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REVIEW PAPER

A Systematic Synthesis of Behavioral Interventions for Food Selectivity of Children with Autism Spectrum Disorders

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Abstract This systematic review provides a synthesis of behavioral interventions for food selectivity (FS) in children with autism spectrum disorder (ASD). A multistep search strategy was employed to identify experimental studies published in peer-reviewed journals between 1984 and 2015. Thirty-one studies met inclusion criteria. Participant characteristics, study characteristics, and intervention outcomes were summarized and appraised to identify evidence-based practices. The results suggest that behavioral interventions of FS for children with ASD are often effective at improving feeding behavior (e.g., increasing acceptance and swallowing of target foods), but evidence for adequate reduction of mealtime challenging behavior is lacking, and the studies reviewed fell short of meeting a set of standards for evidence-based practices in special education. Treatment recommendations and directions for future research are discussed.

Keywords Autism · Food selectivity · Pediatric feeding disorders · Evidence-based practices

The prevalence of feeding problems among individuals with developmental disorders (DDs) has been estimated between 67 and 89 % (Ledford and Gast 2006; Palmer and Horn 1978; Williams et al. 2000). Consistent with this estimate, evidence suggests a strong correlation between feeding problems and symptoms of autism spectrum disorder (ASD) for children up to age 12 (Badalyan and Schwartz 2012; Curtin et al. 2015; Martins et al. 2008; Nadon et al. 2011; Schreck et al. 2004). Additionally, feeding problems may place children with ASD at greater risk for deficiencies in nutrients (e.g., calcium and protein) important for healthy brain functioning (Johnson et al. 2014; Sharp et al. 2013). Therefore, effective interventions for feeding problems are critical for the DD population in general and perhaps the ASD population, in particular.

A feeding problem is classified as a pediatric feeding disorder (PFD) when the problem is associated with clinically significant social, developmental, or health problems (Kedesdy and Budd 1998; Suarez et al. 2014). PFD are multidimensional, biobehavioral conditions (Burklow et al. 1998) characterized by a combination of medical problems (e.g., reflux disease), skill deficits, and/or learned feeding and mealtime behavior in children (Manikam and Perman 2000) and, in some cases, clinically significant growth and nutrition deficiencies (Piazza 2008). PFD is complex and heterogeneous in clinical presentation and diagnosis (American Psychiatric Association (APA) 2000; World Health Organization 1993; APA 2013), etiology, and issues related to classification (e.g., Burklow et al. 1998; Kedesdy and Budd 1998; Linschied 1992). Thus, it may be useful for the purpose of developing effective behavioral interventions to conceptualize PFD as a continuum of moderate to severe behavioral and biomedical feeding problems ranging from food selectivity (FS) to food refusal (FR).

The clinically significant consumption of a highly limited variety of nutritive foods is a defining feature of FS (Piazza 2008). This type of PFD is moderate in the severity of behavioral features (e.g., turning head away from food, elopement, hitting the feeder) (e.g., Levin and Carr 2001; Pizzo et al. 2012; Tarbox et al. 2010; VanDalen and Penrod 2010; Valdimarsdottir et al. 2010); not typically associated with

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biomedical factors (e.g., little nutritional deficiency or need for medical intervention) (Piazza 2008); and characterized by consumption of a limited variety of types, textures, or other dimensions of food (Greer et al. 2008; Kedesdy and Budd 1998; for a review, see Field et al. 2003; Piazza 2008). In contrast, FR is high in the severity of behavioral features (e.g., vomiting, gagging, self-injurious behavior) (Borrero et al. 2010; Freeman and Piazza 1998; Piazza, et al. 2003; Williams et al. 2010); typically associated with biomedical factors (e.g., significant nutritional and/or growth deficiencies or gastroesophageal reflux) (Bachmeyer 2009; Field et al. 2003; Greer et al. 2008; Piazza et al. 2003; Piazza 2008); and characterized by refusal to consume all or most foods or liquids (Borrero et al. 2010; Field et al. 2003; Greer et al. 2008; Piazza, et al. 2003; Williams et al. 2010). FS and FR are both associated with inappropriate mealtime behavior such as aggression towards the feeder or self (Freeman and Piazza 1998; Seiverling et al. 2014) and may be associated with difficulties chewing and/or swallowing (e.g., Field et al. 2003).

FS is the most common feeding problem demonstrated by children with ASD (Sharp et al. 2010; Twachtman-Reilly et al. 2008). Although medical treatment and management of PFD is important for some children, the most common and only empirically supported (Sharp et al. 2010) treatment for children with ASD is behavioral intervention based on applied behavior analysis (ABA). Behavioral intervention focuses on the environmental antecedents and contingent consequences of specific appropriate and inappropriate feeding behavior and acknowledgement of the potential role of sensory, motor, medical, bio-behavioral factors, and early traumatic feeding events (e.g., Manikam and Perman 2000; Piazza 2008; Piazza et al. 2015; Piazza and Roane 2009). Thus, behavioral intervention can be viewed as central to an interdisciplinary bio-behavioral approach to treating feeding problems (Greer et al. 2008; Varni 1983).

The behavioral intervention literature for PFD has been reviewed in multiple studies, sometimes in combination with behavioral interventions for FS and/or FR for children with or without ASD (e.g., Bachmeyer 2009; Ledford and Gast 2006; Marshall et al. 2014; Matson and Fodstad 2009; Seubert et al. 2014; Sharp et al. 2010). Overall, the conclusions from this non-exhaustive list of prior reviews converge to suggest that behavioral interventions for FS of children with ASD are effective, but that additional research involving rigorous design and study characteristics is needed.

