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RESEARCH ARTICLE

Effects of a Lag Schedule with Progressive Time Delay on Sign Mand Variability in a Boy with Autism

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Abstract

For some children with autism, mand training can produce highly repetitive manding unless the environment is arranged in a manner that promotes mand variability. Prior research demonstrated that mand training using a lag schedule and progressive time delay increased variability in vocal manding in children with autism. Whether lag schedules have similar effects on sign mand topographies is unknown. The current study evaluated the effects of mand training with a Lag 1 schedule of reinforcement and progressive time delay (TD) on topographical variability and the development of a sign mand response class hierarchy in a boy with autism. The results suggest independent use of all sign mand topographies occurred, a mand response class hierarchy was developed, and topographically variant sign manding increased under the Lag 1 + TD schedule compared to a Lag 0 schedule of reinforcement. Implications for practitioners, limitations, and directions for future research are discussed.

Keywords Lag schedule · Mand · Operant variability · Response class hierarchy · Time delay

During mand training for individuals with language delays or deficits (e.g., autism), a response such as saying "juice" is taught by presenting a relevant establishing operation (EO; e.g., giving access to salty popcorn and withholding juice) and using prompting, rapid prompt fading, and differential reinforcement to transfer control over the target response from the prompt to the EO and contingent access to juice (Sundberg & Partington, 1998; see Shafer, 1994, and Wallace, 2007, for reviews of common procedures and concepts). However, unless the environment is arranged to support a variety of requests from the speaker, procedures commonly used in mand training for some children with autism can produce invariant (i.e., repetitive) manding (e.g., Carr & Kologinsky, 1983; Silbaugh, Falcomata, & Ferguson, 2017).

Behavioral variability is critical for contacting reinforcement in a changing environment (e.g., Sidman, 1960). Invariant manding may disadvantage a speaker when reinforcement mediated by a listener requires saying something differently by either (a) failing to obtain reinforcement or (b) exhibiting resurgence of challenging behavior as the listener withholds reinforcement for invariant responding (e.g., Volkert, Lerman, Call, & Trosclair-Lasserre, 2009). At least two general types of invariant manding are commonly observed.

First, invariance may occur across mands, such as when a child repeatedly emits mands for only one of multiple reinforcers concurrently available. For example, in the presence of playdoh, juice, and a book, invariant manding may take the form of the child repeatedly asking only for the playdoh across trials. Alternatively, invariance may occur within a given mand response class for a single reinforcer. For example, a child may invariantly emit the vocal mand topography "playdoh" across repeated instances of taking turns playing with playdoh with a peer. For some children, topographically invariant instances of a mand emitted over time may be due to extinction of alternative mand topographies during training or to a lack of sufficient response exemplars incorporated into training (Lee, Sturmey, & Fields, 2007; Rodriguez & Thompson, 2015). For example, to establish a topographically variant mand response class, instead of only teaching the child to say "playdoh," the child may benefit from being simultaneously or sequentially taught to say "want," "toy," or

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"playdoh" under the control of the EO for access to playdoh, with contingencies that support variation across instances of turn taking. Wolfe, Slocum, and Kunnavatana (2014) proposed general guidelines for increasing operant variability in children with autism, but specific procedures and guidelines for reinforcing mand variability in practice requires more research.

Multiple studies have evaluated procedures that increase variability or novelty across concurrently available reinforcers (i.e., across mands) during mand training for individuals with intellectual disability (e.g., Duker & van Lent, 1991) or autism (Bernstein & Sturmey, 2008; Betz, Higbee, Kelley, Sellers, & Pollard, 2011; Brodhead, Higbee, Gerencser, & Akers, 2016; Carr & Kologinsky, 1983; Drasgow, Martin, Chezan, Wolfe, & Halle, 2015; Sellers, Kelley, Higbee, & Wolfe, 2015). For example, Bernstein and Sturmey (2008) compared the effects of continuous and intermittent schedules of reinforcement on the emission of alternative mands by two children with autism and vocal manding repertories. A single high-rate mand was placed on an intermittent schedule of reinforcement (e.g., FR10 or FR25), whereas all other mands were reinforced on an FR1 schedule in the presence of four different reinforcers for both children. Relatively higher total counts of alternative mands emitted within sessions were observed when the intermittent schedules were in effect. Although prior research demonstrated procedures that can be used to predict and control topographical variation across mands, other procedures may be needed to establish a topographically variant mand response class, which is one focus of the current study.

