that providing attention during the escape interval represents the way the parent naturally interacted with her child during problem behavior. Jones et al. (2000) conducted their analysis in a classroom during a summer program in which students were engaged in academic instruction during most of the day; academic instruction is therefore likely the context in which problem behavior typically occurred. Although the authors described their test conditions as involving single reinforcers, the exigencies of the natural conditions under which they were analyzing behavior appears to have occasioned a reliance on synthesized contingencies.

DISCUSSION

Prevalence and Features of Synthesized FAs and Treatments

Synthesized FAs have been referred to broadly as modified FAs (e.g., Adelinis & Hagopian, 1999) or have been named based on some feature of the synthesized contingency. For example, Hagopian et al. (2007) called their analysis an *interruption analysis*; Fisher et al. (1998) used the name *analysis of "don't" requests;* Mueller et al. (2005) described their analysis as an FA with an escape-to-attention condition. The myriad of terms used to describe synthesized FAs is likely one reason that about 40% of the articles we identified were found by reviewing reference lists of articles returned by our search terms and not by the search terms themselves (see Figure 2). This is a limitation of this review and of the literature itself and reflects the need for consistent language to describe this subset of FAs. Hanley et al. (2014) was the first publication to apply the descriptor *synthesized* to a procedure in which multiple reinforcers were combined in a single test condition, and to suggest the general relevance of synthesis in FAs. Although the studies we reviewed share the key component of synthesis, their features and outcomes have not been collectively described and interpreted together through a common lens. Synthesis is a nuanced feature of FAs and treatments; tacting its presence is important because it ties together a group of studies that otherwise appear unrelated, and it places them within the same conceptual framework. To illustrate, one finding of our current review is that the use of synthesis in FAs and treatments is not new; the earliest example we reviewed was published in 1995 (O'Reilly, 1995; an SEOA evaluating attention and escape in the context of sleep deprivation). The novelty of these approaches lies not with the methods per se but with the encompassing label applied to these arrangements and the fact that researchers have begun to examine the relative benefits of synthesized and isolated contingencies (e.g., Call & Lomas Mevers, 2014; Fisher et al., 2016; Ghaemmaghami et al., 2015; Hanley et al., 2014; Santiago et al., 2016; Slaton et al., 2017; Zangrillo et al., 2016).

Beavers et al. (2013) reported that 59.7% of all FA applications were conducted in highly specialized settings (inpatient units and institutions). By contrast, this type of setting was the category least reported for synthesized FAs and treatments. It is possible that natural, less restrictive settings (e.g., homes, schools, clinics) represented the majority of all synthesized FA and treatment applications because these locations are likely more conducive to analyzing combinations of variables that typically co-occur in the course of daily life (and perhaps less conducive to isolating individual reinforcers). For example, a child who engages in problem behavior at home when asked to get dressed in the morning may temporarily escape this demand and easily access any number of toys that happen to be available in his bedroom. Conducting an FA to isolate escape and tangibles in this context could pose some practical challenges (i.e., access to toys would need to be blocked or otherwise prevented during the escape condition). Similarly, it is possible that the smallest percentage of applications were reported on inpatient units because these settings often have the time and resources available to conduct extended analyses in modified environments where reinforcers are more easily controlled (e.g., session rooms). It is also worth noting, however, that the population served on inpatient units is generally not representative of the broader population of individuals who engage in problem behavior. The successful implementation of synthesized FAs in natural settings is important to note because surveys of FA usage among practitioners have indicated that most practitioners do not conduct FAs before treating problem behavior; the reasons provided generally relate to effort, time, and lack of resources (Ellingson, Miltenberger, & Long; 1999; Oliver, Pratt, & Normand, 2015; Roscoe, Phillips, Kelly, Farber, & Dube, 2015). The successful implementation of synthesized FAs in natural settings suggests that they may be a viable option for practitioners who work in these settings.