This study aimed to extend prior reviews by addressing two remaining issues. First, there are no published comprehensive systematic syntheses of behavioral treatments of FS of individuals with ASD to the exclusion of other feeding problems (e.g., FR). Given that most clinical presentations of FS are distinct from those of FR, a separate examination of the evidence base for FS may be particularly informative for practitioners and future research focused on this population. Second, future dissemination of effective treatments for FS of children with ASD in clinical and educational settings will likely depend in part on the movement towards applying standards to identify evidence-based practices (EBPs; i.e., evidence-based reform) in special education (SPED). Yet, previous reviews have not compared the evidence for behavioral treatment of FS of children with ASD to any such standards, such as those proposed by the Council for Exceptional Children (CEC; Cook et al. 2014), a prominent and highly influential professional organization in SPED. A comparison of the literature to CEC standards could offer readers a different perspective from which to evaluate the literature, highlight where the literature falls short in terms of those standards, and promote wider recognition and use of best practices in the treatment of PFD. A comprehensive systematic synthesis of behavioral intervention research may (a) facilitate the dissemination of effective treatments to settings where EBP is mandated (e.g., special education placements in schools), (b) promote levels of caution in using such procedures commensurate with the quality and extent of all of the relevant evidence, and (c) encourage future research on this highly prevalent and understudied problem.

Thus, the purposes of this systematic review were to (a) summarize study and participant characteristics of behavior analytic treatments for FS in children with ASD, (b) evaluate methodological rigor and evidence quality using current standards for EBP in SPED, and (c) discuss treatment recommendations and directions for future research.

Method

Search Procedures

A two-stage multicomponent search and screening process was used to identify articles for inclusion in the review. In stage 1, the first author searched five electronic databases, including PsycINFO, Medline, Education Source, Education Resources Information Center (ERIC), and the Cumulative Index of Nursing and Allied Health Literature (CINAHL) Plus with full text, for relevant peer-reviewed journal articles written in English and published between 1984 and 2014. The following search terms were entered into the database search fields: autis* or PDD-NOS, or "developmental dis*", or asperger*, food or feed*, and selectiv*, not refus* or "medically fragile." The search yielded an initial 106 studies. Twenty-four studies remained after titles and abstracts were scanned to eliminate studies involving only assessment or description of feeding behaviors, literature reviews, and investigations of non-behavioral interventions (e.g., pharmacology studies). Next, we entered the titles of all included studies and studies cited by included studies in Google Scholar and identified 11 additional studies to be considered for possible inclusion in the review. Finally, stage 1 of the search concluded

with co-authors replicating the preceding search procedures, which resulted in the addition of four more studies. These 39 studies (i.e., 24 from electronic databases; 11 from Google Scholar; and 4 from replication by co-authors) were considered in detail using the inclusion criteria described later. This detailed screening identified 28 meeting inclusion criteria. These studies were then coded and summarized by the first author.

Stage 2 of the search process was initiated in January 2016 to identify new studies that might have been published during the time spent coding studies identified in stage 1 of the search. Additionally, the search was expanded to include searching websites of journals that may not have been available through electronic database searches (e.g., *The Behavior Analyst*, *Behavior Analysis in Practice*, and *The Psychological Record*.). Stage 2 of the search generated three additional studies that met inclusion criteria to be coded and summarized.

For all 31 included studies (28 from stage 1 and 3 from stage 2), agreement between the first author and a co-author was reached (100 % consensus) on the inclusion of the study. Any initial disagreements were resolved through discussion and/or consultation with other co-authors.

Inclusion and Exclusion Criteria

Studies were included in the review if they (a) included at least one participant with autistic disorder, ASD, Asperger's disorder, pervasive developmental disorder (PDD), or pervasive developmental disorder not otherwise specified (PDD-NOS); (b) evaluated a behavioral intervention of FS; and (c) used a single-subject design including graphed data to allow for visual analysis of treatment effects and outcomes. A study was excluded if a participant was medically fragile or had a history of total food refusal and/or gastrostomy tube dependence.

Data Extraction and Inter-coder Agreement

A coding guide developed by the first author was used to extract data from studies on (a) participant characteristics, (b) study characteristics, and (c) methodological rigor and quality based on EBP criteria set by the CEC. Any features of studies that contained information relevant to the aims of this review were incorporated into the coding guide to minimize bias associated with making post hoc selections (Cooper 2010). Each coding guide section consisted of a checklist summary template for each study consisting of close-ended (i.e., yes/no questions) and open-ended (space for notes/comments) response options based on written guidelines for data collection and operational definitions. This data extraction process was based on procedures described in Verschuur et al. (2014).

After the first author coded data using the coding guide, individual sections were distributed to co-authors to replicate the data extraction process and facilitate calculation of inter-coder reliability (Cooper 2010). Data were extracted for study characteristics first, followed by participant characteristics and quality, effects, and evidence. Some coding guide items were discussed in advance of data extraction to minimize errors. In addition, to minimize the likelihood of inter-coder variability and error after study characteristics were coded, a precoding coder training was implemented prior to coding participant characteristics and CEC data. Specifically, coders coded studies from the FR literature until inter-coder agreement was 90 % or better for two consecutive practice studies or 80 % or better for three consecutive practice studies.

An overall mean inter-coder agreement was determined individually for each coding guide section by averaging study summary inter-coder agreements. For each study summary in a coding section, the first author counted the total number of agreements on close-ended response options, and divided the total by the number of agreements plus disagreements, and multiplied the quotient by 100 % to yield a percentage agreement for that study. Study summary agreements were then added and divided by the total number of studies, which yielded the mean inter-coder agreement for that coding section. When mean inter-coder agreement was calculated for a given section, the first author compared and discussed the data for close-ended responses with the coders until 100 % agreement was obtained. Mean inter-coder agreement was 96 % (range, 83 to 100 %) for participant characteristics, 85 % (range, 76 to 95 %) for study characteristics, and 92 % (range, 68 to 100 %) for methodological rigor and quality. This process was completed for 28 of the 31 total studies included in the review (i.e., 90 %, not including studies identified in stage 2).

Dependent Variables

Operationalized definitions, including examples and non-examples of dependent variables, were developed and incorporated into the coding guide (Cooper 2010). Dependent variables related to participant and study characteristics consisted of percentages of studies or participants with primary or secondary characteristics. For example, the percentage of studies that used a pretreatment direct assessment was calculated by dividing the total number of studies (31) by the number of studies with that characteristic and converting the quotient to a percentage. The exact type of direct assessment (e.g., functional analysis) was considered a secondary characteristic. The percentage of studies with a given secondary characteristic was calculated by dividing the number of studies with the secondary characteristic by the number of studies with the primary characteristic and converting the quotient to a percentage.

