Research Report

Effects of Lag Schedules of Reinforcement on Variable Manding in Preschoolers With Disabilities

Journal of Early Intervention
2023, Vol. 45(4) 370–390

DOI: 10.1177/10538151221137796
journals.sagepub.com/home/jei
SAGE

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Abstract

Functional communication training (FCT) is an evidence-based intervention that while often effective, can result in rote responding, reduced generalizability of target behavior, and resurgence of challenging behavior (CB) during treatment lapses. Lag schedules of reinforcement have been successfully used to address these concerns. We applied an increasing lag schedule within FCT to increase the variability and persistence of appropriate responding of four young children with disabilities while maintaining low levels of CB during treatment. Our results provide evidence regarding the effects of lag reinforcement on appropriate communication and CB during treatment and lapses in treatment with children with autism and Down syndrome. This research provides a new perspective to the field given, we assessed functional communication during baseline, assessed generalization to new contexts, and assessed social validity via both masked raters and participants' mothers. We discuss the implications of this work and provide future directions for researcher and practice.

Keywords

functional communication training, lag reinforcement, early childhood, challenging behavior, autism, Down syndrome

Young children often engage in challenging behavior (CB) as they are learning to be social and communicate across contexts and people. Certain forms of CB are expected in all children and are likely to lessen as children learn social, emotional, and communication skills. However, some CB needs to be specifically addressed when it (a) presents in more severe topographies, such as aggression, property destruction, elopement, or self-injurious behavior (SIB); (b) occurs with greater or more consistent frequency or intensity; or (c) persists past expected developmental milestones. Research indicates that children with intellectual or developmental disabilities are likely to engage in persistent and severe CB than their typically developing peers (Cooper et al.,

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2014). A recent literature review found that between 48% and 60% of children with intellectual disabilities and 90% of children with autism spectrum disorder (ASD) were reported to engage in CB (Simó-Pinatella et al., 2019).

The prevalence of CB in children with disabilities is important, given that CB left unaddressed during early childhood is associated with later social maladjustment, parental stress, illegal behavior, and potential school failure (Dunlap et al., 2006; Durand & Moskowitz, 2015; Jones et al., 2015; Powell et al., 2006). Preschool children with CB are also expelled at high rates, leading to lost instructional time and missed opportunities for socialization with peers (Gilliam, 2005). To further exacerbate the issue, teachers report a lack of training to address CB (Reinke et al., 2011; Snell et al., 2012; Vinh et al., 2016). Given these potentially detrimental consequences, it is imperative that professionals and caregivers have effective tools to reduce rates of CB.

The complex communication needs of many children with disabilities, including those with autism and Down syndrome, likely contribute to increased rates of CB (Light & Drager, 2007). Functional communication training (FCT; Carr & Durand, 1985) is an evidence-based intervention often used with individuals with complex communication needs and a history of persistent CB (Steinbrenner et al., 2020). Traditionally in FCT, the function of the CB is determined via a functional behavior assessment (FBA) or functional analysis (FA), after which individuals are taught to emit a single communicative request—known as a "mand"—to replace CB (by serving the same function). Thus, CB that previously resulted in reinforcement is no longer effective, with reinforcement delivered contingent on appropriate mands instead.

Although this method can be extremely effective in replacing CB with appropriate communication (Durand & Moskowitz, 2015), it has notable limitations. Specifically, (a) reinforcement of a single mand can result in rote responding (Rodriguez & Thompson, 2015), and thus a reduced ability to repair communication breakdowns (Keen, 2003); (b) a single mand or mand topography might not be appropriate for all communication partners or settings, reducing generalizability (Ringdahl & St. Peter, 2017); and (c) if reinforcement of the replacement mand is not provided for every mand emitted it often fails to persist while CB resurges (Ringdahl & St. Peter, 2017; Wacker et al., 2011), impacting maintenance (Schieltz et al., 2017). These potential limitations are important, given treatment lapses are common across typical and natural settings (Ringdahl & St. Peter, 2017). Taken together, these factors might result in less robust FCT outcomes and resurgence of CB (Chezan et al., 2017).

Considerable research suggests reinforcing variability might address these limitations in applied contexts (Rodriguez & Thompson, 2015; Silbaugh et al., 2021; Wolfe et al., 2014). One notably effective method to promote variable responding is lag schedules of reinforcement (i.e., those in which reinforcement is contingent on a response differing from a predetermined number of previous responses; Page & Neuringer, 1985). Lag schedules of reinforcement have been used to increase variability across verbal and nonverbal behaviors, such as food selectivity (Silbaugh & Falcomata, 2016), responses to questions (i.e., intraverbals; Lee et al., 2002; O'Neill & Rehfeldt, 2014), phonemes (Koehler-Platten et al., 2013), and labeling (i.e., tacts; Heldt & Schlinger, 2012). They have the potential to enhance FCT by increasing the rate of variable manding, which might act to maintain appropriate behavior (such as functional communication) and prevent or postpone recurrence of undesired behavior (e.g., CB) following lapses in treatment (Rodriguez & Thompson, 2015; Wolfe et al., 2014). For example, if the vocal mand "my turn" is taught to a child to replace toy snatching, teaching (and requiring) that child to instead sign "my turn" or vocally mand "turn please" may result in increased persistence of appropriate requests for a toy—rather than a return to toy snatching—if the first communication response is not honored.

As seen in Wolfe et al.'s (2014) review on variability and Silbaugh et al.'s (2021) review on lag reinforcement, researchers have applied lag schedules in a variety of ways. For example, many researchers have required that a response differ only from the previous response, regardless of overall response diversity; this is referred to as "Lag 1" (vs. Lag 0,in which any appropriate response will earn reinforcement). Others have required participants demonstrate increased diversity in responding, by reinforcing only those that differ from the two (Lag 2), three (Lag 3), or more preceding responses. In addition to a Lag 1 schedule of reinforcement, Leeand and Sturmey (2014) and Argott (2010) programmed additional variability requirements, such that responses would only result in reinforcement if they differed from those of previous sessions in some way. These additional requirements may prevent higher-order stereotypy (e.g., routine-oriented behavior, compulsions; Turner, 1999) in responding—that is, rotating through responses sequentially until reinforcement is earned—which has been noted as a potential effect of lag reinforcement (Wolfe et al., 2014).

Several applied studies have been conducted in which lag reinforcement was used in the context of FCT (henceforth referred to as FCT/Lag). Following an FA and assessment of participants' functional mand modalities (e.g., vocal, sign, picture communication), Adami et al. (2017) analyzed the rate of total mands, variable mands, and CB of two minimally vocal participants with ASD across two reinforcement schedules (i.e., Lags 0 and 1). The authors found little deviation in the rate of total mands (which were consistently high) or the rate of CB (which was consistently below baseline levels) between the FCT/Lag 0 and FCT/Lag 1 schedules. However, the variability of mands was greater in the Lag 1 schedule, which demonstrated that individuals who typically display rote responding may use diverse mands to obtain reinforcement when required to do so.

