A FURTHER EVALUATION OF VARIABLE-ORDER MODELS ON VARIABILITY DURING THE ACQUISITION OF INTRAVERBAL CATEGORIZATION FOR AUTISTIC CHILDREN

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Individuals with an autism spectrum disorder (ASD) exhibit restrictive or repetitive behavior and, therefore, identifying teaching procedures to improve response variability remains a focus for behavior analysts. Peterson et al. (2019) compared varied responding during a varied-order vocal model and rote-order vocal model condition within an adapted alternating treatment design. They found varied-order vocal models produced varied responding that eventually became invariant. The current project systematically replicated Peterson et al. using a multiple-probe design to determine if varied responding would maintain if participants were not exposed to a rote-order vocal model. Initial variability occurred for all children but responding eventually became invariant. These results suggest the findings from Peterson et al. and the results of the current project may demonstrate the process of varied responding becoming invariant when environmental contingencies do not support varied responding. Researchers should continue this line of study to better understand the conditions that maintain varied responding and to better address invariant responding when necessary. Several areas for additional research are discussed.

Keywords: intraverbal categorization, response variability, vocal prompts

The Centers for Disease and Control Prevention estimated that approximately 1 in 36 children are currently diagnosed with an autism spectrum disorder (ASD; Maenner et al., 2023). ASD is a developmental disability characterized by deficits in social skills and communication as well as the presence of restricted or repetitive behavior and/or interests (American Psychiatric Association, 2013). Restricted and repetitive behavior may be conceptualized as a problem of invariance, and therefore, interventions that increase response variability may help address restricted or repetitive behavior for children with ASD (Rodriguez & Thompson, 2015).

Page and Neuringer (1985) demonstrated response variability can be sensitive to operant contingencies, and several researchers have evaluated many behavior-analytic interventions that could improve this dimension of behavior for individuals with ASD (Wolfe et al., 2014). A review on this topic conducted by Wolfe et al. (2014) revealed that most interventions included either a lag schedule of reinforcement or differential reinforcement of novel responses. A lag schedule of reinforcement entails delivering reinforcement only if the current response differs from a predetermined number of previous responses (Page & Neuringer, 1985). For example, a Lag 3 schedule of reinforcement involves delivering the reinforcer if the current response was different from the previous three responses. Researchers have consistently demonstrated the efficacy of lag schedules for increasing response variability for individuals with ASD (for a review, see Silbaugh et al., 2020). However, one limitation of incorporating lag schedules of reinforcement for children with ASD is the return of invariant responding once

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the lag schedule is removed (Lee et al., 2002; Lee & Sturmey, 2006, 2014).

The necessary yet artificial arrangement of a lag schedule warrants the search for other possible interventions that could promote more durable response variability under more naturalistic conditions. Reviews on response variability (Rodriguez & Thompson, 2015; Wolfe et al., 2014) and lag schedules (Silbaugh et al., 2020) show additional antecedent components (e.g., scripts, vocal models, instructions) are often used, primarily when the reinforcement contingency does not initially improve response variability. Rodriguez and Thompson (2015) suggested varied prompts alone may help offset the natural response narrowing effect of ANY contingencies[1], and they mentioned additional research could focus on the relation between providing varied models and response variability during ANY contingencies.

A couple of studies included such an evaluation (Caroll & Kodak, 2015; Peterson et al., 2019). Caroll and Kodak (2015) evaluated the effects of a varied-vocal model with and without instructive feedback on response variability for two children with ASD during the acquisition of intraverbal categorization (i.e., listing exemplars from a specified category). The researchers provided a vocal model prompt of one exemplar combination (from a list of 20 combinations) during each trial of treatment, and the specific exemplar combination rotated across trials; that is, the vocal model varied across trials, resulting in exposure to 20 different exemplar combinations. During the condition with instructive feedback, the researchers stated three additional exemplars following reinforcement of a correct response or following an error-correction procedure of an incorrect response. To measure response variability, the researchers recorded novel exemplar combinations (e.g., "apple, orange, and banana" vs. "orange, apple, and banana" for the category fruit would be two novel combinations) and cumulative novel exemplars (e.g., "apple, orange, and banana" for one trial and "orange, banana, and watermelon" for another trial would be four novel exemplars).