Classification of Feeding Problem Characteristics

To facilitate synthesis, a new classification was created during post hoc data extraction to distinguish between disordered feeding and mealtime challenging behavior. *Disordered feeding* is defined as deficient or developmentally inappropriate oral motor behavior that disrupts chewing and/or swallowing food or liquids, or formation and ingestion of the bolus (e.g., vomiting, packing, gagging, expulsion). *Mealtime challenging behavior* is defined as developmentally inappropriate behavior other than oral motor behavior that prevents or delays the onset, pace, or completion of meals (e.g., hitting, throwing, SIB). Thus, consumption may follow *disordered feeding*, but the two cannot occur simultaneously, while *challenging mealtime behavior* may co-occur with *disordered feeding* and/or consumption.

Classification of Treatment Outcomes

Treatment outcomes of studies were classified as positive, mixed, or negative based on visual analysis of treatment data (e.g., Verschuur et al. 2014). A study was classified as having a positive outcome if improvement in all dependent variables for all participants was observed. A study was classified as having a mixed outcome if improvement in at least some dependent variables or participants was observed. A study was classified as having a negative outcome if no improvements were observed for any participant.

Quality, Effects, and Evidence

The CEC's standards for EBP in SPED were used to assess the quality, effects, and extent of the evidence. First, quality indicators were applied to identify high-quality studies (i.e., high social validity and methodologically rigorous), which were those studies that met all 22 quality indicators relevant to single-subject research. Next, high-quality studies were classified as having positive, mixed/neutral, or negative effects. By considering the effects of high-quality studies only, it was determined if behavior analytic treatment for FS of children with ASD as a whole met criteria to be classified as an evidence-based practice.

Results

Summaries of participant characteristics, study characteristics, and dependent variables for each study are presented in Tables 1, 2, and 3, respectively.

Participant Characteristics

Across the 31 studies included, 45 children between the ages of 2 and 18 years ($M = 79$ months) participated. Twenty-eight children (62 %) were under 7 years of age, the majority of who were male ($n = 37$; 82 %). A secondary diagnosis (e.g., intellectual disability) was reported for nine participants (20 %). Medical information was reported for five participants (11 %). One study (7 %) reported medication use. Nutritional status was reported for one participant (2 %). Bodyweight status was reported for three participants (7 %), two of who were reported to be underweight (67 %) and one was reported to be within normal limits (33 %). No participants were reported to be overweight. The presence or absence of oral motor deficits was reported based on the results of an assessment by an occupational therapist (OT), speech language pathologist (SLP), or other professional for two participants (4 %). A prior treatment history was reported for eight participants (18 %). Seven participants were reported to be receiving services such as ABA, SLP, or OT while the study was ongoing (16 %). One participant was reported to have received behavioral treatment for feeding problems in the past (2 %). Authors reported whether the participant had received ABA in the past to address non-feeding problems for four participants (9 %). No studies reported whether participants had received treatment from an SLP for feeding problems in the past. One participant was reported to have received treatment from an OT to address feeding problems in the past (2 %). For five participants (11 %), the authors reported a hypothesized onset or event believed to have led to the development of FS. For 34 participants (76 %), specific characteristics of the feeding problem were described. For two participants (4 %), the authors explicitly classified the feeding problem as a particular type of selectivity.

Study Characteristics

Pretreatment Assessment of Feeding and Inappropriate Mealtime Behavior All studies included an assessment of feeding or inappropriate mealtime behavior prior to initiating experimental conditions. Thirty studies (97 %) used indirect assessment methods. Twenty-nine of those studies (97 %) assessed feeding, 21 assessed inappropriate mealtime behavior (70 %), and 20 assessed feeding and inappropriate mealtime behavior (67 %). Ten studies (32 %) used direct assessment methods. Eight studies (80 %) that used direct assessment methods assessed feeding, five assessed inappropriate mealtime behavior (50 %), and three assessed both feeding and inappropriate mealtime behaviors (30 %). Eleven studies (35 %) used a validated stimulus preference assessment to identify preferred or non-preferred stimuli, and paired stimulus preference assessments were most common ($n = 9$; 82 %). Twenty-six studies (84 %) described food the participant