Following this, Falcomata et al. (2018) used a withdrawal design, sequentially increasing the lag requirement from Lags 0 to 5, to analyze the effects on the mand variability and CB of two elementary-aged children with ASD and limited vocal ability. Results indicated that FCT/Lags 1 to 5 resulted in a greater number of mands and greater variability of mands than FCT/Lag 0 for both participants, while CB remained at or near zero. These results provided preliminary support for the effectiveness of lag schedules in increasing mand variability while mitigating recurrence of CB during intervention.

Silbaugh and colleagues continued this research with young children with ASD in a series of three studies from 2017 to 2020. Using a Lag 1 schedule, researchers reinforced variability across functionally equivalent vocal mands (Silbaugh et al., 2017, 2020) or signs (Silbaugh & Falcomata, 2019), rather than across various mand modalities, as in the previous studies. In addition, prompting was used to elicit mands, if necessary, during the intervention condition. Across studies, participants increased their use of variable mands, and in the one study that assessed it (Silbaugh et al., 2020), decreased the frequency of CB during sessions. However, given the researchers applied a Lag 1 schedule exclusively, questions remain regarding the effects of thinner reinforcement schedules (e.g., Lags 2, 3), such as those programmed by Falcomata et al. (2018), will generalize to young children. Furthermore, given all applied research has been conducted with individuals with ASD, research is needed to determine whether outcomes will be consistent in individuals without ASD who demonstrate complex communication and behavioral needs (e.g., those with Down syndrome). Importantly, few researchers have directly assessed the generalizability or social validity of these procedures, which is necessary to determine (a) the real-world feasibility of the intervention (i.e., the ability for the intervention to generalize to new communication partners or settings without programming) and (b) the social significance and acceptability of the goals, procedures, and outcomes. Thus, continued investigation into the effectiveness of lag schedules of reinforcement in increasing mand variability, while postponing recurrence of CB during lapses in treatment, is needed to address gaps in current research and identify effective strategies for those working with young children with communication and behavioral needs.

Table 1. Challenging Behavior, Function of Challenging Behavior, and Target Mands.

	Bowie	Tumas	Fawn	Elenore
Challenging behaviors	Hitting Table Slamming Scratching Biting Hair-pulling Yelling Property destruction Self-injurious behavior	Hitting Kicking Stomping Scratching	Hitting Self-injurious behavior Screaming	Scratching Pinching Hitting Elopement Property destruction Disrobing
Target behavioral function	Tangibles	Tangibles	Tangibles	Attention with tangibles
Target mands	Vocal Switch iPad Picture	Vocal Switch iPad Picture	Vocal Switch iPad Picture	Vocal AAC Sign Picture

Note. AAC = alternative and augmentative communication.

Research Questions

The purpose of our study was to address the following research questions related to young children with disabilities (i.e., autism or Down syndrome) and CB.

1. When compared with baseline, will an FCT/Lag schedule result in:
a. an increased variability or frequency of mands?
b. a reduced level of CB?
2. Within an FCT/Lag schedule, will lag schedule *increases* result in:
a. an increased variability or frequency of mands?
b. a CB level at or near zero?
3. Will responses generalize to:
a. relevant implementers?
b. relevant settings?
4. Will social validity raters identify:
a. intervention goals, procedures, and outcomes as highly acceptable?
b. socially significant changes in the children's communication and CB?

Method

Participants and Settings

Bowie was a 42-month-old White, non-Hispanic male with autism who primarily engaged in one- to two-word utterances (i.e., mands, occasional tacts [labels], and echoics). He did not consistently mand to obtain his wants and needs. At these times, and when denied requests, he engaged in a variety of CB topographies, including yelling, aggression toward others, property destruction, and SIB (see Table 1). All Bowie's sessions occurred one-on-one with an implementer (i.e., researcher or Bowie's mother, for generalization sessions) at the kitchen table in his home.

Tumas was a 56-month-old autistic male of Middle Eastern descent who emitted occasional independent functional vocal communication, primarily mands and tacts; he also engaged in scripted speech during conversations and play. Tumas' CB included aggression and property destruction. His mother reported that he engaged in higher-order stereotypy during their daily routines. For Tumas, all sessions occurred one-on-one with an implementer (i.e., researcher or Tumas' mother, for generalization sessions) in their family room at home.

Fawn was a 55-month-old White, non-Hispanic female with autism who emitted occasional one- to three-word vocalizations via a voice-output alternative and augmentative communication (AAC) device programmed with Proloquo2Go. Her CB was typically vocal: yelling/screaming abruptly and loudly. In addition, she occasionally displayed aggression toward self or others. Similar to Tumas, Fawn's parents reported that she engaged in higher-order stereotypy across the day. Half of her sessions occurred in the family room of her home and half were implemented in a clinical observation room at a university-based preschool. Fawn's mother was present during these sessions and acted as implementer during generalization sessions.

Elenore was a 70-month-old White, non-Hispanic female with Down syndrome. She primarily communicated using one- to three-word vocal utterances with limited intelligibility; when prompted, Elenore also emitted one-word utterances via an AAC programmed with Snap + Core First. Elenore's mother reported that Elenore engaged in physical aggression, property destruction, disrobing, elopement, and mouthing. Intervention sessions were conducted in Elenore's preschool, which was the same setting where Fawn's clinical sessions occurred. The FA and the first seven intervention sessions were conducted in a clinic room and the remainder of the intervention sessions occurred in a resource room (to accommodate a new toilet training schedule). Both settings included art materials and classroom posters to approximate Elenore's typical environment. Generalization sessions occurred on the playground, as this was reported to be a typical context for Elenore's CB. These sessions occurred during her scheduled outdoor play time with teachers and peers present.

Experimental Design and Analysis

We determined a function using a multi-element design. For Bowie, Tumas, and Fawn, all FAs consisted of two conditions (i.e., tangible and play, as a control). For Elenore, the FA consisted of two test conditions (i.e., a synthesized attention with tangibles condition and an escape condition) and one control condition (i.e., play). We used a variation of the A–B–A–B design to assess the effects of the intervention on the dependent variables. This variation (i.e., A–B–A–B–C) included a baseline A condition, an intervention B condition (with an increasing lag from FCT/Lag 0 to a culminating FCT/Lag 2 or 3), and a generalization C condition. In addition, for Tumas and Fawn we implemented a B' condition (i.e., A–B–B'–A–B'–C), as described below.

We conducted formative and summative analyses using the visual analysis guidelines outlined by Barton et al. (2016). Namely, we conducted within and across-condition analysis, analyzing the level, trend, variability, overlap, immediacy of change, and consistency of all data. In addition, we used the event lag with contiguous pauses method of sequential analysis (Lloyd et al., 2016) to calculate the contingency strength of (a) subsequent mands given unreinforced mands and (b) CB following unreinforced mands. Results are available from the first author upon request.