Caroll and Kodak found that both children emitted more novel exemplars and exemplar combinations during the condition with instructive feedback. The authors did not evaluate the effects of the varied-vocal model when compared to common teaching procedures during discrete-trial instruction (DTI; e.g., prompting and reinforcing the same response across trials). It is possible a varied-vocal model alone (without instructive feedback) could enhance response variability during the acquisition of intraverbal categorization compared to acquisition that occurs with a rote-vocal model (i.e., a common DTI procedure).

Peterson et al. (2019) used an adapted alternating treatments design to compare varied-order vocal models and rote-order vocal models during intraverbal categorization training for four children diagnosed with ASD to address the possibility that varied-order vocal-model prompts could improve response variability during DTI. During the rote-order prompt condition, the researchers provided a vocal model of one exemplar combination across all trials. During the varied-order prompt condition, the researchers provided a vocal model of four exemplar combinations, rotating the specific combination prompted across trials. They recorded the number of unique response sequences to measure response variability. Peterson and colleagues found a greater number of unique response sequences initially during the varied-order prompt condition compared to the rote-order condition for three of four children, and initial variability occurred in both conditions for the fourth child. For all children, responding in both conditions eventually became invariant.

It is possible the eventual invariant responding found in Peterson et al. (2019) could have been due to a lack of contingencies to support maintenance of varied responding. In other words, reinforcement contingencies favored correct responding, regardless of whether responding was varied or rote. Another possibility is that invariant responding occurred during the varied-order vocal-model condition due to the rapid alternation with the rote-order vocal-model condition (see p. 60 of Hains & Baer, 1989). Rote responding occurred and contacted reinforcement during the rote-order vocal model condition, which could have influenced the

[1] Rodriguez and Thompson (2015) define an ANY contingency as one that would allow but not require varied responding. For example, when asked "how are you?" by a coworker, you could respond "fine, thanks" each time or vary your response across interactions (e.g., doing alright, doing well, pretty good). The coworker's response (and therefore possible reinforcement) will likely not depend on whether your response varies across interactions.

Table 1. Demographic Information for all Children

Participant	Age	Intraverbal Assessment Score	EVT Score (age equivalence)	PPVT Score (age equivalence)
Carl	4:10	50	92 (4:3)	96 (4:8)
Dan	4:10	52	96 (4:1)	97 (4:8)
Frank	5:4	34	81 (3:11)	72 (3:3)
Amy	5:6	56	97 (5:3)	88 (5:4)
Eric	5:6	53	105 (5:10)	107 (6:2)
Ben	6:11	75	107 (7:8)	120 (8:9)

Note. EVT = Expressive Vocabulary Test; PPVT = Peabody Picture Vocabulary Test.

occurrence of rote responding during the varied-order vocal model condition. Therefore, it is still uncertain if a varied-order vocal model, when implemented for sufficient length separated from a rote-order vocal model, could support continued response variability during the acquisition of intraverbal categorization for children with ASD during DTI. Thus, the purpose of the current study was to systematically replicate Peterson and colleagues to evaluate the use of a varied-order vocal model with a multiple-probe design (rather than an alternating treatment design) to eliminate exposure to a rote-order vocal model.

METHOD

Participants, Setting, and Materials

Six children (one female, five males; aged 4:10 – 6:11) diagnosed with ASD completed the study. All children received approximately 3 to 25 hours/week of early behavioral intervention services from a university-based medical center, and all children had intraverbal treatment plan goals at the time of the study. We conducted three assessments at the onset of the study to collect additional information regarding the children's current skill level for intraverbals (i.e., Intraverbal Assessment Subtest; Sundberg & Sundberg, 2011), receptive vocabulary (i.e., Peabody Picture Vocabulary Test – IV; Dunn & Dunn, 2007), and expressive vocabulary (i.e., Expressive Vocabulary Test – 2; Williams, 2007). Table 1 shows the demographic information for all children. The researchers conducted all sessions in a partitioned therapy room that contained a table, chairs, several preferred items, data sheets, and writing utensils.

Response Measurement, Interobserver Agreement, and Procedural Integrity

The primary dependent variables included correct independent responses and the number of different orders of listed exemplars. We defined correct independent responses as the child listing three exemplars in any order for the category provided prior to the delivery of the vocal-model prompt. We totaled the number of correct responses for each session. We defined a different order as the child emitting three correct exemplars in an order that was not yet provided within the session, and we totaled the number of different orders emitted for each session. For example, if the therapist said, "Tell me three types of fruit," and the child stated "orange, apple, and banana" for the first trial of the session and "banana, orange, and apple" for all remaining nine trials, the researcher documented 10 correct responses and two different orders for the session.