Table 1 Summary of participant characteristics

Study	Sex	Age (months)	SD	Medical	Medication	Nutritional status	BW	OM	PTRMT	OTMT	Selectivity onset	Selectivity type
Ahearn 2003	M	168	ID	N	N	N	N	N	N	N	N	N
Allison et al. 2012	M	36	N	N	N	N	N	N	N	N	N	N
Anderson and McMillan 2001	M	50	ID	N	N	N	N	N	N	N	N	N
Barahona et al. 2013[a]	F	216	ID	N	N	Y	Und	N	Y	N	Y	Y
Buckley and Newchok 2005	F	108	N	N	N	N	N	None	N	N	N	N
Ewry and Fryling 2015	M	180	N	N	N	N	N	N	N	Y	N	N
Fu et al. 2015	M	120	N	N	N	N	N	N	Y	N	N	N
Gentry and Luiselli 2008	M	48	N	N	N	N	N	N	N	Y	N	N
Kern and Marder 1996	M	84	N	N	N	N	N	N	N	N	N	N
Koegel et al. 2012	M	83	N	N	N	N	N	N	N	N	N	N
	M	76	N	N	N	N	N	N	Y	Y	N	N
	M	92	N	N	N	N	N	N	N	N	N	N
Levin and Carr 2001	M	72	ID	N	N	N	N	N	N	N	N	N
	M	60	ID	N	N	N	N	N	N	N	N	N
	M	84	ID	N	N	N	N	N	N	N	N	N
	M	78	ID	N	N	N	N	N	N	N	N	N
Luiselli et al. 2005	F	48	N	N	N	N	N	N	N	N	N	N
McDowell et al. 2007	F	48	N	N	N	N	N	N	N	N	N	N
Meier et al. 2012	F	36	N	N	N	N	N	N	N	Y	N	N
Najdowski et al. 2012	M	36	N	N	N	N	N	N	Y	Y	N	Y
Najdowski et al. 2003	M	60	N	N	N	N	N	N	N	N	N	N
Najdowski 2010	F	24	N	N	N	N	N	N	N	N	N	N
	M	48	N	N	N	N	N	N	N	N	N	N
Patel et al. 2007	M	48	N	N	N	N	N	N	N	N	N	N
Penrod et al. 2012	M	108	N	N	N	N	N	N	N	N	N	N
	M	120	N	N	N	N	N	N	N	N	N	N
Penrod et al. 2010	M	48	N	N	N	N	N	N	N	N	N	N
	M	48	N	N	N	N	N	N	N	N	N	N
	M	36	N	N	N	N	N	N	N	N	N	N
Piazza et al. 2002	M	120	N	N	Y	N	N	N	N	N	Y	N
	F	132	ID	N	Y	N	N	N	N	N	N	N
	M	96	ID, AD-HD	N	None	N	N	N	N	N	N	N
Pizzo et al. 2012	M	192	N	Y	N	N	WNL	N	N	N	N	N
Seiverling et al. 2012a	M	48	N	N	N	N	N	N	Y	N	N	N
	M	96	N	N	N	N	N	N	Y	N	N	N
	M	60	N	N	N	N	N	N	Y	N	N	N
Seiverling et al. 2012b	M	36	N	Y	N	N	N	N	N	N	N	N
Sira and Fryling 2012	M	108	N	N	N	N	N	N	N	N	N	N
Tanner and Andreone 2015	M	42	N	N	N	N	N	Y	Y	Y	N	N
Tarbox et al. 2010	M	36	N	Y	N	N	Und	N	N	N	N	N
VanDalen and Penrod 2010	M	60	N	N	N	N	N	N	N	N	N	N
	M	48	N	N	N	N	N	N	N	N	N	N
Valdimarsdottir et al. 2010	M	60	N	N	N	N	N	N	N	N	Y	N
Wood et al. 2009	M	65	N	Y	N	N	N	N	Y	Y	N	N

Data in columns (i.e., *Y* yes, *N* no) indicate whether the study characteristic was reported by the authors

A active, *ADHD* attention deficit hyperactivity disorder, *BW* body weight, *ID* intellectual disability, *N* no, *OM* oral motor deficits, *OTMT* ongoing treatment, *P* passive, *PTRMT* prior treatment, *SD* secondary diagnosis, *Y* yes, *U* unable to determine, *Und* underweight, *WNL* within normal limits

[a] Same participant as Knox et al. 2012

typically consumed. Twelve studies (39 %) described food the participant typically refused. The number of foods reported to comprise participants' diets ranged between 1 (VanDalen and Penrod 2010) and 17 (Seiverling et al. 2012b) foods.

Table 2 Summary of study characteristics

Study	Pretreatment assessment I: indirect/D: direct	Treatment components	Stimuli/feeder	Outcome, gen, main	Measurement
Ahearn 2003	I: INT, FD/D: none	SP	SFU, MFU/ETr	P	Ind/target
Allison et al. 2012	I: none/D: FA, FD, CB	EE, CP, RP, TC	SFU/ETr	P	Ind/target Direct// indirect/CB
Anderson and McMillan 2001	I: INT, FD, CB/D: none	NRS, DRA/F, CP	SFU/CTr	P	Ind/target, Ind/CB
Barahona et al. 2013	I: INT, RR, FD/D: none	SF, CP, TS	MFPB/TCTrGe	P	Ind/target
Buckley and Newchok 2005	I: INT, FD, CB/D: none	SP, CP, RC, DRA/NF	SFU, MFU/ETr	P	Ind/CB
Ewry and Fryling 2015	I: INT, FD, CB/D: DES, ST, FA, FD	HPS, CP,	SFU/ETrGe, MTr	P	Ind/target
Fu et al. 2015	I: INT, FD/D: none	NRS, DRA/F, CP, DRA/NF, MD	MFPB/ETr, MGe	P	Ind/target, Ind/CB
Gentry and Luiselli 2008	I: INT, RR, FD/D: none	SP, CP, DRA/NF, DBF, RL	SFPB, MFPB/MTr	P	Dir/target
Kern and Marder 1996	I: INT, FD, CB/D: none	EE, SP, DRA/F, RP	SFU, MFU/ETr, MTr	P	Ind/target
Knox et al. 2012	I: INT, FD/D: none	SF, CP, TS, DRA/NF, RL, PP	MFPB/TCTrGe	P, M	Ind/target
Koegel et al. 2012	I: INT, FD, CB/D: DES, FD, CB	DRA/F, CP, DBF, RL, AC	NR/CTrGe	P, S, M	Ind/target
Levin and Carr 2001	I: INT, RR, FD/D: FA, CB	DRA/F, SF, EO	NR/ETr	P	Ind/target, Dir/CB
Luiselli et al. 2005	I: INT, FD/D: none	SF, CP, PP	C/TCTr	P	Ind/target
McDowell et al. 2007	I: INT, RS, CB/D: DES, FD, CB	CP, DRA/NF, RL, AC	SFPB/ETrGe	P, M	Dir/target, Dir/CB
Meier et al. 2012	I: INT, FD, CB/D: ST, FD	HP, CP	SF/U	P, M	Ind/target
Najdowski et al. 2012	I: INT, FD, CB/D: none	SP, SF, CP, DRA/NF	SF/U, MF/U, MF/P/B	P	Ind/target, Ind/CB
Najdowski et al. 2003	I: INT, FD/D: FA, CB	EE, DRA/F, CP, DBF,	SF/P/B, MF/P/B	P, S, M	Dir/target
Najdowski et al. 2010	I: INT, FD, CB/D: none	NRS, DRA/F, SF, CP, DBF, RL	SF/U, SF/P/B, MF/P/B	P, S, M	Ind/target
Patel et al. 2007	I: INT, FD/D: none	HPS, CP	SF/U	P	Ind/target
Penrod et al. 2012	I: INT, FD, CB/D: none	DRA/F, DBF, HPS, EO, CP	SF/P/B	P, S, M	Ind/target
Penrod et al. 2010	I: INT, FD, CB/D: none	NRS, DRA/F, CP, RP, DBF	SF/U	P, S, M	Ind/target, Dir/target Ind/CB
Piazza et al. 2002	I: INT, FD, CB/D: none	SP, DRA/F, CP, MP, RP, RL	SF/U, SF/P/B, MF/U	P	Ind/target
Pizzo et al. 2012	I: INT, Q, FD, CB/D: none	DRA/F, CP, RL	MF/P/B	Mix, S, M	Ind/target, Dir/CB
Seiverling et al. 2012a	I: INT, Q, FD, CB/D: none	EE, CP, DNRA	SFU	P	Ind/target, Ind/CB
Seiverling et al. 2012b	I: INT, Q, FD, CB/D: none	EE, DRA/F, SF, CP, RP, CC	MF/P/B	P	Ind/target, Dir/target Ind/CB
Sira and Fryling 2012	I: INT, FD, CB/D: none	DRA/F, CP, TS, DRA/NF, RL, MD	SF/U	P	Ind/target, Ind/CB
Tanner and Andreone 2015	I: INT, Q, FD, CB/D: DES, FD	CP, TS, DRA/NF	MF/P/B	P, S, M	Ind/target, Dir/CB
Tarbox et al. 2010	I: INT, FD, CB/D: none	EE, RL	MF/P/B	P, M	Ind/target
Valdimarsdottir et al. 2010	I: INT, FD, CB/D: DES, ST, FD	NRS, CP, TS, DRA/F, DBF, RL	SF/U, MF/P/B	P, S, M	Dir/target
VanDalen and Penrod 2010	I: INT, FD, CB/D: none	NRS, SP, DRA/F, EO, CP, DBF	SF/U, MF/U	P, S	Ind/target
Wood et al. 2009	I: INT, RR, FD, CB/D: ST, FD	CP	SF/P/B	P	Ind/target, Dir/CB