The overwhelming majority of synthesized FAs included synthesized response topographies (i.e., targeted two or more topographies for reinforcement in the FA). Although Beavers et al. (2013) cautioned against reinforcing multiple topographies of problem behavior, they also found that the majority of published FAs they reviewed (75.9%) targeted reinforcement for multiple topographies of problem behavior. Thus, the tendency to include multiple topographies appears to be relatively common in the FA literature, regardless of whether isolated or synthesized contingencies are used. The inclusion of precursors does not seem to be particularly problematic either, as a number of researchers have demonstrated that precursors and problem behavior are likely maintained by the same reinforcers (Borrero & Borrero, 2008; Fritz, Iwata, Hammond, & Bloom, 2013; Herscovitch, Roscoe, Libby, Bourret, & Ahearn, 2009; Langdon, Carr, & Owen-DeSchryver, 2008; Najdowski, Wallace, Ellsworth, MacAleese, & Cleveland, 2008; Smith & Churchill, 2002). It should be noted, however, that the functional equivalence of precursor and problem behavior has not been demonstrated yet within the synthesized FA literature; this is an important area of future research.

It is also important to note that authors do not typically report which individual topographies occurred during the FA (i.e., data are typically expressed as a combined measure of problem behavior; cf. Beavers et al., 2013), which means it is unknown whether all topographies that were targeted for reinforcement actually contacted reinforcement, whether a subset of topographies occurred, or whether a single topography occurred. Alternatively, in an FA designed to evaluate a single topography, it is possible that other topographies could occur within close temporal proximity to the one target response, resulting in multiple topographies (including those not targeted for reinforcement) contacting reinforcement. For example, Slaton et al. (2017) reported that precursors were reinforced during isolated FAs for some participants because they occurred within 2 s of problem behavior, even though precursors were not scheduled for reinforcement. This lack of clarity regarding which and how many topographies were reinforced in an FA appears common across all types of FAs. Authors who report FAs (either synthesized or isolated) may wish to consider reporting exactly which topographies occurred during the FA; this information would allow future reviews of FA literature to more clearly evaluate the extent to which isolated versus synthesized topographies are being reinforced in FAs.

With regard to the combinations of reinforcers evaluated in SCAs, we found nine general combinations (see Table 3). When viewed through the lens of broad reinforcer categories such as attention, escape, and tangibles, there are a limited number of different combinations of reinforcers that may be synthesized. However, when examined more closely, qualitative variations in these general classes of reinforcement are evident and the number of different possible synthesized contingencies is wide. As an example, Jessel et al. (2016) reported 27 unique contingencies across 30 different SCAs (see their Table 2). The only repeated contingency in that sample was escape from adult-directed to child-directed activity. We do not know to what extent the specific adult- or child-directed activities varied across those participants; it is likely that each application was unique, even though the general contingency was the same. It would be inaccurate to characterize SCAs as representing a small range of possible reinforcer combinations; the qualitative nature of the reinforcers included in SCAs is often distinct. For instance, different synthesized contingencies may include attention, but one may be attention in the form of engaging in child-directed pretend play (e.g., participant Alex in Jessel et al., 2016), and one may be attention in the form of chatting about preferred conversation topics (e.g., participant Karen in Santiago et al., 2016). To say that problem behavior for both individuals is maintained by attention (in combination with other reinforcers) would be accurate and yet it is possible that such a description would lack the necessary detail to replicate the analysis or design a treatment that incorporates the functional reinforcers for problem behavior. The extent to which providing technological descriptions of synthesized reinforcers based on nuanced and qualitative details (e.g., escape from independent academic work to child-directed play with arts and crafts materials) is more beneficial than providing such details based on generic reinforcer categories (e.g., escape to tangibles) remains an empirical question to be answered.