Response Definitions and Measurement

Dependent Variables. Dependent variables included the frequency (or estimated frequency for Bowie) of target mands, variable mands, and target CB (Table 1). These were individually selected and operationally defined based on the behavioral repertoire of each child. *Target mands* were selected via a mand modality assessment. *Variable mands* were target mands that utilized a different modality from the mand emitted immediately prior. *Target*

CB consisted of a variety of behavioral topographies, including yelling, hitting, and property destruction.

Measurement System. We measured the frequency (Tumas, Fawn, and Elenore) or estimated frequency (Bowie) of target mands throughout each 5-min session. The frequency of target mands was measured via timed event recording for Tumas, Fawn, and Elenore. Target mands were considered mutually exclusive from CB, such that a mand co-occurring with CB would only be coded as CB. For each target mand, we marked which modality was used and whether it differed from the previous mand modality. For Bowie, who engaged in rapid rates of short-duration behavior (via multiple mand modalities simultaneously) that made accurate timed event recording unachievable, we estimated the frequency of target behaviors using partial-interval recording (PIR) with a 2-s interval. We corrected the estimated frequency using a Poisson transformation (Yoder et al., 2018) and converted each to a percentage of intervals per session. Given data were binned into 2-s interval rather than marked at their exact occurrence, mands and CB were not mutually exclusive. Finally, each *interval* was coded as variable (i.e., was not identical to the previous interval) or invariable.

Interobserver Agreement. We assessed interobserver agreement (IOA) for $>$ 30% (see Table 2 for exact percentages) of randomly selected sessions across participants and conditions using the point-by-point method of agreement (Ledford et al., 2018). Prior to coding study data, coders were trained on simulation videos until they achieved a minimum 90% agreement for each target variable. The primary coders—master's students in special education—were blind to which videos were selected for IOA. We calculated agreement for the three categories within each emitted mand (i.e., target behavior, variability, and modality) individually to provide a percentage of agreement for each. For Bowie, whose behavior was estimated via PIR, we assessed agreement across each 2-s interval.

General Procedures

Materials. Materials consisted of tangible items maintaining each child's CB (preferred snacks for Bowie, an iPad with preferred apps for Tumas, an iPad with preferred apps and animal figurines for Fawn, and books and dramatic play toys for Elenore) and three AAC devices: a simple switch communicator, an iPad programmed with Tobi Dynavox Compass Connect, and picture communication cards depicting each child's specific mand. All sessions were recorded using a Canon VIXIA digital camera and tripod. Data were collected in vivo with paper and pencil to permit in-the-moment decisions and coded later from video using observational software (ProcoderDV; Tapp, 2003).

Pre-Study Assessments. First, we conducted a caregiver interview and child observation; information from these indirect assessment methods was used to design the FA. We then outlined study procedures for caregivers in a 30-min PowerPoint presentation, during which we specifically they refrain from using the procedures until the conclusion of data collection. Next, we conducted an FA using a design selected individually for each child. For Bowie, Tumas, and Fawn, we conducted a single-function FA (tangible function; Iwata & Dozier, 2008) and we conducted an FA with two test conditions (escape and a synthesized attention with tangibles) with Elenore. Finally, we conducted a mand modality assessment following the procedures of Ringdahl et al. (2009). We assessed each of five mand modalities (vocal, switch, iPad, picture, and sign) individually for a total of 10 consecutive trials; we selected the four modalities with which each child demonstrated the greatest number of independent mands to target during intervention.

Table 2. Average Percentage Interobserver Agreement and Procedural Fidelity by Condition and Phase (Range).

	Interobserver agreement				Procedural fidelity			
	Bowie	Tumas	Fawn	Elenore	Bowie	Tumas	Fawn	Elenore
% assessed	35%	36%	40%	39%	35%	36%	40%	39%
FA control	100	100	100	100	100	100	100	100
FA test	86 (57–100)	86 (71–100)	100	100	100	100	90 (80–98)	100
Baseline	97 (96–99)	97 (97–100)	93 (79–100)	100	97 (95–100)	99	92 (75–100)	89 (67–100)
FCT/Lag 0	98 (97–99)	94 (93–95)	100	99 (98–100)	98 (96–100)	97 (96–97)	98	100
FCT/Lag 1	98 (97–99)	98 (97–99)	—	100	98 (97–99)	93 (92–95)	—	98 (94–100)
FCT/Lag 2	98 (98–99)	—	—	98 (94–100)	94 (83–98)	—	—	98 (95–100)
FCT/Lag 3	99	—	—	—	99	—	—	—
FCT/Lag 0’	—	—	94 (88–100)	—	—	—	90	—
FCT/Lag 1’	—	100	93 (78–100)	—	—	100	94 (89–100)	—
FCT/Lag 2’	—	98 (94–100)	100	—	—	93 (76–99)	95 (90–100)	—
Generalization	99	98	100	100	99	94	93	99

Note. FA = functional analysis; FCT = functional communication training.

Intervention. Sessions occurred three to five times per week (with multiple sessions per visit) for approximately 30 min, across a 5- to 7-week period for each child. Prior to each 5-min session, we provided each child with free access to the reinforcer for 30 s. The session began when the implementer removed the reinforcer. All devices required for target mands were accessible on the table or floor, within easy reach of the child. All dangerous CB was blocked for safety. A White, female BCBA with doctoral-level training in special education implemented all sessions for Bowie, Tumas, and Fawn. A White, female graduate student in special education working toward behavior analysis certification implemented sessions with Elenore. Both implementers had the support (e.g., filming, cuing reinforcement) of a second graduate student for all sessions.

Baseline (A). If the participant emitted target CB, they received 30-s access to the reinforcer identified during the FA. The reinforcer was then removed until CB was again emitted. We ignored mands during all baseline sessions and responded neutrally to any attentional bids, per traditional resurgence design (e.g., Falcomata et al., 2018). This method, which is a true reversal ABAB design, provides a strong demonstration of experimental control that approximates typical responses to CB in real-world settings.

FCT/Lag (B). Prior to beginning each FCT/Lag session, we reviewed the contingency with the child, reminding them of the different mand modalities they could use to request reinforcement. During FCT/Lag 0, each independent mand of any modality was immediately reinforced. Instances of CB were ignored. During FCT/Lag 1, to receive reinforcement each mand modality was required to be different from the modality that occurred directly prior. In addition, each time reinforcement was provided we vocally described why the mand was reinforced (e.g., stating, “Great! That was different.”). FCT/Lag 2 and FCT/Lag 3 procedures were identical to the FCT/Lag 1 condition, except: (a) to receive reinforcement each mand modality was required to be different from the *two* or *three* (respectively) modalities occurring directly prior and (b) prior to the commencement of sessions, pre-session reinforcement was provided for a specific number of mands—two in the Lag 2 condition and three in the Lag 3 condition—regardless of variability (per Falcomata et al., 2018).