Operant variability can be brought under discriminative control and reinforced (Page & Neuringer, 1985). Lag schedules of reinforcement can increase operant variability by delivering reinforcement for a response if it differs from n prior instances, with n equal to the value of the lag. For example, under a Lag 3 schedule, a response is reinforced if it differs from the preceding three responses (e.g., Susa & Schlinger, 2012). Potential advantages of using lag schedules over other procedures that increase mand variability is that they may facilitate generalization through the reinforcement of multiple response exemplars (Silbaugh et al., 2017) and may mitigate challenging behavior when treatment involves reinforcing mand variability (e.g., Adami, Falcomata, Muething, & Hoffman, 2017). A growing body of applied research has demonstrated that lag schedules reinforce variability in verbal behavior for individuals with developmental disorders (Wolfe et al., 2014), and three studies have shown lag schedules can increase variability in manding.

Brodhead et al. (2016) combined script training with lag schedules of reinforcement to bring variability in manding for edible items under discriminative control for three children with autism. Sessions during the treatment evaluation included three different concurrently available edible reinforcers, which were alternated across sessions based on the results of preference assessments. During baseline, all mands were reinforced on an FR1 schedule of reinforcement. Following baseline, script training was used to teach participants to independently use new mand frames, such as "May I have [reinforcer]?" and "I would like [reinforcer]." Also during script training, discriminative control over mand frame variability was established by alternating conditions with two different colored place mats. A green place mat was correlated with reinforcement for varying mand frames under a Lag 2 or Lag 3 schedule, and a red place mat was correlated with reinforcement for repeating the mand frame (i.e., "I want [reinforcer].") that existed in each participant's repertoire before treatment. Discriminated mand frame variability was the dependent variable and the dependent measure was the number of different mand frames emitted per session. The results showed that participants emitted relatively more different mand frames per session under a lag schedule. However, the dependent measure may have been insensitive to the variant dimension of manding because it differed from the response dimension on which reinforcement was contingent under the lag schedule (De Souza Barba, 2012a, b). That is, reinforcement was not contingent on the number of different mand frames emitted within session, but rather mand frames that differed from n different mand frames emitted within session. Additionally, the use of multiple types of reinforcers in a concurrent-operants arrangement does not allow for the assessment of variations in functionally equivalent manding (i.e., multiple topographies or stimulus selections maintained by a single reinforcer).

Adami et al. (2017) evaluated the effects of a Lag 1 schedule of reinforcement combined with functional communication training (FCT; Carr & Durand, 1985) on varied nonvocal manding and challenging behavior in two males with autism diagnoses. The authors used reversal designs consisting of three conditions (i.e., baseline, FCT/Lag 0, and FCT/Lag 1), 5-min sessions, and 30-s reinforcer durations for target responses. During baseline, no mand modality equipment was available and challenging behavior produced the maintaining consequence identified in a prior functional analysis on a continuous schedule of reinforcement. During FCT/Lag 0, three different mand modalities were available (i.e., a card to exchange, a microswitch, and a tablet) and the reinforcer was delivered contingent on the independent selection of any mand modality. The FCT/Lag 1 condition was similar except that the reinforcer was contingent on instances of manding in which the participant selected a mand modality that differed from the last mand modality selected within the session. For example, if on Trial 3 the participant used the tablet to mand, then on Trial 4 he was required to mand by pressing the microswitch or exchanging the card to produce the reinforcer. The results indicated that FCT with lag schedules replaced challenging behavior with manding and that the addition of the Lag 1 schedule of reinforcement increased mand variability across modalities.

