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Evaluating the Emergence of Reverse Intraverbals in Children with Autism

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Abstract Verbal behavior plays a fundamental role in the development of complex social and communication skills. Many children diagnosed with autism spectrum disorder exhibit profound deficiencies in intraverbal repertoires and the development of social relationships. Recent studies that investigated the effects of intraverbal training on the emergence of reverse intraverbals produced mixed results (e.g., Perez-Gonzalez et al., Journal of Applied Behavior Analysis 40:697–701, 2007)). In the current study, a multiple-probe design across four participants with autism was used to evaluate the effects of intraverbal training on the emergence of reverse intraverbals. Intraverbal training consisted of multiple exemplars taught concurrently, bidirectional stimulus-response teaching formats, general case analysis, reinforcement, and a constant prompt delay (CPD) procedure. Participants were trained on intraverbal targets and probes were conducted to assess emergence of untaught reverse intraverbals. Three participants demonstrated the emergence of reverse intraverbals as a result of the intraverbal training procedures. Social validity and maintenance of target responses and emergent reverse intraverbals were assessed.

Keywords Autism · Emergence · Intraverbal training · Verbal behavior

Functional intraverbal skills play a pivotal role in social interactions and provide the foundation for more advanced communication skills such as describing or recalling events, solving problems, requesting assistance, asking questions, categorizing, and telling stories (Ingvarsson and Hollobaugh 2011; Ingvarsson and Le 2011; Kisamore et al. 2011; Miguel et al. 2005; Sundberg and Sundberg 2011). Appropriate verbal

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interactions typically lead to other opportunities for social reinforcement in various social or academic settings (e.g., participating in classroom discussion, joining clubs).

Tact-to-intraverbal (Goldsmith et al. 2007), echoic-to-intraverbal (Bloh 2008; Ingvarsson and Le 2011), receptive-to-intraverbal (Bloh 2008), and textual-to-intraverbal (Finkel and Williams 2001; Vedora et al. 2009) procedures for transferring stimulus control have proven effective for establishing intraverbals. Results of comparison studies indicate that echoic-to-intraverbal is more efficient than tact-to-intraverbal transfer for some learners (Ingvarsson and Le 2011), tact-to-intraverbal is more efficient than echoic-to-intraverbal transfer for other learners (Ingvarsson and Hollobaugh 2011), and that textual-to-intraverbal is more efficient than echoic-to-intraverbal for some learners (Finkel and Williams 2001; Vedora et al. 2009). The efficiency of each procedure is likely a product of participant learning history (Coon and Miguel 2012).

Given the vast number of intraverbals in typical social exchanges, identifying teaching procedures that result in emergent verbal responses may save instruction time, a commodity that is often at a premium for individuals with autism spectrum disorders (ASDs). A response is said to emerge when it has not been directly taught and reinforced (Perez-Gonzalez et al. 2008; Sidman and Tailby 1982). For example, a child is taught the echoic response "moo" when presented with the antecedent verbal stimulus "What does a cow say?" Then, without further training, the child emits the verbal response "cow" when presented with the antecedent verbal stimulus, "What animal says moo?"

Perez-Gonzalez et al. (2007) investigated the emergence of a symmetrical intraverbal relation (i.e., the B-A relation) following training of an A-B relation with two children diagnosed with pervasive developmental disorder (PDD). They referred to the symmetrical intraverbal relation as the "reversible intraverbal relation." Experimenters developed several sets of targets consisting of pairs of unrelated intraverbals (e.g., "Name the opposite of cold" [hot] and "Name the opposite of long" [short]) referred to as "original intraverbals" and their reverse relations (e.g., "Name the opposite of hot" [cold] and "Name the opposite of short" [long]). For each set of targets, the experimenters followed a multistep process. Baseline was conducted in step 1, intraverbal training was initiated in step 2, and probe trials were conducted in step 3. Training of reverse intraverbals was conducted in step 4 using identical procedures to step 2. Results showed that neither participant produced the target reverse intraverbals until they had a history of those relations being directly taught.

One potential limitation of Perez-Gonzalez et al. (2007) was the number of components comprising the antecedent verbal stimulus. It is unclear which component in the antecedent verbal stimuli (e.g., "What's the opposite of cold?" [hot]) may have controlled responding. For example, only the stimulus "cold" could have evoked the correct response (i.e., "hot"), whereas the stimulus "opposite" may not have exerted appropriate stimulus control over the participants' responding. For further discussion regarding complex antecedent verbal stimuli, the reader should see Axe (2008), Michael et al. (2011), and Sundberg and Sundberg (2011). Additional research is needed to evaluate whether individuals might demonstrate emergent responses when simple antecedent verbal stimuli are used. As such, we chose to use single words as antecedent verbal stimuli in the current study to prevent interference by responses that may have already been under the control of potential contextual stimuli.

Another possible explanation for the participants' failure to demonstrate emergence prior to a history of instruction of reverse intraverbals in Perez-Gonzalez et al. (2007) is that the number of intraverbal targets taught in each set may have been insufficient to produce the desired results. It is possible that training with multiple A-B relation examples concurrently (rather than the pair of targets used in Perez-Gonzalez et al.) would have facilitated generalization to subsequent reverse (B-A) intraverbal relations (Rosales et al. 2011; Stokes and Baer 1977). Several researchers have employed this strategy to teach a variety of skills to children with autism including daily living skills, sharing, and offering assistance (e.g., Horner et al. 1987; Marzullo-Kerth et al. 2011; Reeve et al. 2007). The findings of these studies support Stokes and Baer's (1977) assertion that generalization to untrained responses or stimulus conditions can be programmed through the training of sufficient exemplars.