A second important point regarding reinforcer combinations is that authors did not report reinforcer consumption during FAs, which means we do not know to what extent programmed and unprogrammed reinforcers were actually experienced. This is true of synthesized FAs and other FAs. Consider, for example, an SCA that is designed to provide escape, attention, and tangibles. This does not necessarily mean that all three reinforcers were consumed by the participant. It is possible that escape and attention were the only reinforcers experienced during the entire analysis (i.e., the participant declined to engage with the tangible items, or chose to continue engaging with the demand presented). Similarly, consider an isolated escape condition in which escape is provided following problem behavior, and the individual consistently engages in stereotypy during the escape interval. This could reasonably be characterized as an escape-to-stereotypy condition; describing it simply as an escape condition would obscure the fact that we do not know the extent to which problem behavior is maintained by escape, access to stereotypy, or both. Thus, it is possible that a participant in an SCA may not experience all reinforcers in the synthesized contingency; likewise, it is possible that a participant in an isolated FA may experience synthesized reinforcers. Just as authors may wish to begin reporting which topographies actually occurred during an FA, we suggest that there may also be benefits to reporting which reinforcers were consumed during an FA. This would allow future reviews of FA literature to more accurately describe the extent to which synthesized reinforcers are consumed during FAs.

The Value of Naming Synthesis

There are numerous variations to types of FAs, as well as their measurement and design. For example, in addition to the FA model reported by Iwata et al. (1982/1994), authors have reported brief FAs (e.g., Derby et al., 1992; Northup et al., 1991), latency FAs (e.g., Thomason-Sassi et al., 2011), precursor FAs (e.g. Smith & Churchill, 2002), and trial-based FAs (e.g. Sigafoos & Saggers, 1995). These variations are each named and identified separately because their procedures presumably vary enough to warrant distinction, and because it is easier to name a thing than to describe it by its features (e.g., it easier to say *brief FA* than *an FA in which a single session is conducted in each test condition and often a contingency reversal is included).* If we view all FAs as falling somewhere on the continuum between isolated and synthesized, a question that may arise is whether it is even necessary to identify SCAs and SEOAs as specific subcategories of FAs (given that most FAs likely include some type of synthesis, even if it is a synthesis of topographies only). We argue that this distinction is justified because the presence or absence of synthesis in an FA, and the particular type of synthesis, directly influences the conclusions we may draw about the variables responsible for problem behavior; therefore, it is helpful to have a specific name by which to refer to this subset of FAs.

Identifying SEOAs as one variation in FA methods can be useful for several reasons. First, an advantage of SEOAs is that they can evoke problem behavior that is sensitive only to the interaction between EOs and would not otherwise occur (e.g., Call et al., 2005; O'Reilly, 1995). This is a particularly relevant consideration for cases in which no responding or inconsistent responding is observed in the FA. However, although synthesized EOs may sometimes be necessary to evoke problem behavior, a significant limitation of SEOAs is that at least one EO remains in place during the reinforcer interval after problem behavior has occurred. Call et al. (2005) and Dolezal and Kurtz (2010) both noted this as a potential problem with SEOAs. In particular, Call et al. noted that "[i]t is not clear from the current data whether the consequences associated with the other antecedent variable from the combined-antecedent test condition would have also functioned as a reinforcer for problem behavior" (p. 387). In other words, we cannot rule out the possibility that the undelivered reinforcer also maintains problem behavior, nor can we confirm that the single reinforcer provided was in fact the reinforcer for problem behavior. Because some EOs may not be easily detectable (e.g., sleep deprivation), it is also possible that we may not know during any FA which synthesis of EOs is present or not. Given this uncertainty, we suggest that SCAs in which all reinforcers are delivered are preferable to SEOAs (when designing synthesized FAs). An SEOA is less preferable because the fact that at least one programmed EO continues to operate during the reinforcement interval makes it difficult to determine why problem behavior is occurring. It is possible that problem behavior is occurring because it is maintained by the single reinforcer that is delivered, or it is possible that problem behavior is occurring because it is evoked by the remaining EOs (e.g., Call & Lomas Mevers, 2014). When experimenters do implement an SEOA, within-session analyses of responding during reinforcer-present and reinforcer-absent intervals (e.g., Jessel et al., 2016; Roane et al., 1999) would be useful to include as well; the results of such analyses may considerably impact the interpretation of SEOA results. Thus, a second reason it is important to name and recognize SEOAs as a particular type of analysis is so that these limitations and the potential utility of within-session analyses can be considered when interpreting results. Incorrectly assuming that the single reinforcer evaluated in an SEOA is the only reinforcer maintaining problem behavior could result in an ineffective treatment (e.g., Call & Lomas Mevers, 2014).