Silbaugh et al. (2017) investigated the effects of lag schedules on mand variability in two young children with autism. For each participant, a mand topography invariance assessment was used to identify two mands emitted invariantly across trials and to identify two new topographies to target for each mand during the treatment evaluation. A multiple-baseline design across mands with embedded withdrawal was used to evaluate the effects of a Lag 1 schedule of reinforcement with progressive time delay (TD) on topographical vocal mand variability. Sessions were 5 min in duration. During the Lag 0 condition (i.e., baseline), 25 s of reinforcement was delivered contingent on any emitted vocal mand topography. During the Lag 1 condition, 25 s of reinforcement was delivered contingent on independent or prompted variant vocal mand topographies. A vocal mand topography was variant if it differed from the immediately preceding vocal mand topography emitted within the session. Specifically, if the participant did not emit an independent variant vocal mand topography within 2 s of the EO (i.e., the onset of a trial), the experimenter delivered an echoic prompt for a target variant vocal mand topography. If the participant did not emit a variant vocal mand topography for six consecutive trials under a given TD (e.g., 2 s), the TD was increased by 2 s on the seventh trial. Mand variability training increased variability in multiple functionally equivalent vocal mand topographies for both participants and all four mands. The results of a post hoc analysis of relative latencies showed that vocal mand topographies were emitted in a temporally predictably order, suggesting that mand response class hierarchies (Baer, 1982) were modified by incorporation of new mand topographies during treatment. The purpose of the current study was to extend Silbaugh et al. (2017) by (a) evaluating the effects of a Lag 1 schedule of positive reinforcement combined with a progressive TD on the acquisition and variability of multiple sign mand topographies in a boy with autism and (b) analyzing relative response latencies to assess mand response class structure formation.

Method

Participants and Setting

Allen was a 5-year-old boy with a diagnosis of autism who attended a special day school for children with developmental disabilities and received social and academic instruction using applied behavior analysis. Based on information collected during observation and interviews with caregivers and teachers, Allen was selected for participation in this study for three reasons. First, he demonstrated a largely deficient verbal repertoire, consisting mostly of a few spontaneous vocal mands (e.g., for a preferred stuffed animal) and physically guiding adults by hand to request reinforcers. Second, he demonstrated good fine motor skills and generalized gross motor imitation of actions without objects (e.g., clapping) during an informal clinical assessment by the first author. Third, his caregivers and teachers indicated that most prior attempts at expanding Allen's verbal repertoire had been unsuccessful at establishing mands used spontaneously and consistently. Per their report, he had not received prior instruction in sign mand training but had received vocal-, picture exchange-, and tablet-based instruction based on Skinner's analysis of verbal behavior (Skinner, 1957). The study was conducted in the school kitchen, which contained common kitchen appliances, tables, chairs, a piano, and standard research equipment (e.g., toys, camera), shortly after lunch hours.

Response Definitions and Measurement

The primary dependent variables were (a) variant and (b) invariant manding. We measured independent variant sign mand topographies, independent invariant sign mand topographies, and prompted variant sign mand topographies. We collected count data on instances of sign manding from session video recordings using a computer-based data-collection program and converted the count to a rate (i.e., signs per minute) to enable visual analysis. An *independent variant sign mand topography* was defined as an unprompted sign mand topography that differed from the last sign mand topography emitted within the session. For example, if the sign for "toy" was emitted following the independently emitted sign "want," then the sign for "toy" was considered variant. Measurement of variant sign mand topographies in each session began with the second emitted sign mand topography because the first sign mand topography emitted within a session was used by the experimenter to discriminate between invariant and variant manding. All distinguishable gestures toward the reinforcer, other than a reach, were measured (e.g., clap, point). An *independent invariant sign mand topography* was defined as an unprompted sign mand topography that did not differ from the last sign mand topography emitted within the session. A *prompted variant sign mand topography* was one that was evoked by a model prompt provided by the experimenter and topographically different from the last sign mand topography emitted within the session.

Secondary dependent variables were (a) different across-session sign mand topographies and (b) different within-session sign mand topographies. *Different across-session sign mand topography* was defined as a sign mand topography that differed from all previous sign mand topographies emitted in prior sessions and was measured by adding each new emitted sign mand topography during a session to a cumulative total. *Different within-session sign mand topography* was defined as an emitted sign mand topography that differed from all prior emitted sign mand topographies within a session and was measured by counting the number of different signs emitted each session.