An independent observer measured all dependent variables and procedural integrity (PI) for 30 – 48% of sessions dispersed across all conditions for all children. To calculate the exact agreement between the data collector and independent observer, we divided the number of trials for which an agreement occurred by the number of trials with agreement plus the number of trials with disagreement; we then multiplied the decimal by 100 to produce a percentage. Mean IOA scores for correct responding and number of different orders were 89 – 100% and 99 – 100%, respectively.

The independent observer measured PI for the therapist providing the vocal-model prompt at the prescribed delay and for the prescribed order of the exemplars (described more below). We calculated PI by dividing the number of trials for which the therapist provided the prompt at

the prescribed delay (or the prescribed order) by the total number of trials in the session and multiplying by 100 to result in a percentage. Mean PI scores were 99% - 100% for both the prompt delay and prompt order. See Table 2 for more detailed IOA and PI scores for all participants.

Procedures

The project included one phase of category and exemplar selection assessments, one phase of baseline, and a final phase of a prompt evaluation (all described more below). We conducted sessions one to four days a week, with one to four sessions a day. During the category and exemplar selection assessments, sessions consisted of 12 trials. During baseline and the prompt evaluation, sessions consisted of 10 trials.

Preference Assessment

The researchers used a one-trial preference assessment (e.g., Coon & Miguel, 2012; Susa & Schlinger, 2012) to identify an item to provide as a putative reinforcer. Prior to each session, the researcher presented an array of items or pictures of activities the child typically engaged with during clinical sessions and instructed the child to "pick one." The researcher delivered the selected item or activity during intervals for the remainder of the session. However, if the participant requested a different item at any point during the session, the researcher provided the requested item rather than the one selected during the one-trial preference assessment. The researcher conducted another one-trial preference assessment to identify a new item if the participant did not consume or interact with the requested item during the next reinforcement interval.

Category and Exemplar Selection

The researchers consulted with each child's clinical team and caregivers to create an initial list of at least 10 categories each child contacted in their daily lives (e.g., clothing, sports). To identify target categories and exemplars, the researchers conducted 12-trial sessions that consisted of four blocks of three trials, with a different category assigned to each block. One trial consisted of the researcher providing the instruction "Tell me three [category]," with the specific category assigned for that particular trial block. The researcher waited 5 s for the child to provide a response and continued to the next trial if the child did not list any correct exemplars within the initial 5 s. If the child did state a category exemplar, the researcher provided praise after each exemplar listed. If the child listed only one or two exemplars, the therapist waited 3 s, asked "Anymore?" and continued to praise additional correct exemplars. The researcher delivered the preferred item (i.e., one edible or 30-s access to a toy, video, or game) after responding ceased for 5 s following the "Anymore?" prompt. These sessions continued until the researchers identified two categories for

Table 2. Interobserver Agreement (IOA) and Procedural Integrity (PI) Scores

Participant	% of Sessions	% IOA for Correct Responses	% IOA for Order (range)	% PI for Prompt Time	% PI for Prompt Order
Carl	43.75	100	98.57 (90 – 100)	100	100
Dan	30	88.89 (0 – 100)	98.89 (90 – 100)	100	98.89 (90 – 100)
Frank	47.83	100	99.09 (90 – 100)	100	100
Amy	30.43	100	100	99.29 (90 – 100)	100
Eric	47.62	100	99 (90 – 100)	100	100
Ben	34.37	100	99 (90 – 100)	100	100

which the child did not provide any correct exemplars.

After the researchers identified two target categories, they conducted an echoic and tact assessment to identify three target exemplars for each category. In consultation with the clinical team and caregivers, the researchers created an initial list of at least six exemplars for each target category for each child. The echoic and tact assessments consisted of six blocks of two trials, with a different exemplar assigned to each block. The echoic assessment consisted of the researcher stating, "Say [exemplar]," allowing 5 s for a response and providing praise and the preferred item contingent on a correct response. The researcher continued with the next trial if a correct response did not occur within 5 s of the instruction. The researchers conducted the tact assessment in the same manner, except the researcher asked, "What is it?" while showing a picture of the target exemplar. We selected target exemplars for each category if the child responded with 100% accuracy during both the echoic and tact assessment. When more than three exemplars met these criteria, we selected the exemplars we perceived as the three most dissimilar exemplars based on the auditory sound of a vocal model. See Table 3 for the specific categories and exemplars selected for all children.