Multiple exemplars, however, may not be enough to promote an optimal level of generalized responding. Some instructional protocols include the full range of stimulus variations and response requirements in the generalization setting (Cooper et al. 2007). For example, Sprague and Horner (1984) demonstrated that this general case strategy promoted the general use of vending machines for six high school-aged participants. Given these findings and the lack of research on the potential utility of general case analysis in the verbal behavior domain, investigating whether general case analysis may facilitate generalization of intraverbal responses seems warranted. For example, if typical instruction involves training intraverbals using a similar antecedent verbal stimulus (e.g., "The [animal] says [sound]" as exemplified by "The cow says" [moo]), individuals may struggle to respond appropriately when the reverse is tested (e.g., "[Sound] says the [animal]" as exemplified by "Moo says the" [cow]) because they have not been exposed to that antecedent stimulus format.

Therefore, in contrast to the study of Perez-Gonzalez et al. (2007) that trained pairs of intraverbals, the present study implemented multiple-exemplar training (Cooper et al. 2007); that is, ten exemplars (e.g., city-state and state-city relations) were trained concurrently to facilitate generalization to untrained responses (Stokes and Baer 1977). In addition, a general case strategy consisting of bidirectional teaching formats (i.e., both A-B and B-A relations) was used to expose participants to a larger range of stimuli and responses. It was predicted that implementation of both multiple-exemplar training and general case analysis as described would produce the desired results Thus, the purpose of the study was to extend previous research (Perez-Gonzalez et al. 2007) on the emergence of reverse intraverbals in children with autism by (a) using bidirectional stimulus-response teaching formats, (b) teaching multiple exemplars concurrently with a general case strategy to identify a full range of exemplars, (c) using single-word antecedent verbal stimuli, (d) assessing maintenance, and (e) assessing social validity of emergent intraverbal responding.

Method

Participants

To be eligible for participation in this study, participants had to demonstrate the following prerequisite skills: (a) attending, defined as sitting upright with hands on

the table or lap, feet on the floor, and the body positioned toward the experimenter; (b) eye contact, defined as looking at the experimenter in the eye when an antecedent verbal stimulus was presented; (c) generalized vocal imitation, defined as providing an echoic response following a novel antecedent verbal stimulus; (d) tacting, defined as identifying an object or action when presented with a picture depicting that object or action (50–100 tacts; Sundberg 2008); and (e) receptive discrimination, defined as identifying an object or action when presented with a three-picture array and instructed to point to or touch the photo depicting that object or action (50–100 objects or actions; Sundberg 2008). Additionally, participants had to demonstrate deficient intraverbal repertoires and low levels of problem behavior. Evaluations to determine if potential participants met inclusion criteria were conducted prior to the study by the staff at the participants' school. The first four participants who met the prerequisite skills and inclusion criteria were enrolled in the study. None of the selected participants had a previous history of explicitly taught reverse intraverbals in their verbal behavior programs.

Four males who attended a private school for individuals with ASDs participated. All participants had received an independent diagnosis of autism by a physician at least 5 years prior to enrollment in the study. Additionally, parents of the participants completed The Gilliam Autism Rating Scale—Second Edition (GARS-2; Gilliam 1995) to document the occurrence of behaviors characteristic of ASD. Parental ratings for all participants indicated a high probability of autism.

Ray was 18 years old and had received intervention based on the principles of applied behavior analysis (ABA) since age 2 years. Ray obtained a standard score of 71 on the Expressive Vocabulary Test—Second Edition (EVT-2; Williams 2007) and performed all or nearly all skills through level 3 on the mand, tact, listener, and intraverbal subtests from the Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP; Sundberg 2008). Additionally, he performed all skills on the echoic subtest from the VB-MAPP.

Eric was 9 years old and had received intervention based on the principles of ABA since age 6 years. He had a standard score of 78 on the EVT-2. On the VB-MAPP, Eric demonstrated the majority of skills through level 3 for the tact, listener, and intraverbal subtests. He demonstrated all skills on the echoic subtest and was performing at level 2 for the mand subtest.

Alan was 12 years old and had received ABA-based intervention since age 4 years. On the EVT-2, Alan obtained a standard score of 75. He performed all or nearly all skills through level 3 on the mand, tact, listener, and intraverbal subtests on the VB-MAPP. He also demonstrated all skills on the echoic subtest of the VB-MAPP.

Tony was 9 years old and had received ABA-based intervention since age 7 years. Tony scored 51 on the EVT-2 and demonstrated some skills from levels 1 to 2 on the mand, tact, listener, echoic, and intraverbal subtests of the VB-MAPP.

Setting and Materials

All baseline, treatment, and maintenance sessions were conducted in the participants' school. The designated areas contained desks, phones, computers, filing cabinets, a copy machine, a long table, and chairs.

Laminated two-dimensional pictures depicting the outline of a map of the USA and European countries, as well as football team logos, animals, and common objects were used during tact and listener pretests and during baseline and training sessions in mastered task trials. Tokens, token boards, and edibles were also used during training. A laptop computer was used to provide echoic prompts during intraverbal training and a small video camera was used to record some sessions. Instruction was delivered in a one-to-one format with the experimenter seated across from the participant during all pretest and experimental sessions.