Interobserver Agreement and Procedural Fidelity

Interobserver agreement (IOA) and procedural fidelity were assessed by trained observers who viewed videos and independently collected trial-by-trial (i.e., each instance of the programmed EO) data on 33% of sessions randomly selected across all phases. Data collected on variant, invariant, and prompted sign mand topographies were assessed using exact count-per-interval IOA (Cooper, Heron, & Heward, 2007). To calculate IOA, each recording period was divided into 10-s intervals, the total number of intervals with exact agreement was divided by the total number of intervals, and the quotient was multiplied by 100. Mean IOA was 94% (range 85%–100%). Mean fidelity for each select procedural component was calculated by dividing the number correct by the number correct plus the number incorrect and multiplying the quotient by 100. Overall mean procedural fidelity was calculated by dividing the sum of the individual means for each procedural component implemented correctly by the number of components (i.e., 4) and converting the quotient to a percentage. Overall mean procedural fidelity was 100% for the immediacy and duration of reinforcer delivery, response-reinforcer contingency, descriptive praise, and prompt immediacy.

Design and Procedure

Following pretreatment assessment and training, an A-B-A-B withdrawal design was used to evaluate the effects of sign mand variability training on variant signs under a Lag 1 + TD schedule of positive reinforcement (Silbaugh et al., 2017). Three to four sessions per day were conducted with the experimenter, approximately two to three days per week. The participant was given a choice between three different colors of playdoh every 2 to 3 days to minimize reinforcer satiation. A treatment evaluation session was terminated and excluded if no independent sign mand topography was emitted within 1 min of the onset of the first programmed EO of the session. This occurred only once, during the final Lag 1 + TD phase. Allen was given a break for 1–2 min consisting of interaction with the experimenter between sessions of the assessment, training, and the treatment evaluation.

Pretreatment Assessment

The experimenter presented an array of toys and snacks and conducted an approximately 30-min semistructured play session (a) to identify potentially reinforcing toys or activities and (b) to briefly assess Allen's responsiveness to sign mand training. Playdoh was identified as a potential reinforcer based on Allen's sustained engagement and repeated reaches for the playdoh as the experimenter took brief turns. A hand over hand–to–sign mand stimulus transfer procedure with errorless prompting, prompt fading (physical, model, no prompt), and differential reinforcement with reinforcer intervals of 20–30 s was used to teach Allen "clapping" as an arbitrary mand response topography. Following approximately 20–30 trials, Allen emitted multiple consecutive independent responses to brief turns taken by the experimenter. The results of the assessment suggested Allen would rapidly acquire additional sign mand topographies for playdoh during the treatment evaluation using a motor imitation–to–sign mand stimulus transfer procedure. The experimenter's playdoh and associated toys (e.g., plastic plate, spoons) were not available to Allen between sessions.

Next, the experimenter selected three novel sign mand topographies to be targeted during the treatment evaluation. The form of each sign was modified from American Sign Language to minimize response effort. The sign "want" was defined as extending one arm with palms up and bringing the hand toward the body while forming a half fist once or repeatedly. The sign "playdoh" was defined as extending one arm out, hand flat, palm down, and moving the hand toward and away from one's own body once or repeatedly. The sign "toy" was defined as orienting one arm at approximately a 90-degree angle toward the ceiling and tucking the thumb between pointer and middle finger with the tip of thumb pointing up, then twisting the hand clockwise or counterclockwise once or repeatedly. Reasonable approximations of the signs were reinforced throughout the treatment evaluation. Allen's right hand was targeted for sign acquisition.

Pretreatment Sign Mand Training

After the pretreatment assessment was complete, a series of 5-min training sessions were conducted to teach Allen to independently mand for playdoh using the sign "want." Clapping and poorly articulated vocalizations were placed on extinction. During each session, the experimenter repeated the training procedures described in the prior assessment. The exit criterion for training was a single independent instance of the sign "want" within a training session. Allen met the exit criterion at the beginning of Training Session 4. The session was immediately terminated, and baseline (i.e., Lag 0) data collection for the treatment evaluation began.

Experimental Conditions

Lag 0 (Baseline) Allen was provided with free access to the playdoh for 30 s prior to the start of the first session each day, with the exception of the first session, which began immediately after he met the exit criteria for pretreatment sign mand training. The experimenter initiated the session by removing access to the playdoh. Throughout the session, 20-s access to playdoh plus descriptive praise (e.g., "Playdoh! Nice job asking!") was immediately provided on a Lag 0 schedule of positive reinforcement contingent on independent signs for "want." Attempts to leave the table were blocked with the least amount of physical prompting possible by the experimenter.