Table 3. Target Category and Exemplars for all Children

Child	Category	Exemplars
Amy	Sports	Ballet, Football, Swimming
	Vehicles	Bicycle, Car, Truck
Ben	Mammals	Dog, Lion, Rabbit
	Condiments	Sauce, Syrup, Mustard
Carl	Sports	Baseball, Soccer, Swimming
	Insects	Butterfly, Ladybug, Spider
Dan	Outdoor Sports	Baseball, Football, Soccer
	Winter Clothes	Boots, Gloves, Scarf
Eric	Utensils	Fork, Marker, Pencil
	Sports	Football, Hockey, Soccer
Frank	Insects	Bee, Butterfly, Ladybug
	Sports	Basketball, Soccer, Swimming

Baseline

We evaluated the use of a progressive-prompt delay with varied-order vocal models (PPD+VOM) during the acquisition of intraverbal categorization within a multiple probe across categories design. During baseline, we conducted 10 trials for one category during each session. Each trial consisted of the researcher providing the instruction "Tell me three [category]" and allowing 5 s for a response. The researcher continued with the next trial after 5 s without any correct exemplars listed. Due to the category assessment selection process, none of the children could emit correct exemplars for the categories included. Had this occurred during baseline, we would have provided praise and the preferred item; we would have then omitted that category from the project for that child and identified another category instead.

Prompt Evaluation

During PPD+VOM, we first provided a 0-s prompt delay for at least two sessions. During this phase, the researcher provided the instruction "Tell me three [category]" and immediately provided a vocal model prompt of the three target exemplars. We randomized the prompted order of the three target exemplars across trials, using four (of the six) possible orders to expose the children to varied orders while allowing the opportunity for the children to emit a novel order not previously prompted. The researcher provided general praise and the preferred item (as described above) following a correct prompted response. The children did not need to list the exemplars in the same order as prompted to be considered correct.

After at least 9 trials occurred with correct prompted responding for two consecutive sessions, we increased the prompt delay to 2 s. During this phase, the researcher provided the instruction and waited 2 s for the child to respond. If the child emitted an independent correct response during the 2-s delay, the researcher provided praise and the preferred item. Similar to the 0-s prompt delay phase, the child could list exemplars in any order and

contact reinforcement (i.e., ANY reinforcement contingency; Rodriguez & Thompson, 2015). If the child did not respond during the delay, the researcher then provided the vocal-model prompt and implemented the procedures described above for the 0-s prompt delay. If the child provided an incorrect response during the delay (e.g., saying "cat" after the instruction "Tell me three types of fruit."), the researcher repeated the instruction and immediately provided a vocal-model prompt. After two sessions of the 2-s prompt delay condition, we delivered the preferred item only contingent on independent correct responses (i.e., differential reinforcement of unprompted responses; Karsten & Carr, 2009). The criteria for mastery was 90% correct responding across two consecutive sessions. However, we conducted sessions beyond mastery to evaluate the persistence of response variability. We discontinued sessions when the child listed three correct exemplars in the same order for all trials for three consecutive sessions.

RESULTS

Figure 1 shows the number of correct responses that were either prompted (open circles) or independent (closed circles) during the Baseline and Prompt Evaluation phases for Frank (left panel) and Eric (right panel), with the introduction of the prompt evaluation staggered across two categories for both participants (i.e., Insects and Sports for Frank; Utensils and Sports for Eric). Correct responding increased only after the introduction of the PPD+VOM for both categories for Frank and Eric, demonstrating PPD+VOM during the prompt evaluation was efficacious for both participants.