Response Measurement, Interobserver Agreement, and Procedural Integrity

The experimenter served as the primary observer and scored the occurrence of the following dependent variables: correct unprompted responses, incorrect unprompted responses, correct prompted responses, and incorrect prompted responses. Correct unprompted responses were defined as the participant providing the target response within 5 s of the experimenter presenting the antecedent verbal stimulus. An incorrect unprompted or prompted response was scored if the participant provided an error of commission (i.e., incorrect answer) or omission (i.e., did not respond) within 5 s of the presentation of the antecedent verbal stimulus or the echoic prompt, respectively. A correct prompted response was scored if the participant provided a target response within 5 s of the presentation of the echoic prompt.

A secondary observer collected data for interobserver agreement (IOA) purposes during a minimum of 32 % of sessions. IOA data were calculated on a trial-by-trial basis. The number of agreements were divided by the number of agreements plus disagreements and multiplied by 100. Mean reliability was 100 % for all participants across sessions during the first evaluation and replication for Eric and Ray.

An independent observer collected procedural integrity data during a minimum of 32 % of sessions. The observer scored each of the following components as correct or incorrect: (a) presentation of antecedent stimuli, (b) delivery of vocal prompt within the predetermined interval, (c) implementation of the error correction procedure, and (d) appropriate reinforcer delivery. All procedural steps for a trial had to be implemented accurately for the entire trial to be scored correct. Procedural integrity was 100 % for all four participants across sessions in the first evaluation and 100 % for both participants across sessions in the replication.

A second observer also collected procedural integrity data during a minimum of 16 % of sessions for IOA purposes. IOA on procedural integrity was 100 % for all participants across sessions in the first evaluation and 100 % for both participants across sessions in the replication.

Preference Assessment and Reinforcement Systems

Preference and reinforcer assessments were conducted with the participants at the time of their initial enrollment in their current school placement, prior to their enrollment in the current study. A motivational system (i.e., token economy) was established for each individual (see below for a description of each participant's token economy) based on these assessments. Training with token economies was initiated for each participant

upon placement in the school, and token economies had been used with each participant since that training. Thus, all participants had long histories with token economies.

Ray's token economy was a monetary value system that involved dollar and cent amounts written on a small white board upon completion of various activities. A list of preferred snacks and activities was taped to the back of the white board and Ray could exchange the money he earned at various times throughout the day for these preferred items. Eric and Alan's token economies consisted of them earning dimes contingent on correct responses during their academic and social skills programs. Once 20 dimes were earned, Eric and Alan could exchange them for a wide range of preferred activities or edibles. Tony's token economy involved earning pennies for correct responses during academic programs. Once he earned ten pennies, Tony could exchange them for a preferred item. The experimenter used each participant's token economy during the current evaluation. Ray exchanged the money he accrued on his white board for a preferred activity or snack at the conclusion of each session. Eric, Alan, and Tony exchanged their respective tokens at the conclusion of each session for preferred activities that were restricted to this study. Additionally, edibles identified through teacher surveys were used during training for Eric, Alan, and Tony to reinforce correct unprompted responses. These edibles were restricted for use in the current study.

Pre-experimental Procedure

A pool of potential targets were selected for each participant by the clinical director at the participants' school, and behavior analysts assigned to oversee the participants' individualized educational programs in terms of social relevance and academic skill. For example, NFL teams were selected for Ray because he enjoyed watching football with his family. States and cities were selected for Eric and Alan based on their advanced academic skills, and simple word associations were identified for Tony based on his tact and listener repertoire. The experimenter conducted intraverbal, tact, and listener pretests prior to assigning stimuli and beginning the evaluation. Once pretests were completed, intraverbals were assigned to teaching conditions (see below for additional information).

Intraverbal Pretest Intraverbal pretests were conducted to determine if target intraverbals were already in the participants' repertoires. During the pretest, target intraverbals were probed using multiple formats, twice with a fill-in-the blank format (e.g., "Cowboys" [Dallas] and "Dallas" [Cowboys]) and twice with a question format (e.g., "Which football team is from Dallas?" [Cowboys] and "The Cowboys football team is from what city?" [Dallas]).

The experimenter presented the antecedent verbal stimulus and allowed 5 s for a response. No feedback was provided for correct or incorrect responses. Praise and tokens were provided for appropriate sitting and attending about every three trials.

Following the intraverbal pretests, we conducted tact and listener pretests to ensure that participants could correctly identify at least one relevant component of the potential intraverbal target. For potential targets involving states and countries, we only required the participant be able to identify the state or country as a speaker and listener, but did not require a correct response for the relevant city. For potential targets involving football teams, we required the participant be able to correct identify the team name

(e.g., "Cowboys") when shown the team's logo. For potential targets involving associations, we required the participant be able to identify at least one object (e.g., socks) from the pair (e.g., socks [feet]). Correct identification of one relevant component was defined as responding correctly in three out of four trials. If the participant could not identify a relevant component as a speaker and listener, the component was trained or the potential target was discarded. We required this as an attempt to make acquisition of intraverbal targets more functional for the participants.

Tact Pretest The experimenter held up a card and presented the antecedent verbal stimulus (e.g., "What is it?"). Participants had 5 s to respond. No feedback was provided for correct or incorrect responses. Praise and tokens were provided for appropriate sitting and attending about every three trials.

Listener Pretest The experimenter placed a three-card array (e.g., laminated maps of states) in front of the participant and presented the antecedent verbal stimulus (e.g., "touch Florida"). Participants had 5 s to respond. The position of the target card was randomly rotated across trials. No feedback was provided for correct or incorrect responses. Praise and tokens were provided for appropriate sitting and attending about every three trials.