Importantly, we programmed additional variability requirements into our intervention that were not present in other applied lag studies. Specifically, unlike previous research in which a Lag 3 mand would be reinforced if it was different from the three previous mands (but they could be identical to one another; e.g., picture, picture, picture, vocal), we required each of the inter-trial mands within the schedule to be unique from one another to result in reinforcement (e.g., picture, switch, iPad, vocal). This addition was similar to the Iag schedules of Lee and Sturmey (2014) and Argott (2010), both of whom required inter-session variability for response reinforcement. We introduced this requirement to reduce the likelihood of rote responding previously observed with lag reinforcement (Rodriguez & Thompson, 2015; Wolfe et al., 2014) as well as to increase the likeliness that each mand modality would access reinforcement regularly throughout the intervention. In doing so, we hoped to increase the generalization, maintenance, and social and ecological validity of the intervention.

FCT/Lag’ (B’). For Tumas and Fawn, who began to engage in repetitive responding (see the “Discussion” section), an FCT/Lag’ phase was introduced in which (a) mand devices were rotated following each reinforced mand and (b) blocking and redirection were implemented following the emission of a mand that met the reinforcement requirement of the current lag schedule. Specifically, when a mand occurred that met the lag schedule in place, all additional mands were blocked until the child began to engage with the reinforcer, after which mand devices were rotated and access was again permitted. For Tumas, this phase was introduced following FCT/Lag 1, and for Fawn after FCT/Lag 0.

Generalization (C). This condition was identical to FCT/Lag 2 or FCT/Lag 2', with the exception that the intervention was implemented either: (a) by the child's mother with researcher support (e.g., prompting to reinforce a mand or reintroduce the establishing operation [EO], praise for correct implementation; Bowie, Tumas, and Fawn) or (b) in a second setting (i.e., playground with teachers and peers present, Elenore).

Procedural Fidelity. Procedural fidelity (PF) was measured for both the FA and the intervention for > 30% of each condition and phase, per participant (see Table 2 for exact percentages). For the FA, we ensured the response to CB and appropriate behavior, presence/absence of the EO, and presence/absence of control variables (e.g., preferred tangible items available in play condition) were appropriate for each condition. For intervention conditions, we tracked availability of all mand materials, condition-specific response to CB and mands (both omission and commission), length of reinforcement, and appropriate reinstatement of the EO. In addition, two observers scored > 30% (see Table 2 for exact percentages) of randomly selected fidelity sessions across participants and conditions to assess fidelity IOA.

Social Validity. The social validity of the perceived goals, study procedures, and child outcomes was measured via parent and masked rater questionnaires. Each participants' mother completed a researcher-developed questionnaire (i.e., a modified version of the Treatment Acceptability Rating Form—Revised (TARF-R; Reimers & Wacker, 1988) prior to the start of the study and following intervention (Supplemental Table 1). This questionnaire was intended to obtain perceptions of the goals, procedures, and outcomes of the study from consumers of the intervention (i.e., individuals who were impacted by the participant's behavior and invested in their outcomes; Baer et al., 1987). Masked raters rated social validity following the conclusion of data collection by viewing 2-min video clips of baseline and intervention sessions (selected via a random-number generator). Participants were asked to rate the change in child behavior and demeanor, the acceptability of implementer behavior, and the utility and feasibility of procedures using a measure developed for this study (Supplemental Table 2).

Results

Functional Analysis

FA results indicated that denied access to preferred tangibles were functions of Bowie's (Figure 1, top panel), Tumas' (Figure 1, second panel), and Fawn's (Figure 1, third panel) CB, thus intervention focused on replacement behaviors related to this function (Table 1). Data indicate Elenore's CB was maintained by both access to attention with tangibles and escape from demands (Figure 1, bottom panel). The synthesized function was selected for intervention, as Elenore engaged in more severe CB (i.e., property destruction and elopement) to access attention with tangibles than to escape from demands (i.e., task refusal).

FCT/Lag Intervention

Bowie. Bowie's level of total and variable mands exhibited a downward trend throughout the initial baseline condition, while CB remained stable (Figure 2, top panel). There was an immediate increase in both the total and variable mands in the first session of the FCT/Lag condition, whereas CB initially remained stable before sharply decreasing to 0. When the schedule was thinned in Lag 1, there was an increase in both total and variable mands, with additional increases in the Lag 2 phase. CB remained low and variable throughout the Iag phases. Data patterns changed for all variables with the onset of Lag 3: mands remained relatively stable for the first