Identifying an analysis as an SCA also has value for several reasons. The first is that failing to tact the presence of a synthesized contingency (when one exists) may lead to a misinterpretation of results. When multiple reinforcers are delivered simultaneously following problem behavior, the impact of any individual reinforcer is unknown. This is true whether the delivery of multiple reinforcers was planned or not (e.g., "unplanned" synthesis; Asmus et al., 1999; Berg et al., 2007; Harding et al., 2009; Schieltz et al., 2010). We are not suggesting that the variables in "unplanned" synthesis studies should not have been synthesized; rather, we are suggesting that it is important to write clear technological descriptions that tact all of the events following problem behavior so it is clear precisely what contingency was evaluated. It is important to recognize SCAs as a specific variation because results may otherwise be interpreted as indicating control by a single reinforcer, when in fact the impact of that reinforcer is unknown.

A second reason that identifying an analysis as an SCA has merit is that recognizing the inclusion of a synthesized contingency can inform various options for treatment design. Typically, when a single reinforcer is provided in an FA, the treatment consists of providing that same reinforcer for an appropriate alternative response. When a synthesized contingency is applied during an FA, the analyst must determine how those multiple reinforcers will be arranged during treatment. Most treatments based on SCAs have included the same synthesis of EOs and reinforcers as the initial FA. However, it is also possible to design treatment to evaluate the relevance of each individual reinforcer by teaching individual mands for each reinforcer one at a time (e.g., Ghaemmaghami et al., 2015) or by teaching an omnibus mand first, and then differentiating mands for individual reinforcers (e.g., Falcomata et al., 2013). If a particular FA is not identified as including a synthesized contingency, these various treatment options and the possibility of evaluating the role of each reinforcer will likely not be considered, and it is possible that important, relevant reinforcers might be omitted from treatment. There are a number of examples that demonstrate the potential problems (treatment failure) with such an omission (Lalli & Casey, 1996; Mann & Mueller, 2009; Payne et al., 2014; Piazza et al., 1997, 1998; participants Emily and Jeff in Slaton et al., 2017).

The Contributions of Comparative Analyses with and without Synthesis

Most synthesized FAs or treatments did not include a comparison between synthesized and isolated contingencies, which means that in the majority of cases it was not possible to determine whether the use of synthesis was necessary. It is possible that similar outcomes would have been obtained with isolated FAs or treatments. Despite this uncertainty, however, the current results found no difference in likelihood of differentiation between synthesized FAs that included isolated comparisons and those that did not; similarly, we found no differences in efficacy between synthesized treatments that included isolated comparisons and those that did not. Almost all synthesized FAs were differentiated, even though only a small portion of them demonstrated that synthesis was necessary to obtain differentiation. Similarly, most synthesized treatments reported a reduction in problem behavior of 80% or greater, even though only a small portion of these demonstrated that synthesis was critical to the treatment outcome. There were no applications in which a synthesized treatment was found to be ineffective and was abandoned in favor of an isolated treatment. In other words, we did not find any evidence to suggest that conducting an isolated FA first or including an isolated condition as a comparison within a synthesized FA offered any specific advantages with regard to obtaining a differentiated FA or designing a successful treatment. Although the number of synthesized FA and treatment applications is relatively small, the examples published to date do not suggest that conducting a synthesized FA as a first iteration is problematic. Synthesized FAs and treatments have been shown to be effective regardless of whether interactions or main effects are present (e.g., Ghaemmaghami et al., 2016; Hanley et al., 2014; Jessel et al., 2018; Strand & Eldevik, 2017; Strohmeier et al., 2016).