Assignment of Targets Ten intraverbal targets were identified for the first evaluation in the following categories: (a) football teams and cities for Ray, (b) states and cities for Alan and Eric, and (c) objects and places for Tony. For the replication conducted with Eric and Ray, ten European countries and cities were selected as intraverbal targets.

Using a general case strategy construct, the intraverbal targets in each group were arranged to expose the participants to the bidirectional stimulus-response formats and facilitate emergence of reverse intraverbals. Using the cities and states example, the five targets in group A were taught by presenting the state as the antecedent verbal stimulus (e.g., "Florida") and the five targets in group B were taught by presenting the city as the antecedent verbal stimulus (e.g., "Seattle"). During probe trials, the reverse relations were tested for each group; that is, the five targets in group A were probed by presenting the city as the antecedent verbal stimulus (e.g., "Seattle") and the five targets in group B were probed by presenting the state as the antecedent verbal stimulus (e.g., "Florida"). The targets were counterbalanced across participants for Eric and Alan in the first evaluation and for Eric and Ray during the replication. The intraverbal targets were assigned to two groups (group A and group B) of five targets based on the number of syllables in each; that is, the antecedent verbal stimuli and the target responses in group A contained approximately the same number of syllables as the antecedent verbal stimuli and the target responses in group B. This arrangement was intended to equate response effort across groups. Table 1 shows the bidirectional teaching and probe formats for intraverbal and reverse intraverbal targets for each participant in the first evaluation and the replication.

Identification of Mastered Targets Prior to the current evaluation, a list of potential mastered tacts and intraverbals was compiled for each participant from previously mastered tact and intraverbal school programs. These mastered tasks were used to ensure participants contacted a high level of reinforcement during sessions across

Table 1 Bidirectional teaching and probe formats for intraverbal and reverse intraverbal targets

Intraverbals teach and probe assignments for Ray	
Group A—teach (cities)	Group A—probe (teams)
Baltimore (Ravens)	Ravens (Baltimore)
Carolina (Panthers)	Panthers (Carolina)
Denver (Broncos)	Broncos (Denver)
Oakland (Raiders)	Raiders (Oakland)
Pittsburg (Steelers)	Steelers (Pittsburg)
Group B—teach (teams)	Group B—probe (cities)
Cowboys (Dallas)	Dallas (Cowboys)
Lions (Detroit)	Detroit (Lions)
Seahawks (Seattle)	Seattle (Seahawks)
Texans (Houston)	Houston (Texans)
Vikings (Minnesota)	Minnesota (Vikings)
Intraverbals teach and probe assignments for Alan	
Group A—teach (cities)	Group A—probe (states)
Miami (Florida)	Florida (Miami)
Boise (Idaho)	Idaho (Boise)
Williamsburg (Virginia)	Virginia (Williamsburg)
Chattanooga (Tennessee)	Tennessee (Chattanooga)
Reno (Nevada)	Nevada (Reno)
Group B—teach (states)	Group B—probe (cities)
Illinois (Chicago)	Chicago (Illinois)
Washington (Seattle)	Seattle (Washington)
Montana (Helena)	Helena (Montana)
California (Malibu)	Malibu (California)
Texas (Houston)	Houston (Texas)
Intraverbals teach and probe assignments for Eric's replication	
Group A—teach (countries)	Group A—probe (cities)
Spain (Madrid)	Madrid (Spain)
Germany (Berlin)	Berlin (Germany)
England (York)	York (England)
Finland (Helsinki)	Helsinki (Finland)
Italy (Venice)	Venice (Italy)
Group B—teach (cities)	Group B—probe (countries)
Paris (France)	France (Paris)
Copenhagen (Denmark)	Denmark (Copenhagen)
Athens (Greece)	Greece (Athens)
Tralee (Ireland)	Ireland (Tralee)
Oslo (Norway)	Norway (Oslo)

Intraverbals teach and probe assignments for Eric	
Group A—teach (states)	Group A—probe (cities)
Florida (Miami)	Miami (Florida)
Idaho (Boise)	Boise (Idaho)
Virginia (Williamsburg)	Williamsburg (Virginia)
Tennessee (Chattanooga)	Chattanooga (Tennessee)
Nevada (Reno)	Reno (Nevada)
Group B—teach (cities)	Group B—probe (states)
Chicago (Illinois)	Illinois (Chicago)
Seattle (Washington)	Washington (Seattle)
Helena (Montana)	Montana (Helena)
Malibu (California)	California (Malibu)
Houston (Texas)	Texas (Houston)
Intraverbals teach and probe assignments for Tony	
Group A (teach)	Group A (probe reverse)
Beach (sand)	Sand (beach)
Gloves (hands)	Hands (gloves)
Hat (head)	Head (hat)
Bird (feather)	Feather (bird)
Umbrella (rain)	Rain (umbrella)
Group B (teach)	Group B (probe reverse)
Snow (sled)	Sled (snow)
Socks (feet)	Feet (socks)
Juice (cup)	Cup (juice)
Car (garage)	Garage (car)
Library (books)	Books (library)
Intraverbals teach and probe assignments for Ray's replication	
Group A—teach (cities)	Group A—probe (countries)
Madrid (Spain)	Spain (Madrid)
Berlin (Germany)	Germany (Berlin)
Lucerne (Switzerland)	Switzerland (Lucerne)
Helsinki (Finland)	Finland (Helsinki)
Venice (Italy)	Italy (Venice)
Group B—teach (countries)	Group B—probe (cities)
Greece (Athens)	Athens (Greece)
Denmark (Copenhagen)	Copenhagen (Denmark)
Poland (Warsaw)	Warsaw (Poland)
Norway (Oslo)	Oslo (Norway)
Ireland (Tralee)	Tralee (Ireland)

conditions (see below for further information). For each participant, mastery on these programs was defined as 90 to 100 % correct unprompted responding for two consecutive sessions. To ensure maintenance, potential mastered tacts and intraverbal targets were presented to each participant, and the tacts and intraverbals to which the participants responded correctly in three out of four trials were selected for use during mastered task trials. Mastered intraverbals were used for Ray, Eric, and Alan. Mastered tacts were used for Tony as his intraverbal repertoire was limited.