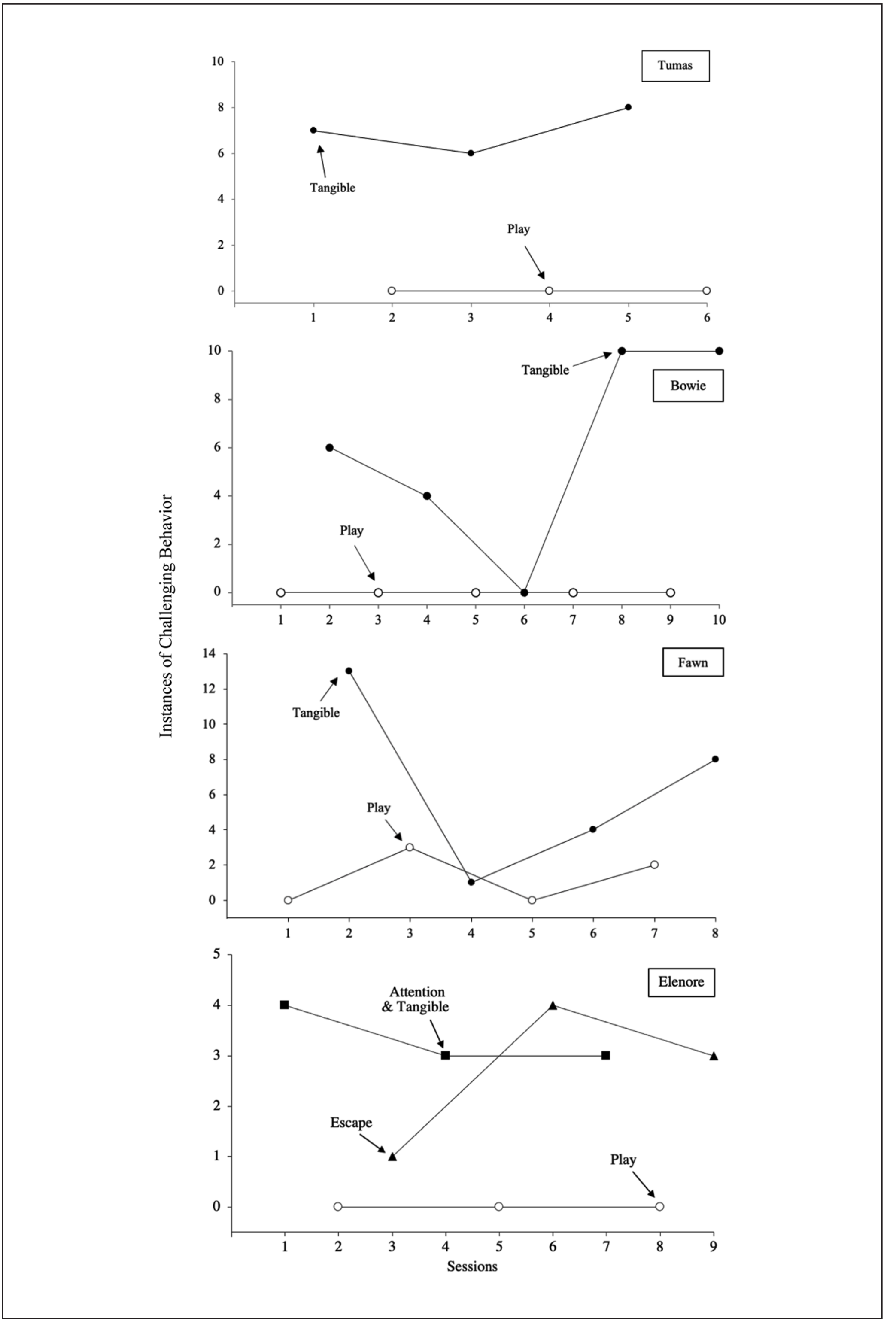

Figure 1. Functional Analysis for Bowie, Tumas, Fawn, and Elenore.

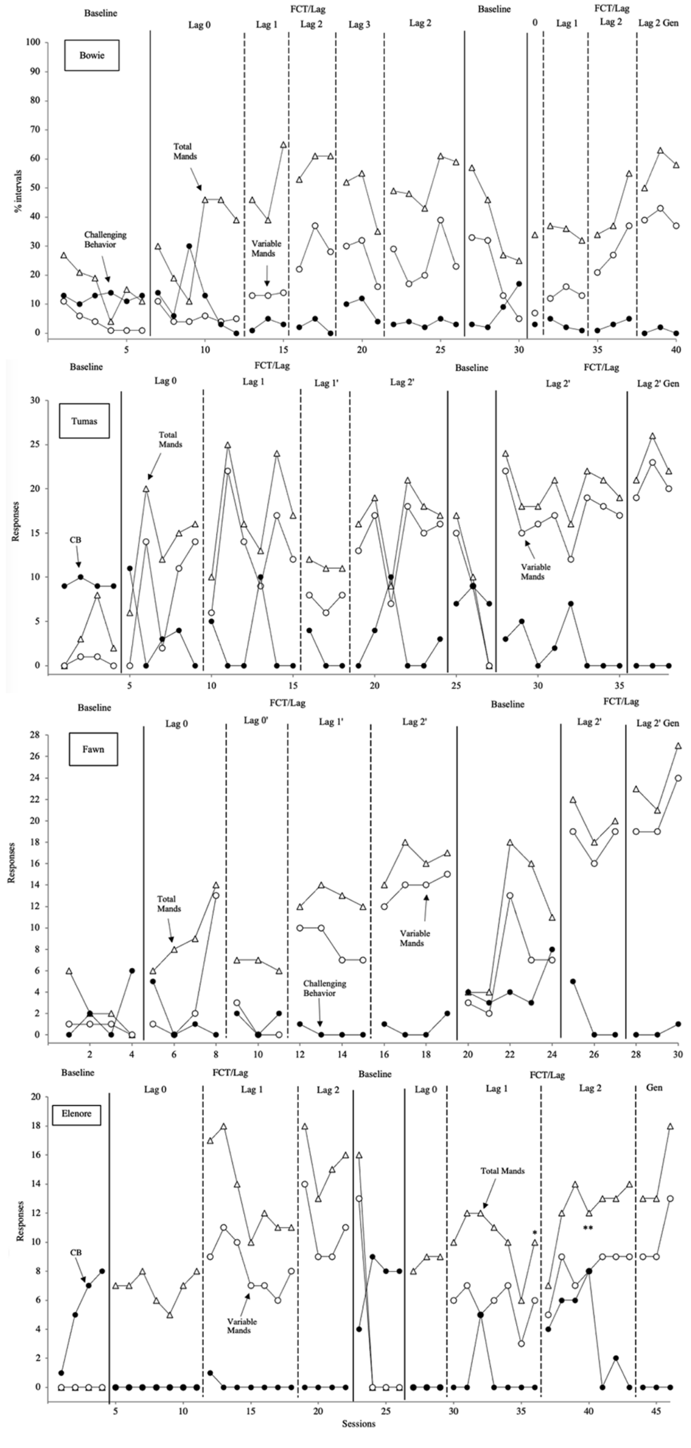

Figure 2. Percentage of Intervals (Bowie) or Frequency of Responses (Tumas, Fawn, and Elenore) for Total Mands (Open Triangles), Variable Mands (Open Circles), or Challenging Behavior (Closed Circles).
Note. CB = challenging behavior; FCT = functional communication training; Gen = generalization condition.

two sessions and dropped sharply during the third, with CB immediately increasing to near-baseline levels. When we returned to Lag 2, data demonstrated patterns similar to those of the initial Lag 2 phase. Upon the reintroduction of baseline, Bowie maintained levels of all variables for the first session, after which mands sharply decreased to baseline levels and CB spiked to its highest level. We attempted a fifth baseline session but chose to stop data collection mid-session when Bowie began to engage in severe SIB (e.g., forcefully banging head on table), which had not been previously demonstrated. Due to this response, rather than return to Lag 2 (as was proposed) we returned to Lag 0 and increased the response requirement when data were stable. Patterns during this condition were similar to those of the initial intervention condition. During the generalization condition Bowie had his highest levels of total and variable mands.

Tumas. Tumas' total mand frequency demonstrated an increasing trend for the first three baseline sessions, followed by a steep decline; variable mands remained low and stable and CB high and stable (Figure 2, second panel). When the intervention commenced, he had an immediate increase in levels of total and variable mands, with both demonstrating an increasing trend for the remainder of the Lag 0 phase. After an initial increase, the level of CB decreased and became more variable. In the Lag 1 phase, total and variable mands were high and variable. During this phase, Tumas began to display repetitive behavior, manding with more modalities than was necessary to receive reinforcement. Thus, we introduced the Lag 1' phase, which resulted in an immediate reduction and stabilization of mands throughout the phase. When Lag 2' began, Tumas' mands immediately increased and stabilized (Session 21 was an exception) and CB remained variable (possibly in response to the blocking and redirection of additional mands during the lag' modification, which may have been aversive). Upon the return to baseline, Tumas continued to emit a consistent level of mands during the first session after which both total and variable mands demonstrated a sharp decrease. CB immediately returned to baseline levels. Once the intervention was reinstated, Tumas' level of total and variable mands immediately increased to levels at or equal to the previous Lag 2' phase and remained high and stable. Levels of CB decreased but were variable. Tumas demonstrated his highest frequency of both total and variable mands during generalization, while CB remained at zero.