Pretreatment assessment: CB challenging behavior, *DES* descriptive, *FA* functional analysis, *FD* feeding, *INT* interview, *Q* questionnaire, *RR* record review, *RS* rating scale, *ST* structured. *Treatment components*: *AC* antecedent choice, *CP* contingent praise, *DBF* demand or bite fading, *DNRA* differential negative reinforcement of alternative behavior, *DRA/F* differential reinforcement of feeding responses with high preferred food, *DRA/NF* differential reinforcement of feeding responses with non-food items, *EE* escape extinction, *EO* presession establishing operation, *HPS* high-probability sequence, *MP* mandibular prompt, *MD* modeling, *NRS* non-removal of the spoon, *PP* paced prompting, *RP* re-presentation, *RC* response cost, *RL* rules, *SP* simultaneous presentation, *SF* stimulus fading, *TC* time-contingent presentation of preferred stimuli, *TS* token system. *Stimuli/feeder*: *CTr* caregiver ran treatment, *CTrGe* caregiver ran treatment and generalization, *C* cup, *ETr* experimenter ran treatment, *ETrGe* experimenter ran treatment and generalization, *MGe* mother ran generalization, *MTr* mother ran treatment, *MF/P/B* multiple foods with plate or bowl, *MF/U* multiple foods with utensil, *NR* not reported, *SF/P/B* single food with plate or bowl, *SF/U* single food with utensil, *TCTrGe* teacher ran treatment and generalization, *TCTr* teacher ran treatment. *Outcome*, *generalization*, *maintenance*: *M* response maintenance, *P* positive outcome, *S* stimulus generalization. *Measurement*: *Dir/CB* direct measurement of challenging behavior, *Dir/target* Direct measurement of target feeding response, *Ind/CB* indirect measurement of challenging behavior, *Ind/CB* indirect measurement of challenging behavior, *Ind/target* Indirect measurement of target feeding response

Table 3 Summary of dependent variables pertaining to child behavior

Study	Disordered feeding	Mealtime challenging behavior	Other	Study	Disordered feeding	Mealtime challenging behavior	Other
Ahearn 2003	B	None		Najdowski 2003	B	None	
Allison et al. 2012	B, C	NV, BDH		Najdowski 2010	B, C	None	
Anderson and McMillan 2001	Ex, B	BDH, SIB		Patel et al. 2007	B	None	
Barahona et al. 2013	C	None		Penrod et al. 2012	B	None	Comp
Buckley and Newchok 2005	P	None		Penrod et al. 2010	G, V, Ex, MC, C	NV, B, Th	
Ewry and Fryling 2015	A	None		Piazza et al. 2002	B	None	
Fu et al. 2015	B, Rf	NV, BDH, Th, Agg		Pizzo et al. 2012	G,V, Ex, SS,B	BDH, Th, SIB, Agg, MDT	
Gentry and Luiselli 2008	B	None		Seiverling 2012a	G, Ex, B	NV, BDH, Th, MDT	
Kern and Marder 1996	B	None		Seiverling 2012b	B	NV, BDH, SIB, Agg,	
Knox et al. 2012	C	None		Sira and Fryling 2012	V, Ex, B	NV, BDH, Th	
Koegel et al. 2012	None	None	SR, Com, LoA	Tanner	G, NV	None	LoA
Levin and Carr 2001	C	Th, SIB, Agg		Tarbox et al. 2010	C	None	
Luiselli et al. 2005	C	None		Valdimarsdottir et al. 2010	B	None	
McDowell et al. 2007	G, V, Ex, B	NV, BDH, Th, E, SIB, Agg	SR	VanDalen and Penrod 2010	Sw, B, C	None	
Meier et al. 2012	B	None		Wood et al. 2009	G, P, B	El	
Najdowski et al. 2012	G, Ex, MC, B,	NV, Th,					

When the behavior is desirable, such as "swallows" or "bites of food consumed," low levels of the behavior can be considered disordered. Due to space constraints, only the first author is listed for each study