Experimental Design and General Procedure

A multiple-probe design across participants was used to evaluate the effects of intraverbal training on the acquisition of intraverbals and emergence of reverse intraverbals. The evaluation was conducted twice with Ray and Eric for replication purposes. The experimenter conducted one session per day, 5 days a week. Each session consisted of either 40 trials (i.e., 30 intraverbal trials and ten mastered tact or intraverbal trials) or 50 trials (i.e., 30 intraverbal trials, ten mastered tact or intraverbal trials, and ten reverse intraverbal probe trials).[1] These 40- or 50-trial sessions were alternated such that reverse intraverbal probe trials were conducted every other session.

The experimenter conducted intraverbal training until the participants' correct unprompted responding reached 100 % for two consecutive sessions. Following mastery of intraverbals, reverse intraverbal probe trials were conducted during every session (as opposed to every other session) to provide the participants additional opportunities to demonstrate mastery of the reverse intraverbals. Training of reverse intraverbals was implemented if a flat trend in responding to reverse intraverbals was observed for five consecutive sessions following mastery of intraverbals. Direct training of reverse intraverbals was only necessary for Tony.

Baseline During intraverbal trials and during reverse intraverbal probe trials, the experimenter presented the antecedent verbal stimulus (e.g., "Florida") and the participant had 5 s to respond. No feedback was provided for correct or incorrect responses during these trials. During trials of mastered tasks, the experimenter presented an antecedent verbal stimulus (e.g., "Birds build nests in the" [trees]) or held a photograph of an animal or a sport and presented the antecedent verbal stimulus (e.g., "What is this?"). Praise and tokens were provided for correct responses on a fixed ratio (FR 1) only during mastered task trials. Trials of mastered tasks were presented in each session in accordance to the 3-to-1 ratio specified in the "Experimental Design and General Procedure" section above (i.e., ten mastered tact or intraverbal trials were interspersed with 30 intraverbal trials). Baseline continued until participants demonstrated 0 % correct unprompted responding for a minimum of four consecutive sessions.

Intraverbal Training During intraverbal trials, the first session included trials with a 0-s prompt delay. During these trials, the experimenter presented the antecedent verbal

[1] *Intraverbal trials* refer to trials in which the participants were required to respond and feedback was provided based on the participants' response. *Reverse intraverbal probe trials* refer to trials in which the participant was not required to respond to and no consequences were provided if a response was provided.

stimulus (e.g., "Florida") and immediately provided an echoic prompt (e.g., "Miami"). Praise, tokens, and edibles (except for Ray) were provided for correct prompted responses. Beginning with the second session, the prompt delay was increased to 5 s and praise/tokens/edibles were delivered for correct unprompted responses only.

The experimenter implemented an error correction (EC) procedure following incorrect unprompted responses during intraverbal trials. The EC procedure consisted of the experimenter providing an echoic prompt and allowing the participant the opportunity to respond. Then, the experimenter re-presented the trial until the participant engaged in a correct unprompted response. Praise and tokens/edibles were provided during EC trials following correct unprompted responses. Error correction data are not included in the session data.

During training, the echoic prompts were prerecorded on and presented using a laptop computer (Stevenson et al. 2000). A prerecorded male voice was used to deliver prompts in an attempt to help the participants discriminate between the antecedent verbal stimulus and the echoic prompt. To provide the prompt, the experimenter cued and played the recorded prompt from the laptop.

During intraverbal trials, the schedule of reinforcement for correct unprompted responses was thinned from FR 1 to VR 3 when the participants reached 90 % correct unprompted responding; that is, an edible or a token was delivered following each correct unprompted response until the participants' correct unprompted responding reached 90 %. At that time, an edible or token was delivered every three correct unprompted responses on average. This strategy was implemented to prepare participants for extinction conditions during probe trials of reverse intraverbals when edibles, tokens, or praise was not provided contingent on correct unprompted responses.

During reverse intraverbal probe trials, the experimenter presented the antecedent verbal stimulus (e.g., "Miami") and the participant had 5 s to respond. No feedback or differential consequences were provided.

During trials of mastered tasks, the experimenter presented an antecedent verbal stimulus (e.g., "Birds build nests in the [trees]") or held a photograph of an animal or sport and presented the antecedent verbal stimulus (e.g., "What is this?"). Praise, tokens, and edibles were provided for correct responding an FR 1 schedule during mastered task trials until participants demonstrated 50 % correct unprompted responding during intraverbal trials. This was done to ensure a high density of reinforcement during training. Once a participant demonstrated at least 50 % correct unprompted responding during intraverbal trials, praise and tokens/edibles were no longer provided during mastered task trials. At that point, praise and tokens/edibles were provided only for correct unprompted responses on an FR 1 schedule which was thinned as described above.