Fawn. Fawn's frequency of mands demonstrated a decreasing trend throughout baseline, culminating with 0, while variable mands were low (Figure 2, third panel). CB was low and variable with a spike in the final baseline session. Although CB data were not stable, because Fawn was engaging in increasingly severe SIB during Session 4 we chose to begin the FCT/Lag intervention. With the first FCT/Lag session both total mands and variable mands demonstrated an immediate increase and an increasing trend; CB decreased to floor levels. Given the rapid increase in mand level was in part due to the commencement of Fawn's repetitive manding, we then introduced a Lag 0' phase. Fawn's use of mands—both total and variable—decreased and stabilized, with similar data patterns in Lag 1'. Fawn emitted an increased frequency of total mands and variable mands during Lag 2', and both had an increasing trend. CB remained low and generally stable throughout the intervention condition. When baseline was reintroduced, Fawn's total and variable manding immediately dropped, after which both sharply increased in Session 22 and then demonstrated decreasing trend. CB demonstrated an immediate increase during the first baseline session, remained stable for the next three sessions, and increased sharply the final session. With the reintroduction of Lag 2', she had an immediate increase in total and variable mands (to their highest levels yet demonstrated) and a rapid decrease in CB. Fawn's mands maintained during the first two sessions of generalization, with a notable increase in both during the final session, while CB remained at or near 0.

Elenore. As seen in Figure 2 (bottom panel), Elenore emitted no mands during baseline, with CB increasing steadily throughout the condition. Upon introduction of the FCT/Lag intervention, the level of total mands immediately increased and remained stable (with no overlap with baseline) while CB dropped to zero; Elenore emitted no variable mands during this condition. Total and variable mands immediately increased in level with the onset of Lag 1, with no overlap with Lag 0 levels. Lag 2 mand levels were similar to those of the previous condition, with a slight increase in stability. CB remained at or near zero for both Lag 1 and 2 conditions. When the intervention was withdrawn, all variables returned to baseline levels. Similarly, all variables returned to levels consistent with the initial Lag 0 condition when this condition was reinstated. When Lag 1 was reintroduced, Elenore increased her use of both total and variable mands. However, levels were not as high as in the initial Lag 1 condition. Similar results were seen when comparing the first and second Lag 2 conditions, with the exception that both total and variable mands demonstrated an increasing trend and stabilization during the second Lag 2. Elenore did display instances of CB during the second Lag 1 and 2 conditions. In session 32, in which Elenore was wearing shoes with no socks, disrobing was coded each time she took off her shoes. This behavior stopped when she was given socks. Following this, when the implementer was absent (i.e., the 36th–41st sessions), CB rose to moderate levels with an increasing trend. CB immediately decreased upon her return. As with previous participants, Elenore maintained her frequency and variability of manding during the generalization condition, with zero instances of CB.

Mand Modality

Bowie's use of the four mand modalities varied across conditions and lag schedules (Figure 3, top panel). He manded with the switch most frequently across all conditions except the original baseline condition. He manded with the iPad second-most frequently, followed by picture exchange, and vocal communication. Vocal mands were emitted primarily in the baseline condition and during leaner schedules, suggesting a relation between modality and condition/phase.

Tumas' primary communication modalities were consistently the switch and iPad, which were used approximately equally within each condition and phase (Figure 3, second panel). Thus, no relation between modality and condition or schedule was identified.

Fawn demonstrated clear changes in mand modality usage across conditions and phases (Figure 3, third panel). Like Bowie and Tumas, she began the intervention communicating primarily via the switch and iPad. However, she began regularly manding via sign in Lag 1', and by Lag 2', this modality had replaced switch mands. Fawn began to use picture exchange during Lag 2' as well. These results indicated a relation between the use of both sign mands and picture exchange mands and the lag schedule, with the frequency of these modalities increasing with schedule thinning.

Elenore's data (Figure 3; bottom panel) were less clear, given she did not mand during the first baseline condition and manded via all four modalities during the second. However, a relation was identified for Elenore between varied modality use and the lag condition in place, in that during Lag 0 conditions she manded via picture only and manded across all modalities for Lags 1 and 2. In addition, she emitted a greater frequency of vocal mands during Lag 2 (3.4 vocal mands per session, on average) than Lag 1 (1.8 vocal mands per session, on average). Taken together, these data indicate a relation between mand modality and the FCT/Lag intervention as a whole, but not specifically related to the Iag requirement in place.

IOA and PF

Total IOA was high—average IOA at or above 80%—across participants, phases, and conditions (Table 1). As seen in Table 2, PF was high (at or above a mean of 89% per condition and phase)

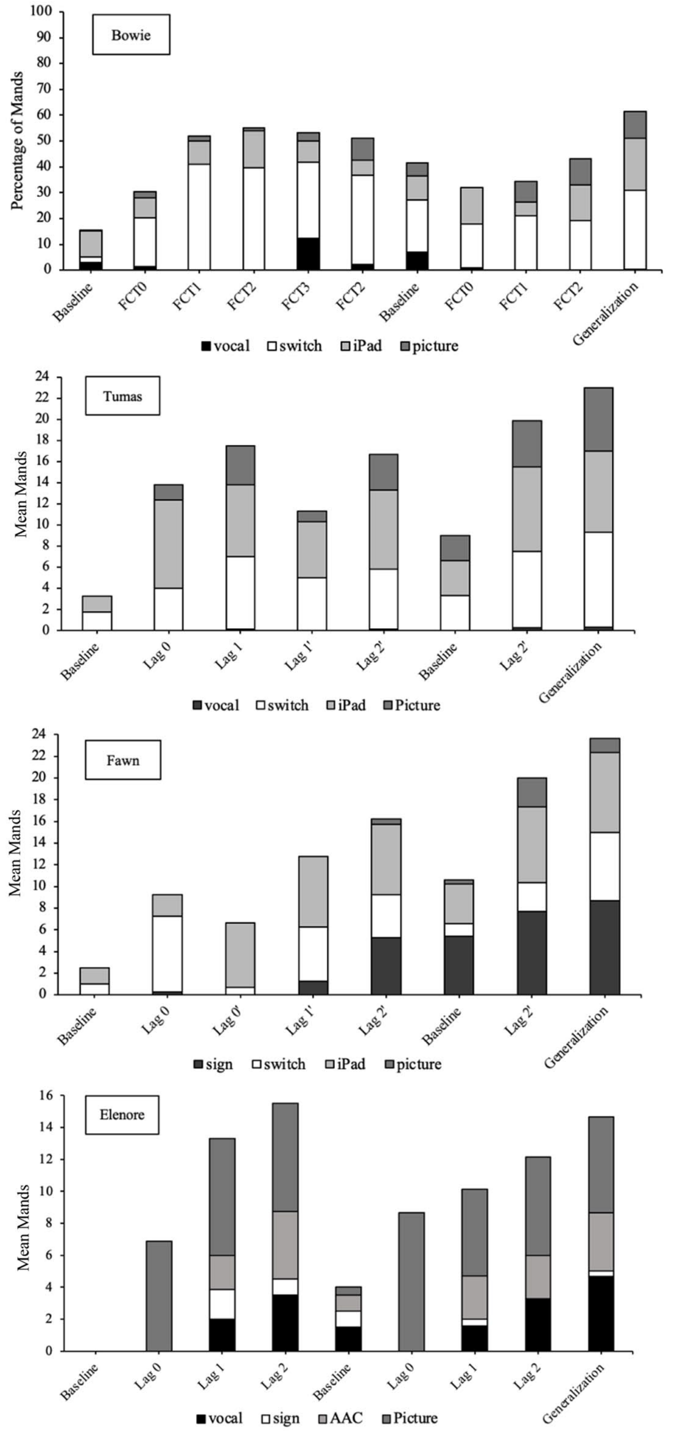

Figure 3. Percentage of Mands (Bowie) or Mean Frequency of Mands (Tumas, Fawn, and Elenore) Emitted by Phase/Condition and Modality.
Note. AAC = alternative and augmentative communication; FCT = functional communication training.