Disordered feeding: A acceptance, defined as past the plane of the lips, *B* bites of food consumed, *C* consumption, referring to the latency or amount of food consumed, *CRD* chewing, rumination, drool, *Ex* food expulsion, *G* gagging, *MC* mouth Clean, *P* pace of consumption, *P* packing, *SS* sucking or spitting, *S* swallows, *V* vomiting. *Mealtime challenging behavior*: *Agg* aggression towards others, *BDH* batting, disruption, head turning, *El* elopement or out-of-seat, *MDT* miscellaneous disruptive topographies, *NV* negative vocalizations, *Rf* refusal to open mouth, *SIB* self-injurious behavior, *Th* throwing food or mealtime stimuli. *Other*: *Com* comments, *Comp* compliance with one-step instructions related to mealtime stimuli, *LoA* level of acceptance, according to a scale of hierarchically organized target responses, *SR* spontaneous requests for new and/or non-preferred foods

Mealtime Settings, Stimulus Arrangements, and Feeders All (100 %) studies described the mealtime setting to some extent. Settings included homes, schools, and clinic settings. Twenty-nine studies (94 %) described the mealtime stimulus arrangement, such as whether participants were presented with one or more foods on a utensil and/or plate. The majority of studies ($n = 17$; 59 %) presented the participant with a single food on a utensil. All studies identified the feeder. A feeder was an experimenter or therapist in 19 studies (61 %) and the participant's teacher or classroom aide in four studies (13 %). For studies in which a parent was the feeder, which parent (i.e., mother, father) often was not specified. The feeder was specified as the participant's mother in 11 studies (35 %) and the participant's father (and mother) in 1 study (3 %). Seven studies (23 %) utilized a free-operant arrangement (i.e., participants were allowed to eat at a pace not constrained by the rate of bite presentation), and 25 studies (81 %) utilized a discriminated or restricted operant arrangement (i.e., the pace of the meal was constrained by the rate of bite presentation).

Treatment Components and Procedural Details Ten studies (32 %) reported procedural fidelity. A predetermined number of bites ($M = 14$, range 4, 40) were presented each session in 20 studies (65 %). One food was targeted per session in 10 studies (32 %) and multiple foods ($M = 4$, range 3, 8) were targeted per session for 23 studies (74 %). Seven studies (23 %) incorporated visual stimuli to control responding during meals.

A total of 22 different treatment components were utilized. When contingent praise was viewed as a treatment component based on the rationale that it could be reasonably expected to enter into functional relations with controlling mealtime stimuli, 27 studies (96 %) evaluated a treatment consisting of two or more components. One study (4 %) evaluated a treatment component (simultaneous presentation) in isolation. Differential reinforcements of target feeding behavior with high preferred food ($n = 14$, 45 %), escape extinction (EE) including non-removal of the spoon ($n = 12$, 39 %), and contingent praise ($n = 27$, 87 %) were replicated more than any

other treatment components, followed by rules ($n = 10$; 32 %), simultaneous presentation ($n = 7$; 23 %), stimulus fading ($n = 7$; 23 %), demand fading ($n = 7$; 23 %), and differential reinforcement of feeding responses with non-food reinforcers ($n = 9$; 29 %).

Dependent Variables Ten studies (32 %) measured adult behavior as a dependent variable, and this was typically done during assessment of procedural fidelity. All studies measured child behavior as a dependent variable either directly or indirectly. Approximately 29 different dependent variables (i.e., distinguished topographically or in terms of dimensional or dimensionless quantities) were measured. Although a distinction between disordered feeding and challenging mealtime behavior was not made in any of the reviewed studies, a summary of child behaviors measured and classified as disordered feeding or challenging mealtime behavior is displayed in Table 3. The most frequently measured child behaviors were bites of food consumed ($n = 21$; 68 %), other aspects of consumption ($n = 9$; 29 %; e.g., latency or amount in grams consumed), batting at the spoon and/or head turning ($n = 9$; 29 %), negative vocalizations ($n = 9$; 29 %), throwing food or other mealtime stimuli ($n = 8$; 26 %), food expulsion ($n = 7$; 23 %), and gagging ($n = 7$; 23 %). Eight ($n = 9$; 29 %) studies included a clean mouth as part of the operational definition of the target response. Fourteen studies (45 %) measured mealtime challenging behavior either during a functional analysis or across treatment; however, only eight (26 %) graphed data collected on mealtime challenging behavior in addition to data collected on the target feeding behavior (Allison et al. 2012; Anderson and McMillan 2001; Levin and Carr 2001; McDowell et al. 2007; Pizzo et al. 2012; Seiverling et al. 2012a, b; Wood et al. 2009). All studies assessed inter-observer agreement. Seven studies (23 %) utilized a questionnaire to assess the social validity of the treatment, and three of these studies (10 %) included EE, including non-removal of the spoon (NRS) (Najdowski et al. 2010; Penrod et al. 2010; Seiverling et al. 2012a).

Measurement Procedures Thirty studies (97 %) measured feeding responses targeted for increase (Buckley and Newchok 2005, measured packing, rather than a feeding response targeted for increase). Six studies (19 %) used direct measures of the target feeding behavior. Twenty-six studies (84 %) used indirect or derivative measures of the target feeding behavior. Fourteen studies (45 %) measured inappropriate mealtime behavior. Of those 14 studies, 6 used a direct measure of inappropriate mealtime behavior and 9 used an indirect measure of inappropriate mealtime behavior.

Generalization, Maintenance, and Treatment Outcomes The overall outcome as reported by the authors of the included studies met criteria for classification as positive for 30 studies (97 %) and mixed for 1 study (3 %). Nine studies (29 %) assessed the target feeding or inappropriate challenging behavior during a stimulus generalization phase defined by three or more consecutive data points. Twelve studies (39 %) assessed the target feeding or inappropriate mealtime behavior during a response maintenance phase defined by three or more consecutive data points.