Reverse Intraverbal Training Reverse intraverbal training was composed of sessions consisting of three reverse intraverbal probe trials interspersed with seven mastered task trials for a total of ten trials per session. The format of the reverse intraverbal training trials and the mastered task trials was the same as described in the "Intraverbal Training" section. Mastery criterion was 100 % correct unprompted responding for two consecutive sessions. Following mastery of a trained reverse intraverbal, five probe sessions were conducted to provide the participant with additional opportunities to demonstrate emergence of the remaining untrained reverse intraverbals. Reverse

intraverbal training was only necessary for Tony and these data are not included in the session data.

Maintenance Maintenance of intraverbals was evaluated after mastery-level responding was demonstrated during intraverbal teaching trials and reverse intraverbal probe trials. As in baseline, sessions consisted of 50 trials (30 intraverbal trials, ten mastered tact or intraverbal trials, and ten reverse intraverbal probe trials). No feedback was provided for correct or incorrect responses during any of these trials. Praise and tokens were provided only for appropriate sitting and attending. Maintenance sessions were conducted every 3 days for Ray, Eric, and Alan. Tony was available for three maintenance sessions, during which he demonstrated mastery-level responding with both intraverbals and reverse intraverbals.

Social Validity Nine items derived from the Treatment Acceptability Rating Form (TARF; Martens et al. 1985) were compiled to assess social validity. A group of teachers and parents was provided with written protocols used in the current evaluation and asked to rate the items using five-point Likert-type scale (1 = strongly disagree, 5 = strongly agree). The items included effectiveness in producing untrained responses, normative comparison to age-matched peers, efficiency, and overall benefits to the participants.

Results

Figures 1 and 2 depict the percentage of correct unprompted responses for intraverbals and reverse intraverbals for all participants during baseline, training, and maintenance conditions in the first and replication evaluations. During baseline, all participants' correct responses were at zero for intraverbals and reverse intraverbals.

Ray's responding in intraverbal and reverse intraverbal trials during his first evaluation is displayed in Fig. 1 (first panel). After training was implemented, Ray demonstrated mastery-level responding for intraverbal targets in 13 training sessions (390 training trials without error correction trials) and required 11 probe sessions to achieve mastery-level responding for the reverse intraverbals without direct training. Ray continued to demonstrate mastery-level responding for intraverbals and reverse intraverbals during maintenance. Figure 2 (second panel) depicts the replication results for Ray. He demonstrated mastery-level responding for intraverbals in seven training sessions (210 training trials without error correction trials). Similar to his first evaluation, Ray acquired the reverse intraverbals without direct training, requiring seven probe sessions to demonstrate mastery. During maintenance, he demonstrated high levels of correct unprompted responses.

Figure 1 (second panel) depicts Eric's correct unprompted responding in intraverbal and reverse intraverbal trials during his first evaluation. Eric mastered intraverbals in ten training sessions (300 training trials without error correction trials) and reverse intraverbals in six probe sessions following implementation of training. Acquisition of reverse intraverbals occurred without direct training. Eric continued to demonstrate mastery-level responding for intraverbals and reverse intraverbals during maintenance.

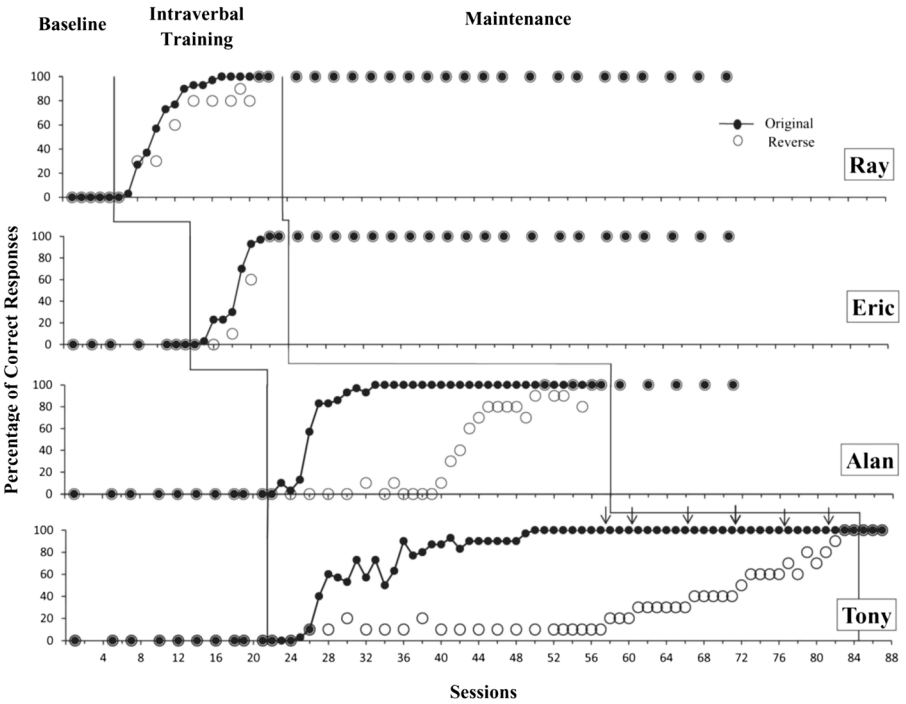

Fig. 1 Percentage of correct unprompted intraverbals and reverse intraverbals for all four participants. Each *filled data point* is computed from three presentations of ten intraverbals; each *open data point* is computed from one presentation of ten reverse intraverbals. The *small arrows in the bottom panel* indicate training of reverse intraverbals for Tony