Lag 1 Procedures in this condition were similar to Lag 0 with some exceptions. Access to playdoh was delivered for 20 s immediately contingent on the first independent sign mand topography emitted in each session. For the remainder of each session, 20-s access to playdoh plus descriptive praise was immediately provided contingent on prompted and independent variant sign mand topographies. Only the three target sign mand topographies (i.e., "want," "toy," "playdoh") were eligible for reinforcement, and importantly, the participant had no exposure to sign mand training targeting the topographies for "toy" or "playdoh" prior to this phase. The lag schedule was combined with a progressive TD procedure to transfer control over the "toy" and "playdoh" sign mand topographies from model prompts to the EO and programmed reinforcer. If Allen did not emit a variant sign mand topography during the 2-s TD, the experimenter delivered a model prompt (sometimes paired with a verbal prompt, "Do this," to increase prompt effectiveness) for a target variant sign mand topography selected nonsystematically by the experimenter (i.e., best attempt at random choice of variant topography). Thus, Allen was permitted to sign repeatedly during the TD until a variant sign mand was emitted (i.e., within 2 s) or evoked (i.e., by a prompt). The experimenter continued to deliver the prompt at 2-s intervals until the prompt evoked the target variant sign mand topography. The length of the TD would have increased by 2 s every six consecutive trials that Allen failed to emit a variant sign mand topography, although this was not necessary for any sessions.

Results

All target sign mands were emitted during the treatment evaluation. Data on specific topographies are not shown. Figure 1 displays the rates of independent variant, independent invariant, and prompted variant sign mand topographies. During baseline (i.e., Lag 0), moderate rates of independent variant manding were stable and rates of independent variant manding were low and steady. Coinciding with the introduction of Lag 1 + TD, a moderate increase in prompted variant manding occurred along with a moderate decrease in the level of independent invariant manding and a moderate-to-large increase in the level of independent variant manding with a slightly ascending trend. The return to baseline resulted in an immediate decrease to a zero rate of prompted variant

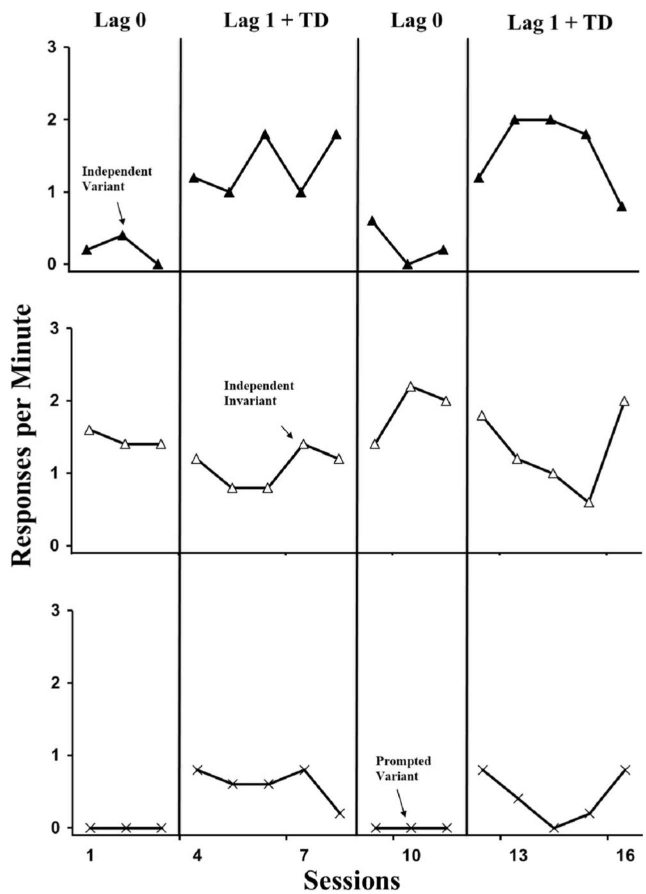

Fig. 1 Rates of independent variant (top panel), independent invariant (middle panel), and prompted variant (bottom panel) signing per session during conditions in which reinforcement was contingent on (**a**) any independent target sign mand topography (Lag 0) or (**b**) variant target sign mand topographies (Lag 1 + TD)

manding (no prompts occurred), an increase in level and a shift to ascending trend in independent invariant manding, and a return to the baseline level of independent variant manding. Reintroduction of the Lag 1 + TD resulted in replications of the changes in prompted variant, independent invariant, and independent variant manding observed in the first Lag 1 + TD condition.