Figure 1 also shows the number of different orders Frank and Eric emitted for listing three exemplars when researchers provided a vocal-model prompt (gray bars) and when children provided exemplars independently (black bars). When researchers provided a 0-s prompt, Frank emitted one to three orders during each session for both categories, which is less than the four (of six possible) orders prompted. When researchers increased the prompt delay to 2s, Frank emitted more than one order independently for one session of the Insect category and for three sessions of the Sports category; responding then became invariant, meeting the discontinuation criteria for invariance after seven and eight sessions of the prompt evaluation for the Insect and Sports categories. For Eric, the 0-s varied-order vocal-model prompt resulted in four different orders for both categories; he echoed the vocal model provided during these sessions. When researchers provided a 2-s prompt delay,

Figure 1. Results for Frank (left panel) and Eric (right panel)

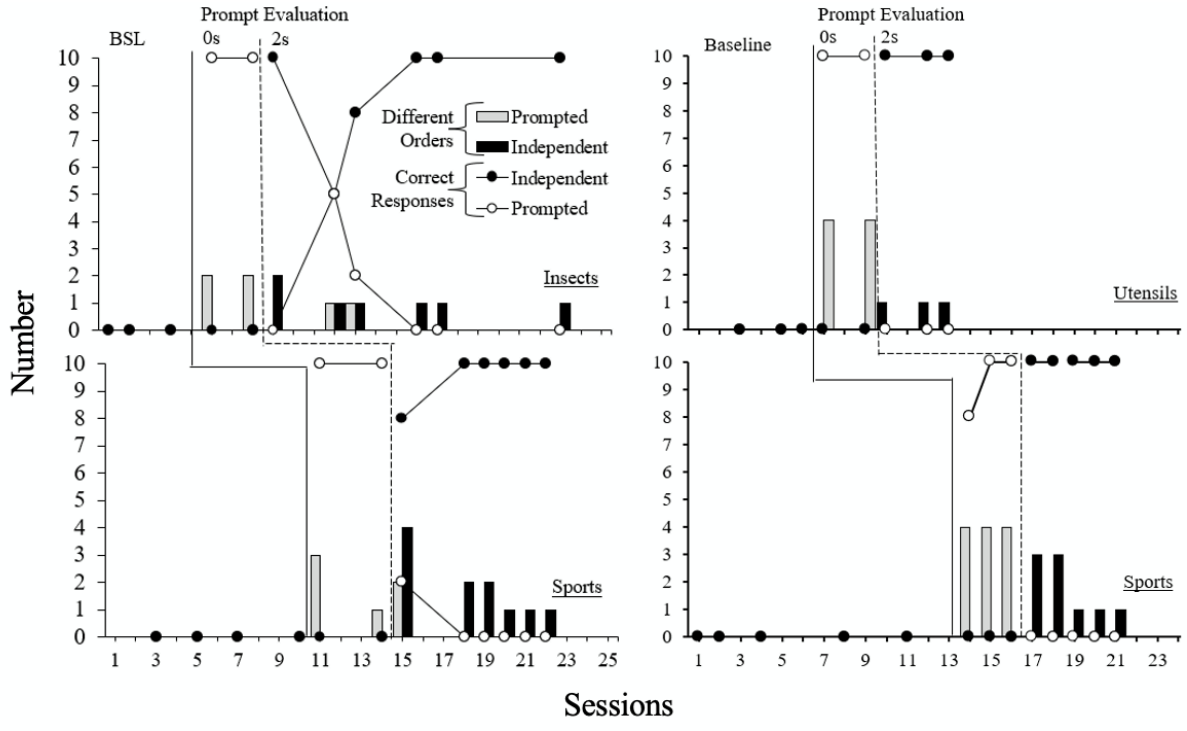
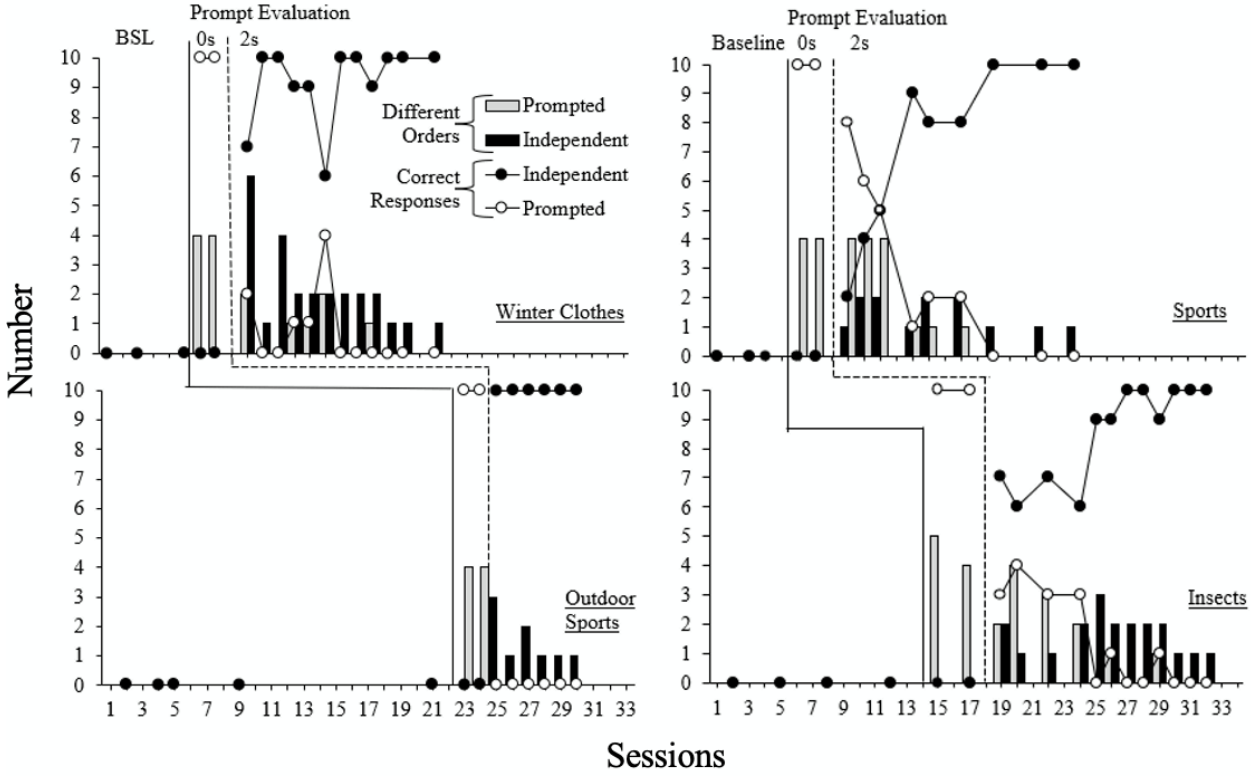