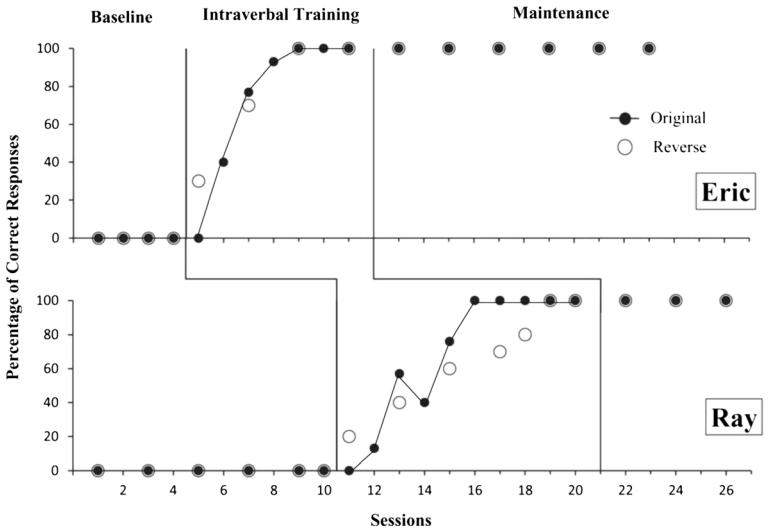

Fig. 2 Percentage of correct unprompted intraverbals and reverse intraverbals for Eric and Ray during intrasubject replication. Each *filled data point* is computed from three presentations of ten intraverbals; each *open data point* is computed from one presentation of ten reverse intraverbals

Figure 2 (first panel) shows the replication results for Eric. Correct unprompted responding increased very quickly once training was initiated. Eric required six training sessions (180 training trials without error correction trials) to master intraverbals and four probe sessions to master reverse intraverbals. As in his first evaluation, Eric acquired the reverse intraverbals without direct training. During maintenance, he demonstrated mastery-level responding of correct unprompted intraverbals and reverse intraverbals.

Results for Alan are depicted in Fig. 1 (third panel). Alan demonstrated mastery level of intraverbal responding in 13 training sessions (390 training trials without error correction trials). Following mastery of intraverbals, he demonstrated low levels of correct responding in reverse intraverbal trials. Correct unprompted responding in reverse intraverbal trials began to increase during his 20th session and mastery was reached in session 30. Alan demonstrated high levels of correct unprompted responding for intraverbals and reverse intraverbals during maintenance.

Figure 1 (fourth panel) displays Tony's responding in intraverbal and reverse intraverbal trials. Following an increasing trend, correct unprompted responding in intraverbal trials leveled off at 90 % for six consecutive sessions (i.e., one of the ten intraverbals was not acquired). At this time, a 0-s prompt delay was reinstated for the intraverbal target for which Tony consistently emitted an incorrect unprompted response. After two sessions with trials conducted at 0-s prompt delay, the prompt delay was increased to 5 s. Tony demonstrated mastery-level responding for all intraverbals in training session 30 (900 training trials without error correction trials). Following mastery of intraverbals, he demonstrated minimal correct responses during reverse intraverbal probes; he responded correctly to one reverse intraverbal for five consecutive sessions. Reverse intraverbal training was implemented in session 36. Following mastery-level responding of a trained reverse intraverbal, five probe sessions were conducted to provide Tony with additional opportunities to demonstrate emergence of the remaining reverse intraverbals. It was necessary to teach Tony all nine reverse intraverbals to which he responded incorrectly during probe trials. Three reverse intraverbals were taught individually and the remaining six reverse intraverbals were taught in pairs. Tony demonstrated mastery-level responding for reverse intraverbals in session 63.

To provide further details regarding training duration for each participant, we calculated the total number of training trials, including error correction trials, required for each participant to reach the mastery criterion. In the first evaluation, Ray required 512 training trials, Eric 465 training trials, Alan 541 training trials, and Tony 1270 training trials to reach the mastery criterion. During the replication, Eric and Ray required 237 and 340 training trials, respectively.

Results for the social validity measure show scores averaging between 4.0 and 4.5 across the nine items surveyed. Raters assessed the intervention as being effective in producing untrained verbal responses, appropriate for children with moderate to high functioning verbal skills; efficient; and simple to implement. Scores also indicate that the intraverbal responses selected for training are comparable to intraverbal responses that are present in the verbal repertoires of age-matched peers. Overall, raters found the intervention to be beneficial for the participants.

Discussion

The present study investigated the effects of concurrent multiple-exemplar training, bidirectional stimulus-response teaching formats, reinforcement, and single-word antecedent verbal stimuli on the acquisition of intraverbals and the emergence of reverse intraverbals. Overall, results suggest that the protocols used in the present evaluation are effective in producing the desired results for some children. Ray, Eric, and Alan demonstrated mastery-level responding for intraverbal targets and emergence of reverse intraverbals following implementation of intraverbal training. Ray and Eric began responding correctly in reverse intraverbal trials simultaneously with correct unprompted responding of intraverbals. In contrast, Alan demonstrated emergence of reverse intraverbals following mastery of taught intraverbals. Examples of errors during training and probe trials for Ray, Alan, and Eric included "Africa" when responding to the antecedent verbal stimulus "Lions" (i.e., Detroit Lions), "Pacific Ocean" when responding to the antecedent verbal stimulus "Oakland," and unintelligible vocalizations (Ray); inappropriate echoic responses (Eric); and "I don't know," incorrect state/city names, and errors of omission (Alan).