Table 1 provides a summary of cumulative different across-session sign mand topographies and mean independent different within-session sign mand topographies. Figure 2 provides session-by-session cumulative different mand topographies. The cumulative total increased from two in the first session to five by the end of the first Lag 1 + TD session, and the mean different within-session sign mand topographies increased from an overall mean of 1.67 in the Lag 0 conditions to an overall mean of 2.6 in the Lag 1 + TD conditions.

The first author assessed mand response class structure using procedures described in prior research (Richman, Wacker, Asmus, Casey, & Andelman, 1999; Silbaugh et al., 2017). First, he generated transcripts of within-session sign mand topographies, including independent and prompted

Table 1 Summary of cumulative different across-session sign mand topographies and mean independent different within-session sign mand topographies

	First Session	Final Session
Cumulative different across-session sign mand topographies	2	5
	Lag 0	Lag 1 + TD
Mean independent different within-session sign mand topographies	1.67	2.6

target and nontarget sign mand topographies from session videos for all sessions. Next, he determined the relative latencies of each independent sign mand topography for each session on a trial-by-trial basis by assigning a ranking of 1 or 2 based on the order in which the two most frequent sign mand topographies occurred. Last, he calculated the percentage of trials in which a given independent sign mand topography was the first response within a session by dividing the number of trials in which a sign mand topography was given a rank of 1 by the number of trials (i.e., instances of the EO) for the session and converting the quotient to a percentage. For example, in a session in which an EO was presented 10 times, the sign mand topography "want" might be emitted first 8 times and the sign mand topography "toy" might be emitted first 2 times. Therefore, the percentage of trials in which the sign mand topography was ranked 1 for the session would be 80% for "want" and 20% for "toy."

Figure 3 displays the percentage of trials per session in which each of the three most frequently independently emitted sign mand topographies were ranked first. "Want," "clap," and "playdoh" were emitted in a relatively predictable temporal order across trials, mostly during Lag 1 + TD sessions. "Want" was most likely to be emitted first during Lag 0 and Lag 1 + TD conditions (Lag 0: $M = 95\%$ of trials per session; Lag 1 + TD: $M = 83\%$ of trials per session). During the first Lag 1 + TD condition, "clap" ($M = 8\%$ of trials per session) or "playdoh" ($M = 3\%$ of trials per session), in that order, were the second most likely sign mand topographies to be emitted

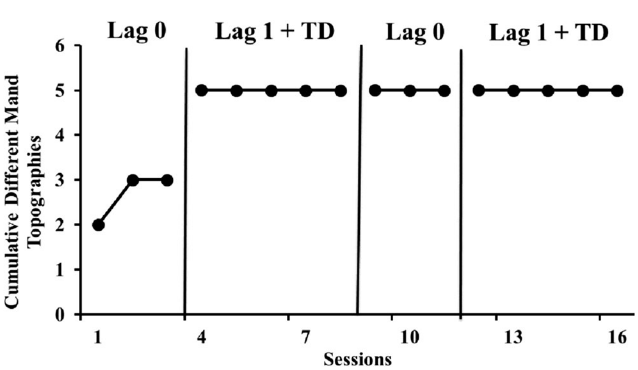

Fig. 2 Cumulative different sign mand topographies exhibited across sessions and Lag 0 and Lag 1 + TD conditions