It is important to note, however, that we did not evaluate the total number of published function-based treatments with isolated reinforcers, and therefore cannot speak to what proportion of all treatments synthesized examples represent. Most cases in which an isolated treatment was compared to a synthesized treatment were cases in which the isolated treatment had already proved ineffective (which is why the synthesized treatment was being considered); this obviously impacts that average MBLR for the isolated treatments we reviewed. It is also important to note that among the synthesized treatment applications that included schedule thinning, many extended the delay to reinforcement for only a few minutes or a few responses (e.g., Payne et al., 2014; Rispoli, Camargo, Machalicek, Lang, & Sigafoos, 2014; Santiago et al., 2016; Strohmeier et al., 2016). None included follow-up data to determine if treatment effects persisted over time (e.g., several months or a year). Our conclusions regarding the efficacy of synthesized treatments must therefore be tempered by these boundary conditions under which they have been reported. However, these boundary conditions are similar to those under which function-based treatments with isolated reinforcers have been reported (i.e., most treatments designed from isolated FAs also do not include extended schedule thinning to values that are practical in home or school environments or maintenance data regarding treatment effects over time, and extremely few report social validity data). Although we cannot determine the extent to which synthesized treatments are more or less likely to be effective than isolated treatments, it is reasonable to conclude that synthesized treatments designed from synthesized FAs are likely to be effective.

Areas of Future Research

There are several potential limitations of SCAs that should be evaluated. One limitation of SCAs is that the presentation of synthesized putative EOs could mask problem behavior if some of those supposed EOs actually have an abative effect. For example, removing tangible items and presenting demands that involve interacting with the individual may mask problem behavior evoked by the absence of tangible items and attention. A second limitation is that there are currently no published SCAs focused exclusively on automatically reinforced problem behavior. It is thus unclear how this type of responding would present in an SCA or whether this arrangement is appropriate to automatically reinforced problem behavior. It is possible that a synthesized control condition with access to materials and attention would effectively compete with automatically reinforced behavior, thus producing differentiation (similar to the pattern of responding in an isolated FA in which the alone condition is differentiated relative to the play condition). It is also possible that no arrangement of variables in the control or test conditions will compete with the response, thus producing an undifferentiated SCA (similar to the pattern of responding in an isolated FA in which responding is elevated and undifferentiated in all conditions).

Given these first two limitations, one important area of future research will be consecutive controlled case series that report each iteration of an SCA in cases in which the initial SCA is undifferentiated, as well as the conditions under which each application was eventually differentiated (if at all), similar to the large-*n* study by Hagopian, Rooker, Jessel and DeLeon (2013) and the recent study by Jessel et al. (2018). Studies of this nature will allow strengths and limitations of SCAs to be more clearly revealed, which in turn will allow for analyses of procedural modifications to address them.