During the replication evaluation, Eric and Ray demonstrated faster acquisition of intraverbal targets and emergence of reverse intraverbals than in the first evaluation, providing additional evidence as to the effectiveness of the protocols used in the present study. Although we attempted to equate intraverbal targets within evaluations, we did not equate them across evaluations. Thus, Ray and Eric may have acquired the intraverbals more rapidly in the replication evaluation because the targets were less difficult than those selected for the first evaluation. On the other hand, the faster acquisition of intraverbals and emergence of reverse intraverbals could be attributed to the participants' recent instructional history. If so, it could be concluded that repeated exposure to intraverbal training may promote mastery-level responding of reverse intraverbals and more rapid acquisition of subsequent intraverbals and reverse intraverbals for some children (e.g., Perez-Gonzalez et al. 2008). Future studies should consider controlling for the difficulty of targets across evaluations to investigate the potential effects of recent instructional history and the difficulty of targets on rate of acquisition.

The protocol used in this study was not effective in producing the desired results for Tony. Although he demonstrated mastery-level responding for intraverbal targets, albeit at a slower rate than the other participants, he failed to demonstrate emergence of reverse intraverbals even after training of reverse intraverbals was initiated; that is, following training of each reverse intraverbal, Tony continued to respond incorrectly to the remaining untaught reverse intraverbals. Tony's errors during intraverbal training consisted of errors of omission or inappropriate echoic responses (i.e., imitating the antecedent verbal stimulus). It should be noted that Tony engaged in frequent vocal and motor stereotypy throughout the day, and these competing behaviors may have interfered with instruction. In addition, Tony's verbal repertoire was the most limited among the four participants as demonstrated by his EVT-2 and VB-MAPP scores. Outcomes for Tony are consistent with the results of some participants from previous research (Perez-Gonzalez et al. 2008; Petursdottir et al. 2008a, b) in that he failed to demonstrate the emergence of the symmetrical intraverbal relation (B-A).

The use of single words as antecedent verbal stimuli could be considered a potential limitation because they were provided out of context. Thus, it could be argued that the target responses may have been in the participants' repertoires and incorrect responses may have resulted from the lack of additional stimuli. This is unlikely, however, because all four participants responded incorrectly during intraverbal pretest trials which the antecedent verbal stimulus was presented within context (i.e., question and fill-in-the blank formats).

Another potential limitation should be noted in the social validity assessment. Reviewers were asked to rate the intervention based on a description of protocols. It is possible that the raters could not obtain sufficient information from the written descriptions and they might have provided different scores had they been given the opportunity to view video-taped sessions. Future studies could address this by showing raters video clips demonstrating the intervention and having them complete ratings based on these clips.

Overall, the findings from the present evaluation do not support previous research (Petursdottir et al. 2008a, b) in which intraverbal training did not result in the emergence of reverse intraverbals. However, results from the three participants in the present study who demonstrated emergence of reverse intraverbals following intraverbal training extend the findings by Perez-Gonzalez et al. (2007). That study showed that teaching additional sets of reverse intraverbals did facilitate the emergence of novel reverse intraverbals in subsequent trials for both participants. Despite incorrect responding during intraverbal pretests across participants, the relatively advanced intraverbal repertoires demonstrated by Ray, Eric, and Alan bring into question to what extent the novel aspects of the intervention in this study contributed to the positive results. It is possible that these participants would have demonstrated emergence of reverse intraverbals using teaching procedures that have failed to produce positive results in the past with participants whose intraverbal repertoires were possibly less advanced. This possibility should be addressed in future research.

In addition, results from the three participants from the present evaluation who demonstrated emergence of reverse intraverbals following intraverbal training support previous research (Marzullo-Kerth et al. 2011; Reeve et al. 2007; Sprague and Horner 1984; Stokes and Baer 1977) in demonstrating that training multiple exemplars concurrently in conjunction with a bidirectional stimulus-response teaching format (i.e., general case strategy) appears to be an effective training package that may promote emergence of reverse intraverbals for some children. Future studies could continue this line of research to determine the optimal number of exemplars to train concurrently.

Perhaps the most intriguing results stem from Alan's unexpected feedback in the early stages of the current investigation. His comments may help shed light on covert behavior (Skinner 1957) that may have exerted control over responding. Prior to the sessions during which emergence of reverse intraverbals began to occur, Alan said on a few occasions, "Oh, that one goes with…" when an antecedent verbal stimulus was presented, then emitted the correct response (e.g., "Illinois"). Based on this observation, it could be argued that Alan was beginning to identify the symmetrical relation between the reverse intraverbals and the intraverbals as a result of the bidirectional teaching formats used in the present evaluation.

Considering the variety and complexity of stimuli controlling verbal behavior, learning appropriate verbal exchanges can be a daunting task for individuals with

autism and other developmental disabilities (e.g., Finkel and Williams 2001; Sundberg and Sundberg 2011; Taylor and Harris 1995; Weiner 2005). Thus, interventions designed to increase intraverbal repertoires and promote generalization to untrained verbal relations seem like a worthwhile effort, as it would be prohibitive to teach children with autism all the potential intraverbal responses required for advanced verbal exchanges.

Although adequate experimental control was demonstrated in the current evaluation, training was introduced at the same time for the third and fourth participants due to time constraints. Had we introduced training for these participants individually, a more clear demonstration of control might have been achieved. Future research could sequentially introduce training across participants to increase experimental control. Future research should also investigate whether additional language assessments may reveal any minimal participant characteristics that may be necessary for the emergence of intraverbal responses. Additionally, additional research is needed to evaluate how the procedures used in the current study could be used to teach individuals with autism to demonstrate emergent responses to more complex antecedent verbal stimuli (e.g., intraverbal conditional discriminations).

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