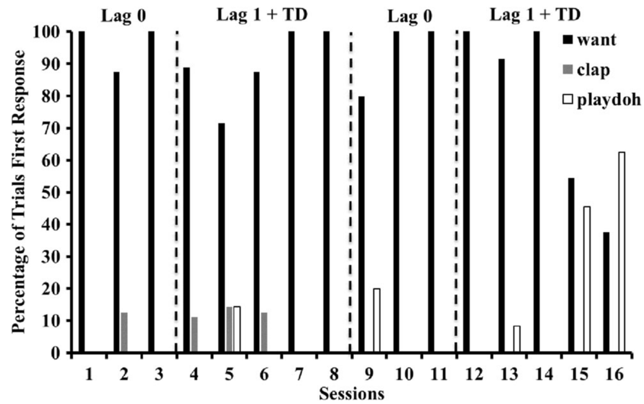

Fig. 3 Percentage of trials per session in which a given independent sign mand topography occurred first during Lag 0 and Lag 1 + TD conditions. Data are displayed for the three most frequent sign mand topographies

first. During the second Lag 1 + TD condition, "playdoh" was the second most likely sign mand topography to be emitted first ($M = 23\%$ of trials per session).

Discussion

Much behavior-analytic research has demonstrated that mand training can increase the manding repertoires of individuals with language delays or deficits (e.g., Shafer, 1994; Sundberg & Partington, 1998; Wallace, 2007). For some, common mand training procedures may produce invariant patterns of manding insensitive to changes in contingencies mediated by a verbal audience. Procedures that reinforce mand variability may mitigate or replace repetitive manding, but unfortunately such procedures are lacking. Therefore, the current study aimed to extend prior research on the reinforcement of mand variability (i.e., Silbaugh et al., 2017) by evaluating the effects of a Lag 1 + TD procedure on the acquisition of new sign mand topographies and topographical sign mand variability. Visual analysis of the results depicted in Fig. 1 suggests a largely nonvocal boy with autism acquired and varied multiple functionally equivalent sign mand topographies when variant and invariant manding contacted the contingencies that composed the Lag 1 + TD condition. This finding is consistent with prior research that suggested mand variability can be directly reinforced (Brodhead et al., 2016; Silbaugh et al., 2017) and provides additional support for the notion that lag schedules are a promising approach to establishing adaptive mand variability.

New insight about mand variability training may be gained by comparing some differences between the current study and the procedures described by Silbaugh et al. (2017). First, Silbaugh et al. (2017) evaluated the effects of the procedures on topographical vocal mand variability in children with autism. However, the current study demonstrated the procedures can also increase nonvocal topographical mand variability (i.e., sign variability). Second, the current study targeted variability within a recently acquired mand with a very brief reinforcement history, whereas Silbaugh et al. (2017) targeted mands with a presumably much longer reinforcement history. This difference may explain why the participants in Silbaugh et al. (2017) did not emit all target alternative mand topographies prompted during sessions, but Allen did. That is, when the outcomes of the two studies are compared, it may be inferred that a mand with a brief reinforcement history relative to a mand with a longer history may be more sensitive to procedures used to incorporate a variety of topographies into the response class, thereby establishing a new mand response class hierarchy. If so, mand variability training may have a more significant clinical impact when implemented early in intervention programming targeting manding. Third, the participants in Silbaugh et al. (2017) exhibited clear reductions in levels of invariant manding when variant manding levels were elevated in Lag 1 + TD conditions, and although prompts were not technically eliminated from the treatment, prompts were not delivered in many sessions for both participants, suggesting that the Lag 1 schedule alone was sufficient to maintain mand variability. In the current study, Allen exhibited relatively similar levels of invariant manding across conditions, and prompts were used in most Lag 1 + TD sessions to evoke a variant response. Additional research is needed to identify variables that determine levels of invariant manding when variant manding is reinforced.

Basic variability research (Odum, Ward, Barnes, & Burke, 2006; Stahlman & Blaisdell, 2011; Wagner & Neuringer, 2006) suggests operant variability may be increased by introducing delays to reinforcement following relatively repetitive baseline responding. In the current study, during Lag 0, the first instance of sign manding emitted in each trial was immediately reinforced. However, because Allen was permitted to emit multiple responses in each trial during Lag 1 + TD sessions until the contingency was met, reinforcer delivery was contingent on variant sign mand topographies but also delayed in relation to early invariant responses in the trial. Thus, it is possible that differences in mand variability between phases in the current study may have been determined by delays to reinforcement in relation to the first response emitted on trials rather than the lag schedule. Future research could further clarify the relative effects of lag schedules and delays to reinforcement on manding by using multiple schedules to compare rates of mand variability across conditions in which (a) reinforcement is delivered according to the lag schedule described in the current study and (b) reinforcement is delivered independent of variant responding but following a brief delay yoked to the average delay to reinforcement under the lag schedule. Relatively elevated rates under the lag schedule would provide additional support for the hypothesis that increased variant manding under a lag schedule is attributable to a dependency between reinforcement and the variant dimension of manding.