Quality, Effects, and Evidence

The results of the assessment of quality, effects, and evidence based on CEC standards for EBP are summarized in Fig. 1. Four studies (13 %) met CEC standards for high-quality studies (Barahona et al. 2013; Penrod et al. 2010, 2012; Wood et al. 2009). One of those four studies met criteria for classification as having positive effects (Penrod et al. 2010). The reporting of procedural fidelity was the quality indicator satisfied by the

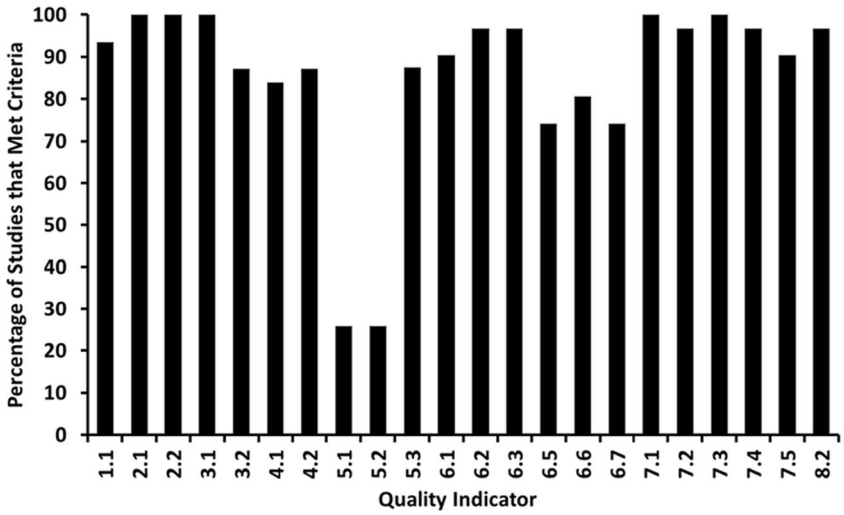

Fig. 1 Summary of data collected on methodological quality, expressed as percentages of the total studies for which data on each indicator were extracted, using the council for exceptional children's indicators of high-quality studies. Data were collected only using indicators relevant to single-subject designs studies; therefore, no data were collected on indicators 6.4, 6.8, 6.9, 7.6, 8.1, and 8.3

fewest studies (quality indicators 5.1 and 5.2; 26 % of studies reported procedural fidelity).

Discussion

When treatment outcomes were assessed using visual analysis alone, the results suggested that behavior analytic treatments for children with ASD and FS between the ages of 2 and 18 years have positive effects on disordered feeding and inappropriate mealtime behavior. In contrast, when studies were compared to the CEC standards for treatment effects, requiring demonstration of a functional relation for at least three participants in a single study, only one high-quality study met criteria for classification as having positive effects (Penrod et al. 2010). This finding warrants future research on the relative validity of criteria for classifying the effects of treatments for the purpose of identifying EBP. Overall, the results also provide some evidence that improvements in feeding problems maintain over time and generalize to other foods.

Overall, the results of this systematic synthesis indicate that medical and health information were rarely reported. The lack of medical and health information reported in the included studies may be an artifact of excluding participants considered medically fragile (i.e., those for whom medical information would be the most relevant) in favor of maintaining focus on behavioral as opposed to medical intervention. However, underreporting health and medical participant characteristics conflicts with experts' recommendations that prior to behavior analytic treatment, biomedical explanations for the feeding problem and/or oral motor deficits should be ruled out (e.g., Kedesdy and Budd 1998; Manikam and Perman 2000; Piazza 2008; Piazza and Roane 2009; Rommel et al. 2003; Rudolph and Thompson 2002). It is unclear if such explanations were ruled out but not reported or if these factors were not considered in the majority of studies included in this review. More detailed descriptions of medical and health characteristics of participants in future studies could help clarify the type of feeding problem to which a treatment is being applied and may assist practitioners in selecting an appropriate treatment for their client.

Researchers have emphasized the important relationship between nutrition and development (e.g., Volkert and Vaz 2010), and evidence suggests that children with ASD and feeding problems have nutritional deficiencies relative to typically developing children (e.g., Sharp et al. 2013). However, the results of the current synthesis yielded no information with respect to whether children who have received treatment had nutritional deficiencies or improved their nutrition status following treatment. Therefore, future studies should consider assessing the potential effects of behavioral treatments on nutrition and providing information about the severity of the feeding problem in the form of participants' nutritional status. Further, the majority of studies did not report participants' prior treatment history. More information on responsiveness to prior feeding and non-feeding-related interventions, including specific skills taught in prior interventions, could be useful for identification of effective treatment components.

FS and FR, and subtypes such as selectivity by texture or selectivity by type, may require different treatment components. Characteristics of the feeding problem were not described for 24 % of participants, and the majority of studies did not report an estimate of the onset of FS or a hypothesized triggering event or explicitly classify the nature of the participant's selectivity (e.g., texture, type, brand, temperature). To assist practitioners in selecting treatment components best suited for the characteristics of the feeding problem they aim to treat, future studies could provide a more thorough description of the feeding problem being targeted in intervention.

A distinct advantage of the behavior analytic approach to PFD is the use of FBA to directly inform treatment in the context where the problem occurs (e.g., Piazza et al. 2015). However, the results of this synthesis suggest that all but one study used indirect assessment methods (e.g., interview) while less than half of studies used direct assessment of the feeding problem (e.g., descriptive assessment of mealtime behavior based on direct observation), not including stimulus preference assessments. Additionally, when participants' acceptance of foods was assessed, less than half of the studies described characteristics of foods participants accepted and refused. The descriptions were largely qualitative (i.e., simply reported if the child accepted or rejected a given food or food group), suggesting that designation of most participants as selective was based on caregiver report rather than direct observation. The finding that a critical feature of a behavior analytic approach was largely omitted from most of the reviewed studies suggests a future avenue of research evaluating direct assessment methods and development of standardized direct pretreatment assessments. Specifically, future research might advance the selection of appropriate treatment components by utilizing more systematic descriptive and structured assessments to characterize specific problems with feeding (e.g., packing, selective by texture) or mealtime challenging behavior prior to treatment.