Figure 2. Results for Dan (left panel) and Carl (right panel)



Eric emitted only one order independently for the Utensils category and emitted three different orders for two sessions of the Sports category before responding became invariant. Eric's responding met the discontinuation criteria for invariant responding after five and eight sessions for Utensils and Sports, respectively. The results in Figure 1 demonstrate the PPD+VOM produced varied responding initially for both Frank and Eric but responding ultimately became invariant.

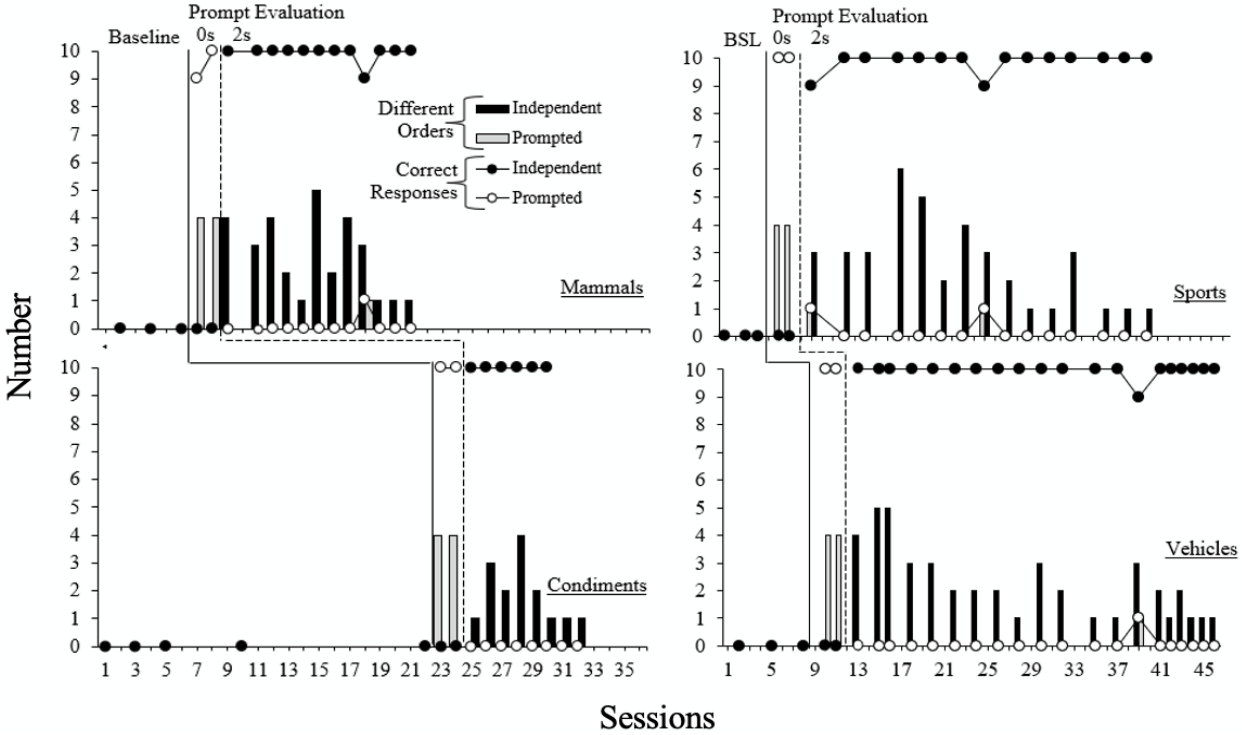
Figure 2 shows similar results for Dan (left panel) and Carl (right panel). The PPD+VOM increased intraverbal categorization and produced initial response variability that eventually became invariant for both participants. Reviewing the results for response variability more closely, Dan echoed the varied-vocal model-prompts during the 0-s prompt delay phase for both categories; varied responding continued independently with the 2-s prompt delay, and he emitted two novel orders not previously prompted during one session for Winter Clothes. Carl also echoed the prompts with a 0-s prompt delay for both categories, and he emitted one novel (unprompted) order during one session for Insects. Carl's responding required additional prompts with a 2-s delay, and he independently emitted at least two orders for both categories. Responding for both participants became invariant for all categories after 8 – 14 sessions within the prompt evaluation.

Similar findings can be seen in Figure 3 for Ben (left panel) and Amy (right panel). Intraverbal categorization improved with the PPD+VOM, and initial response variability occurred. Both children echoed the vocal models provided during all categories, and their responding remained varied independently with a 2-s prompt delay. In addition, Ben emitted one novel (unprompted) order for one category, and Amy emitted up to two novel orders for both categories. However, responding eventually became invariant for both participants and categories after 10 – 22 sessions within the prompt evaluation. Although PPD+VOM improved intraverbal categorization and produced initial response variability, all children eventually listed the same three exemplars in the same order during all trials for three consecutive sessions.

DISCUSSION

The current study systematically replicated Peterson et al. (2019) by using a multiple-probe

Figure 3. Results for Ben (left panel) and Amy (right panel)



design to evaluate the use of a varied-order vocal model on response variability during the acquisition of intraverbal categorization with children with ASD. For all children, initial variability occurred, and responding eventually became invariant. These results provide some evidence to suggest the results from Peterson and colleagues may not have been due to exposure to the rote-order vocal model included in the second condition of the adapted alternating treatment design. Rather, it is possible the results of the current study and the results of Peterson et al. demonstrate the process of responding becoming invariant (see also Glodowski & Rodriguez, 2019 for another example). In both studies, the reinforcement contingency implemented allowed for any correct response sequence to contact reinforcement rather than one specific correct response. However, the process of reinforcement increases the future probability of the response that resulted in reinforcement. Therefore, across trials (and instances of reinforcement), behavior eventually became invariant, although the specific reinforcement contingency would have allowed (but not required) continued response variability.

Although the current study contributes to the growing body of literature on better understanding and improving response variability for children with ASD, there are a couple of limitations that should be noted. One limitation includes the lack of incorporating teaching procedures that could lead to the emergence of intraverbal categorization (e.g., identification of categorical items; Grannan & Rehfeldt, 2012; Miguel et al., 2005). It may be possible that higher levels of variability occur following these types of teaching procedures. Additional research could compare the effects of varied-order vocal modeling and the effects of procedures likely to result in the emergence of behavior on response variability.