for all participants. PF IOA for the FA was 100% across children, and IOA for the intervention was 90% for Bowie (*range* = 78%-100%), 99% (*range* = 98%-100%) for Tumas, 97% (*range* = 87%-100%) for Fawn, and 100% for Elenore.

Social Validity

Participants' Mothers. Overall, the participants' mothers rated the intervention as having high social validity, as demonstrated by the results of the TARF-R pre- and post-treatment questionnaires (Supplemental Table 1), with some exceptions. All found the intervention to be more or equally acceptable than anticipated pre-treatment, more or equally effective than anticipated, and felt their child experienced less discomfort than anticipated. Furthermore, Bowie, Fawn, and Elenore's mothers rated their child's behavior as less severe post-treatment with fewer undesirable side effects than expected. At post-treatment, Bowie and Tumas' mothers reported an increased agreement with the belief that the procedures were likely to result in permanent improvements in their child's behavior. They, along with Elenore's mother, were willing to carry the treatment out independently and believed other family members would also be willing.

Masked Raters. Thirty-three masked raters completed the social validity assessment. There were no distinct patterns based on respondent's background or the child viewed. Masked raters indicated that child behavior was more appropriate and child affect more positive during intervention than during baseline (Supplemental Table 2). Raters indicated the intervention procedures were developmentally appropriate for preschool children, would not be difficult to implement in a 1:1 setting, would result in positive behavior change within a short period, and could be used across children, behaviors, and settings. However, they did not feel as strongly that the procedures would be easy to implement in a group setting.

Discussion

We implemented an FCT with lag reinforcement procedure with four young children with disabilities. We identified a functional relation between total and variable mands and the intervention, associated with the lag schedule in place, for all children. All participants were responsive to the intervention: we observed increases in functional manding and decreases or destabilization in CB. Our outcomes support previous research and demonstrate this intervention is effective for use with young children with disabilities and CB. Furthermore, our results advance current findings, as we found that FCT with lag reinforcement might delay recurrence of CB during treatment challenges while temporarily maintaining appropriate manding. This has the potential to provide significant, real-world benefit for these children, who are less likely to persist with appropriate mands in the absence of immediate, specific reinforcement.

Response to Intervention

FCT/Lag 2 vs. Lag 3. Bowie was the only participant with whom we conducted FCT/Lag 3 sessions. Upon implementing this phase, we found that even though he emitted all four mand modalities repeatedly (as seen in Figure 3, top panel) he did not consistently engage in four distinct mand modalities sequentially (in any order), which was required to result in reinforcement per our FCT/Lag procedure. Thus, he received reinforcement only a few times during each Lag 3 session. This rapid decrease in reinforcement appeared to result in ratio strain and a decrease in manding. For Tumas, Fawn, and Elenore, we increased to a maximum schedule of Lag 2 rather than Lag 3 due to the undesirable outcomes of Bowie's intervention. These results suggest that requiring *each* mand to be unique from a designated number of mands before is likely to result in ratio strain after multiple lag increases. This, along with participant age, might account for why Falcomata and colleagues (2018)—who reinforced mands that were different from *any* of the designated number of previous mands—demonstrated success with lag schedules up to Lag 5, whereas ours did not. Our results indicate that our procedures, which were introduced in an attempt to decrease rote responding and increase reinforcement across all mand modalities, may not be appropriate for young learners. It is important for the field to identify if participant age or the deviations from previous lag requirements were responsible for the inconsistencies across studies. Thus, future researchers are encouraged to assess the effects of lag reinforcement with young children using lag requirements with a more developed research base.

Mand Modality. We identified a relation between the percentage of mands emitted by modality and the lag schedule for Bowie (Figure 3, top panel). Falcomata et al. (2018) found similar results in that both participants consistently demonstrated an increasingly even distribution across modalities as the lag schedule increased. However, we did not identify a similar relation for Tumas and Fawn (Figure 3, second and third panels, respectively). Although both children generally emitted a more balanced allocation of modalities as the intervention progressed, there did not appear to be a relation between mand allocation and the lag schedule. This might have been due to (a) the repetitive responding of both children (which was not a factor for Bowie) or (b) the variables associated with each modality, including response effort, novelty, and preference (Ringdahl et al., 2009).

Importantly, however, Elenore's patterns of responding were markedly different from the other study participants, which provide exploratory data regarding the intervention's potential utility with preschoolers with Down syndrome. Specifically, a possible ceiling effect was observed with Elenore, where total and variable mands increased substantially following the initial intervention conditions (i.e., those prior to the reversal) but were less frequent during intervention conditions following the reversal. For example, Elenore consistently paired her vocal and sign mands at the beginning of the intervention, resulting in a greater level of manding than was necessary to access reinforcement, but stopped pairing the mands after the reversal. Thus, total and variable mands decreased when compared with the initial intervention phases although she was still accessing the same amount of reinforcement. Her response pattern indicates an increased fluency with the intervention across time, such that she emitted the minimum response requirement to access reinforcement across conditions.

Modifications. We provided modifications for Tumas and Fawn, who both engaged in repetitive behavior (i.e., higher-order stereotypy) during the FCT/Lag condition. Tumas demonstrated this by sequentially manding in a specific order. Although the reinforcer was provided with fidelity when the lag schedule was met, he would postpone interaction with the reinforcer until the chain was complete. Fawn demonstrated the same behavior and also returned mand materials to their original location if moved. We believe these behaviors were likely occasioned by our specific lag requirements. First, because we provided a contingency review at the start of each session, we hypothesize mands became controlled by rule-governed behavior (rather than by the reinforcement contingency alone). Second, because we required *each* response to be different from a specified number before (per the lag in place), it is possible that we inadvertently reinforced Tumas and Fawn's higher-order stereotypy when they began to emit mand modalities sequentially. Given this behavior was non-functional, our response was the introduction of an FCT/Lag' phase in which blocking and redirection were provided contingent on sequential manding and items were rotated following each reinforcer removal. Over time, this modification appeared to weaken the response-to-automatic reinforcement relation for both Tumas and Fawn. Silbaugh et al. (2017) found similar results in which they applied response blocking to prevent access to invariable behavior (i.e., food consumption). Our outcomes build on their findings and support the utility of blocking and redirection within FCT with lag reinforcement to address repetitive behavior. However, these data also suggest that the "traditional" FCT/Lag procedure might be more appropriate than our procedure for participants who display higher-order stereotypy, given repetitive responding is a noted limitation of lag schedules (Rodriguez & Thompson, 2015; Silbaugh et al., 2021; Wolfe et al., 2014).