The data on mealtime settings, stimulus arrangements, and feeders suggest that behavioral treatments of FS for children with ASD are effective in schools, homes, and clinics, when implemented by experimenters, therapists, school staff, and caregivers. Most studies used a discriminated operant arrangement (i.e., discrete trial-based) and arranged the meal such that the participant was presented with a spoon containing a single target food. Future research could examine (a) whether stakeholders prefer treatment outcomes consisting of the child eating independently in a free-operant arrangement over those that require more effort on the adult's part and/or continuation

of contrived features of the mealtime arrangement, and (b) procedures that transition feeding from discrete trial to free-operant arrangements.

Mealtime challenging behavior is a defining feature of PFD and may maintain feeding problems by producing socially mediated negative reinforcement in the form of escape or avoidance of non-preferred foods and/or positive reinforcement in the form of higher-quality attention from feeders or access to higher preferred foods (Piazza 2008; Piazza and Roane 2009; Piazza et al. 2015). Accordingly, it is important to assess the evidence that behavior analytic treatments improve this feature of FS for children with ASD. Although studies that graphed mealtime challenging behavior demonstrated reductions, the behavior continued to occur to some extent in all phases with the exception of one study (McDowell et al. 2007). Therefore, when the distinction between disordered feeding and mealtime challenging behavior is considered, behavior analytic treatments for FS appear to produce relatively better improvements in disordered feeding than in mealtime challenging behavior. Future research could utilize the distinction between disordered feeding and mealtime challenging behavior in an attempt to (a) provide finer-grained analyses of treatment components that improve specific feeding problems, (b) identify maximally effective and minimally intrusive treatments, and (c) give more consideration to the relative contributions of precise behavioral processes (e.g., respondent and operant) underlying feeding problems. The resulting lack of evidence for adequate reduction of mealtime challenging behavior suggests that there is also a need for research on behavioral interventions that replace mealtime challenging behavior with socially acceptable forms of behavior in the context of treating FS, which may include targeting mealtime social and communication skills.

Most studies (86 %) combined two or more treatment components, including praise, making it difficult to conclude with certainty in many cases precisely which treatment components were responsible for changes in target behaviors, suggesting that more research on individual treatment components, sequential analyses, and component analyses are warranted. Two general best practice approaches to selecting behavioral treatment components are (a) ruling out the effectiveness of least intrusive procedures (e.g., response-independent delivery of preferred stimuli) before resorting to more intrusive procedures (e.g., EE) and (b) ruling out the effectiveness of the most empirically supported treatment components (i.e., EBP) regardless of their intrusiveness before resorting to less empirically supported treatments. An alternative approach is to start with the least intrusive among the most empirically supported treatment components, and the results of this synthesis allow for recommendations for practitioners based on the latter.

The finding that differential reinforcement, EE (including NRS), contingent attention, simultaneous presentation, stimulus fading, and demand fading were most frequently replicated warrants recommending that practitioners consider a three-tiered approach in which these treatment components comprise the first tier and are applied first, either sequentially or in combination before utilizing treatment components from lower tiers, while also considering that additional treatment components and/or functional analysis may be needed to reduce levels of mealtime challenging behavior. Other treatment components that may comprise a second tier, based on moderate empirical support pending further evaluation and replication, are the high-probability instructional sequence, presession establishing operations, token reinforcers, representation, paced prompting, and antecedent choice. Treatment components that have not been replicated, but which are tied to fundamental principles of behavior and therefore may comprise a least empirically supported but potentially effective third tier, are physical prompting at the mandibular joint, response-independent access to preferred stimuli, contingent choice, response cost, differential negative reinforcement of alternative behavior, and modeling (which was replicated once).

The frequent replication of the effectiveness of EE (including use in combination with differential reinforcement) suggests that EE may be a critical component of an effective ABA-based treatment for children with FS and ASD and therefore should be prioritized in treatment efforts across tiers. Yet, only three studies assessed the social validity of EE. If stakeholders find the short-term effects of EE aversive (e.g., escalated mealtime challenging behavior and/or perception of treatment as "force feeding") and avoid the use of the procedure, thereby failing to contact reinforcement produced by successful treatment, use of this critical treatment component may be hindered. Thus, additional research on social validity that may help to identify variables that influence stakeholders' implementation of EE is warranted.

Stakeholders often find themselves in a position in which they need to make informed treatment decisions about how to address feeding problems in a manner that supports the child's best interest, by considering the best scientific evidence and coordinating treatments between home and school settings. Dissemination of EBP in behavioral treatments of FS to special educators in particular is important because feeding problems and associated nutritional consequences may have a negative impact (e.g., more stress, poor nutrition, low energy, dependence on others for self-care) on a child's responsiveness to academic instruction (Lefton-Greif, and Arvedson 2008; McKirdy et al. 2008) and their association with mealtime challenging behavior may warrant implementation of a behavior intervention plan at school.

When the CEC standards were applied, behavior analytic treatments of FS for children with ASD were classified as having insufficient evidence to be designated as an EBP. The lack of data on treatment integrity was the most frequently

omitted quality indicator. Rigorous monitoring and assessment of treatment integrity can minimize the likelihood of type 1 and type 2 errors and threats to internal validity such as experimenter bias and treatment drift (Cooper et al. 2007). And beyond the scientific rationale for assessing treatment integrity, economic and political factors such as recommendations or requirements of professional organizations, task forces, and major sources of funding including the National Institutes of Health (NIH) provide additional rationale for doing so (McIntyre et al. 2007). Thus, future research should monitor and assess treatment integrity. Lastly, failing to meet a set of standards for EBP does not negate the collective evidence for the effectiveness of this treatment approach. The CEC standards (Cook et al. 2014) are only one of several different sets of EBP standards in SPED proposed by different organizations (e.g., Gersten et al. 2005; Horner et al. 2005; Wong et al. 2014). We applied the CEC standards because the CEC is widely recognized as a leader in evidential standards in the field of special education. Application of a different set of EBP criteria, for example, one which takes into account decision-making processes integrating the best available evidence, clinical expertise, and client values and context (Slocum et al. 2014), might suggest a different conclusion. Although aspects of the evidence rendered from the current synthesis did not meet CEC criteria for EBP, the majority of the reviewed studies demonstrated positive outcomes, thereby highlighting the promise of behavioral intervention for FS of children with ASD as an emerging EBP in special education pending additional studies that meet EBP standards.

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