Another limitation of the current study is that each session consisted of 10 trials of the same category, which could lead to faulty stimulus control and the eventual occurrence of invariant responding. We used this arrangement to remain consistent with previous research on response variability during the acquisition of intraverbal categorization (e.g., Lee & Sturmey, 2006; Susa & Schlinger, 2012), and future research should evaluate whether including multiple target categories within a session influences continued response variability.

There are several additional avenues for ongoing research in this line of study. The current study only included three target exemplars for each category, whereas Caroll and Kodak (2005) incorporated multiple primary and

secondary target exemplars that allowed children to be exposed to more than 20 exemplar combinations across trials. It is possible that higher levels of variability occur when teaching procedures include more responses that could satisfy the reinforcement contingency. Therefore, future research could consist of an evaluation of the number of exemplars included on response variability during the acquisition of intraverbal categorization.

In addition, Peterson et al. (2019) and the current project extended Carroll and Kodak (2015) by evaluating the influence of varied-vocal models without instructive feedback on response variability. Future research could entail evaluations of rote-vocal models with instructive feedback, or evaluations of instructive feedback alone, on response variability. This line of research would help determine the effects of various treatment components, or the combination thereof, on response variability for individuals with ASD during the acquisition of intraverbal categorization.

Furthermore, although previous researchers evaluated variability of intraverbal categorization, additional research should be conducted on other responses. For example, a line of research on response variability includes the use of lag schedules on mand variability during functional communication training for individuals who engage in problem behavior (e.g., Adami et al., 2017; Silbaugh & Falcomata, 2019; Silbaugh et al., 2020). Certainly, restricted behavior of children with ASD could occur across multiple responses, and therefore, future research should focus on how to improve variability of responses relevant to specific treatment goals. Somewhat related, it may be likely that individuals with ASD engage in repetitive behavior across several response topographies and in multiple settings; therefore, a fruitful avenue of research could also be evaluating the generalization of treatment effects for varied responding across various topographies and settings.

Related to response generalization, it is possible that the level of severity of restricted or repetitive behavior for individuals with ASD (e.g., Bodfish et al., 1999) may influence responsiveness to various interventions that target response variability. For example, Frank did not echo all four orders when a 0-s prompt was provided, and his responding became invariant after fewer sessions compared to the other participants. Anecdotally, his responding across various response topographies and settings outside this research project seemed more restricted and repetitive. Additional research could evaluate possible correlations among the severity of restricted and repetitive behavior and various aspects of treatment effects (e.g., initial improvements, maintenance, generalization).

Moreover, continued research should focus on identifying interventions that produce varied responding that maintains over time for individuals with ASD. Our findings show varied responding does not maintain when reinforcement contingencies would allow but does not require it. Although a growing body of literature shows the efficacy of lag schedules of reinforcement on response variability, responding becomes invariant when lag schedules are no longer implemented (e.g., Lee et al., 2002; Lee & Sturmey, 2006). In addition, several studies demonstrated the occurrence of initial response variability with various prompting strategies during skill acquisition that eventually becomes invariant across time (e.g., Glodowski & Rodriguez, 2019; Peterson et al., 2019). Therefore, researchers have yet to determine interventions that effectively support continued response variability for individuals with ASD. One area of research that would more directly address the maintenance of varied responding could include evaluations of intermittent schedules of reinforcement. That is, lag schedules, various prompts, or both may help establish initial varied responding; thereafter, transitioning to an intermittent schedule of reinforcement for instances of varied responding could help maintain varied responding.

In addition to identifying the conditions to establish and maintain varied responding for individuals with ASD, it could be worthwhile to determine the conditions under which varied and invariant responding occurs for individuals regardless of diagnosis in natural settings. This line of research could help reveal existing contingencies that maintain varied responding as well as the conditions of invariant responding that may not pose a socially significant concern. Ultimately, better understanding the natural contingencies surrounding varied responding could help inform possible intervention when invariant responding is a target for treatment.

In conclusion, given restricted or repetitive behavior is a common characteristic of individuals with an ASD, identifying treatments to improve and maintain response variability seems worthwhile. Continued evaluations such

as the current project and the additional research suggested could yield beneficial information to better understand response variability and ultimately better treat invariant responding when such response patterns are of social significance.

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