Inspection of the data in Table 1 suggests that Allen only emitted approximately the level of sign mand variability required to produce the reinforcer in Lag 1 + TD phases. This finding is largely consistent with the results of prior research (Brodhead et al., 2016; Silbaugh et al., 2017). The cumulative different across-session sign mand topographies summarized in Table 1 demonstrate that Allen acquired five new functionally equivalent sign mand topographies across only 19 (i.e., 3 sessions of pretreatment sign mand training and 16 sessions of sign mand training) 5-min sessions, including the arbitrary sign acquired during pretreatment assessment (i.e., clapping). This finding may be considered particularly striking considering that Allen's team had reported great difficulty with identifying reinforcers that consistently maintained independent manding and that mand training in other modalities (i.e., vocal, electronic devices, card exchange) had largely been unsuccessful.

The relative latencies of the three most frequent sign mand topographies were compared to assess mand response class structure. The data depicted in Fig. 2 show that although Allen emitted high rates of independent variant sign manding during the Lag 1 condition, for the majority of sessions, "want" was the first sign mand topography emitted, which suggests that new sign mand topographies were incorporated into the mand during treatment in a manner that resulted in the formation of a response class hierarchy. In the first Lag 1 + TD condition, the second most frequent sign mand form emitted was the arbitrary clap response established during the pretreatment assessment. By the end of the second Lag 1 + TD condition, the second most frequent sign mand topography emitted was "playdoh," and differences in relative response strength (as assessed by indirect measurement using relative response latencies) between "want" and "playdoh" largely diminished in the last two sessions. Future studies could focus more on variables (e.g., lag schedule value, number of mand topographies targeted, parameters of reinforcement, length of contact with the lag schedule) that may influence the effects of mand variability training on the relative response strength of new members integrated into the response class. That is, such studies might shed some light on how mands, and perhaps by analogy socially mediated challenging behavior, come to be organized probabilistically as new members enter the functional response class.

The current findings may also have theoretical implications related to the emergence of more complex verbal behavior. When Allen varied sign mand topographies within a trial under the lag schedule, he typically emitted the response sequence "want" followed by "playdoh," or "want" followed by "toy." Structurally, these response patterns are equivalent to two-word sentences, suggesting that schedules selective for verbal operant variability and their associated contexts may play an important role in the development of novel word combinations from the members of an existing repertoire and the transition to use of longer-mean-length utterances. In natural environments, the early emergence of mands in the form of sentences may reflect naturally occurring contingencies of reinforcement selective for topographical variability and the formation of mand response class hierarchies consisting of new and existing response forms. Any underlying principle may apply to other verbal operants as well. In some cases, when individuals with language delays or deficits fail to demonstrate an increased mean length of utterance despite intensive high-quality behavioral intervention, the outcome may reflect in part a failure of the program to systematically provide a verbal environment selective for verbal variability, and future avenues of research could investigate these possibilities.

The lack of data on maintenance and social validity is a limitation that should be addressed in future research. In addition, the current study did not evaluate the effects of the Lag 1 condition in the absence of prompts, so additional research in which prompts are eliminated from the current procedures is necessary to evaluate the effects of a Lag 1 schedule alone. Future research could also examine the effects of mand variability training targeting topographical variability during the treatment of challenging behavior using FCT (Carr & Durand, 1985) to assess potential clinical advantages over the traditional approach, which does not use schedules selective for variability. Last, the generality of the current findings is unknown pending replication with additional participants.

Implications for Practice

- Demonstrates how practitioners might combine prompts with lag schedules to teach and reinforce mand variability in children with autism;
- Demonstrates increased topographical sign mand variability attributable to a lag schedule with prompting;
- Provides evidence for the development of a new sign mand response class hierarchy using a lag schedule with prompting.

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Compliance with Ethical Standards

Conflict of interest We report no conflicts of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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