A third limitation is that we do not know how likely it is that an SCA will include unnecessary (i.e., extra, nonfunctional) reinforcers, nor do we know the short- or long-term impact of treatments that incorporate (possibly) unnecessary reinforcers. Fisher et al. (2016) raised the concern that including unnecessary stimuli as reinforcers may make a treatment needlessly cumbersome; this is an empirical question that has not yet been answered. To date, there are only two examples of SCAs in which a comparative treatment analysis specifically demonstrated that the synthesized contingency included unnecessary reinforcers (Slaton et al., 2017). SCA-based treatments were effective in both cases, and the inclusion of incidental reinforcers did not appear to yield any undesirable side effects in the context of clinical intervention. However, this evaluation was not extended to additional phases of treatment or to other contexts, which means there are very limited conditions under which the inclusion of unnecessary reinforcers during treatment has been evaluated. Although the inclusion of unnecessary reinforcers did not preclude a differentiated analysis or effective treatment for these participants, it is important to note that such inclusion could be problematic in contexts other than clinical intervention (e.g., participant selection for specific research questions that rely on identifying a single reinforcer). Future research should evaluate long-term efficacy and social validity of synthesized treatments that include potentially unnecessary reinforcers. This could be done by replicating the procedures described by Slaton et al., 2017, and for any participants for whom both treatments appear effective at the initial stage, extending the comparison to determine the point at which one treatment fails (or whether they both remain effective through the end of treatment).

Another area for future research is evaluating how synthesized treatments compare to isolated treatments over time in cases in which the synthesized treatment initially appears more effective (e.g., participants Emily and Jeff in Slaton et al., 2017). In most studies in which a synthesized treatment was found to be more effective than an isolated treatment, the comparison was only conducted during initial phases of treatment (e.g., Bachmeyer et al., 2009; Call & Lomas Mevers, 2014; Lalli & Casey, 1996;

Piazza et al., 1997; Piazza et al., 1998; Slaton et al., 2017). It is therefore unknown how these treatments may compare to each other during additional phases implemented under leaner schedules of reinforcement, in the natural contexts in which problem behavior occurs, for longer session durations, and with the participant's typical caregivers. Although there are a number of examples of SCAs in which the assessment process or treatment process and outcomes were socially validated by caregivers (e.g., Hanley et al., 2014; Jessel et al., 2018; Lloyd et al., 2015; Santiago et al., 2016), none of these studies included a comparative treatment analysis, which means that although there is some evidence indicating that SCA-based treatments and outcomes are acceptable to caregivers, we do not know whether they are more or less acceptable than treatments with isolated contingencies. Treatment comparisons that evaluate the efficacy and social validity of synthesized versus isolated contingencies at different stages of intervention will therefore be important.

A next area of research related to long-term efficacy and social validity of SCA-based treatments is the extent to which these treatments are preferred by the individuals who experience them. It is possible that even when isolated contingency treatments are equally effective, recipients of treatment may prefer a synthesized contingency in which a greater number of reinforcers is available. Preference analyses (e.g., Hanley, 2010; Luczynski & Hanley, 2009) may be particularly important in cases in which an isolated FA suggests that problem behavior is maintained by escape. For example, Zarcone, Fisher, and Piazza (1996) alluded to this possibility when examining positive versus negative reinforcement contingencies during free time. These experimenters conducted a reinforcer analysis in which stacking different color cups produced a break only (isolated escape condition) or a break with tangible items (SCA escape + tangible condition). Cup stacking was consistently higher in the SCA condition when a break and preferred items were both provided. This was not a functional analysis of problem behavior but is relevant to the current discussion because it demonstrates an example of preference for "escape to something" versus "escape to nothing."

Answering questions in the lines of research described above will provide valuable information from which to make additional practice recommendations regarding the use of SCAs. Absent this information, we feel the examples of SCAs available in the literature at this point are sufficient to recommend that their use be considered when analyzing and treating problem behavior. With any FA format, there are always questions that remain unanswered: Evaluating single reinforcers (as in an SEOA or isolated FA) does not indicate whether any interactive effects are present or whether problem behavior is evoked by other EOs; evaluating reinforcers in combination (as in an SCA) does not indicate whether any main effects are present. Selecting an analysis format therefore requires the analyst to decide what information she or he is willing to forego. The 55 studies reviewed here suggest that not knowing the influence of each individual reinforcer in a synthesized contingency does not preclude a differentiated FA or an effective treatment; in fact, it may be less problematic than not knowing whether an isolated FA has failed to detect other relevant reinforcers.

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