Generalization. Finally, the results from generalization sessions are promising, although more research is needed to draw experimental conclusions. Programming for variability during the intervention may promote generalization across contexts, where reinforcement may not be delivered predictably after every mand. All participants maintained their level of FCT/Lag 2 mands and CB when the intervention was implemented by their mothers or in a natural context. In fact, in this condition each child demonstrated mands at a frequency consistent with or higher than their highest number to date. Despite the introduction of novel and uncontrolled variables, there was no decrease in fidelity when the intervention was provided by mothers (with in vivo coaching) or in a natural context for any child (Table 1). This demonstrates that (a) children might perform better when FCT/Lag schedules are provided by known implementers and (b) such implementers can provide FCT/Lag reinforcement to fidelity with support. In addition, these results demonstrate that teaching and reinforcing a variety of mands, rather than a single mand, to young children with complex communication needs can improve their ability to communicate across a range of contexts and persist in communication attempts if not understood. This has significant and immediate real-world utility given the environmental inconsistencies in access to AAC, caregiver familiarity across communication devices or responsiveness to them, and other contextual variables.

Social Validity

Our research provides meaningful, quantitative data as to the social validity of the FCT/Lag intervention. Social validity data were provided by parents of participants and masked raters (i.e., professionals in ABA and special education, the two fields most likely to utilize these procedures in applied settings). On average, raters found the intervention to be meaningful, generally resulting in socially significant changes for participants (see Supplemental Tables 1 and 2). In addition, our studies are the first in which significant others (e.g., parents, teachers) were included as implementers and procedures were conducted in real-world settings (i.e., homes and school), with demonstrated generalization across implementers and settings. This speaks objectively to this procedure's social validity, given the intervention was effective under conditions that closely resembled typical settings.

It is important to note that while our measures provide data indicating the social validity of the study goals, procedures, and outcomes, they do not specifically measure the perceived social significance of teaching and reinforcing variable mands. That is, all questions posed to raters pertained to the intervention package as a whole and not to the specifics of programming variability. This is a noteworthy absence that should be addressed in future research.

Limitations

IOA and PF of some sessions fell below 80%. For IOA, these low percentages were for a single variable only, and occurred in one session with Bowie, three with Tumas, and five with Fawn. Typically, these low IOA values occurred early in the coding process (i.e., FA, FCT/Lag 0) and were related to low levels of behavior (i.e., two vs. three CBs in a session). Although it is possible these low values indicate possible observer bias or drift, because averages were generally well above acceptable levels across participants, conditions, and variables, we feel our data are valid and can be considered accurate depictions of the behaviors. For PF, one FCT/Lag 2' session for Tumas and one baseline session for Fawn fell below 80%. These low fidelity values resulted from failing to reinforce pre-session mands and several errors of omission and commission for Tumas, and from failing to reinforce all instances of CB during baseline for Fawn.

The use of PIR rather than event recording to code Bowie's data could also be considered a limitation. Although PIR has been demonstrated the most accurate interval system to estimate count, its use comes with compromise in data precision (e.g., inflation of perceived effect). For this reason, we applied PIR using the best-known strategies for avoiding these pitfalls. Specifically, we: (a) applied to behaviors of short duration (< 1 s per behavior); (b) chose 2-s intervals, given small intervals are recommended to improve data accuracy and (c) applied the Poisson correction, a probability distribution of the rate of occurrence that has resulted in increased data accuracy (Yoder et al., 2018).

Although intentionally designed and implemented, a potential limitation was how the lag' modification—in which mands were restricted and mand devices were rotated in the lag' phases but not during baseline—might have altered data patterns for Tumas and Fawn. Given this modification restricted mands during intervention but not baseline, the level of mands during intervention was reduced; this has the potential to impact the validity of results. However, we believed the modification would best reflect the intervention as intended for these participants because additional mands emitted in the absence of the modification would not be related to the contingency (i.e., they would instead be a function of higher-order stereotypy).

A final limitation relates to the lesser environmental control within Elenore's sessions when compared with those of Bowie, Tumas, and Fawn. The change in intervention setting in the middle of the study (to the resource room) might have impacted the data. Although the resource room was a closer approximation of Elenore's classroom than the clinic, there were competing, non-study materials that could not be removed, which might have decreased levels of manding. Similarly, her primary implementer was absent for five sessions (36-40), awhich may have occassioned the increase in the level of CB during these sessions. On several occasions during this absence, Elenore manded for the primary implementer and engaged in CB directed at the new adult: It is hypothesized that theprimary implementer was a preferred adult and the unfamiliar one was less preferred. If true, this might have potential implications for generalization across implementers.

Future Research

Our results suggest multiple avenues of applied research related to FCT with lag reinforcement. First, future researchers should consider if and when requiring within-trial novelty in FCT/Lag is beneficial, and when it might result in less therapeutic outcomes. They also might identify methods of determining the maximum lag schedule for each participant before undesired behavior emerges. In addition, expanding the intervention to include more socially and ecologically valid procedures is imperative. This might include analysis of the level of PF required to produce viable outcomes (and the subsequent coaching required to increase the feasibility, generalizability, and maintenance of effects) as well as refined social validity assessments that directly assess the perceived social significance of programming variability within FCT. Finally, researchers should extend the research on lag reinforcement to include individuals with different diagnoses and functional repertoires to determine whether findings and response patterns generalize across populations.

Implications for Practice

Given children with disabilities are more likely to engage in CB than their typically developing peers and patterns of CB during early childhood are associated with negative outcomes, teaching children with complex communication needs and CB to use appropriate communication is an essential component of early childhood intervention. Effective reinforcement-based interventions, such as FCT, should be used during early childhood to support children with patterns of CB; however, children are likely to revert back to CB when a trained mand is no longer reinforced, as often occurs with traditional FCT. Our results suggest that children benefit when taught how to get their needs met using multiple functional communication responses. FCT with lag reinforcement may be a practical and effective way to teach young children to expand their communication repertoire, thereby increasing the likelihood that they will contact reinforcement across contexts and delaying the resurgence of CB. This may be particularly useful for individuals who demonstrate minimal mand persistence in the absence of specific and predictable reinforcement. Researchers should consider using FCT with lag schedules of reinforcement with individuals who display these characteristics. In contrast, this intervention may not be as effective for individuals who display ritualistic behaviors or perseverate on routines.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The research described in this article was supported in part by Grant H325H140001 from the Office of Special Education Programs, U.S. Department of Education.

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Supplemental Material

Supplemental material for this article is available online.

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