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RESEARCH ARTICLE

Control by Compound Antecedent Verbal Stimuli in the Intraverbal Relation

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Abstract

Control by compound antecedent stimuli in verbal behavior represents an understudied but promising area of research. To date, reference to compound verbal stimulus control has generally only included descriptions of convergent multiple control. A sizeable experimental literature exists on the topic of compound stimulus control, which differs from convergent multiple control in that the stimulus elements often do not have a prior conditioning history (i.e., do not separately strengthen any response). The current study attempted to bridge the experimental and verbal behavior literatures by including a two-component antecedent verbal stimulus during intraverbal training for which neither component currently served an evocative function. Subsequent analyses of stimulus control suggested overshadowing by temporal location in the compound verbal stimulus and lack of emergence of the divergent intraverbal relation across all sets. Additional research is needed on compound stimulus control and verbal behavior researchers may be poised to answer several questions relevant to the experimental and verbal behavior literatures on the topic.

Keywords Compound stimuli · Intraverbal · Multiple control · Stimulus control

Intraverbals typically emerge by the age of two and become increasingly complex over time (and conditioning history; Sundberg & Sundberg, 2011). Despite the relevance of the intraverbal to the development of advanced speaker and listener repertoires (Sundberg & Michael, 2001), early discussions of the intraverbal lamented the dearth of research in the area (Sundberg, 1991). Indeed, Sautter and LeBlanc (2006) identified only 14 articles on the intraverbal relation through 2004. In a subsequent review, Aguirre et al. (2016) reported an additional 53 articles being published on the intraverbal from 2005 to 2015, including 12 articles being published in 2015 alone. In a recent citation analysis of *The Analysis of Verbal Behavior* (TAVB),

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Cariveau et al. (2020) found that two of the three most-cited articles published in the journal were on the intraverbal relation (Axe, 2008; Sundberg & Sundberg, 2011). This growing preponderance and prominence of research on the intraverbal was further punctuated by a special issue in TAVB on the intraverbal relation in 2016.

In the special issue, Sundberg (2016) and Palmer (2016) authored discussion papers on the intraverbal relation. In both articles, the multiple control of verbal behavior was emphasized (Axe, 2008; Michael et al., 2011). Michael et al. (2011) classified two types of multiple control previously described by Skinner (1957): convergent and divergent multiple control. In convergent multiple control, two or more variables strengthen a single response, whereas divergent multiple control involves a single variable strengthening a class of incompatible responses (Michael et al., 2011; Palmer, 2016). In an often-used example, the verbal stimulus "red" would strengthen several incompatible responses such as "apple" and "firetruck," while the antecedent "white" would strengthen other incompatible responses such as "rabbit" and "house." These serve as examples of divergent multiple control. In contrast, "red, white, and…" would strengthen a single response "blue," an example of convergent multiple control. Of note, convergent multiple control is characterized by the presentation of a compound stimulus (i.e., a stimulus that includes two or more separable components; Sundberg, 2016), which requires additional consideration in the intraverbal relation.

Sundberg (2016) discussed compound verbal stimulus control and provided a similar definition to Eikeseth and Smith (2013). Specifically, these authors note that "a compound verbal stimulus involves two or more S^Ds that each independently evoke behavior, but when they both occur in the same antecedent configuration, a different S^D is generated" (Sundberg, 2016, p. 113). Eikeseth and Smith (2013) endorse that a "typical" means to establish compound stimulus control involves the direct training of each component separately before presenting them together as a compound stimulus. The definition shared by these authors would seemingly require that compound verbal stimulus control only include instances of convergent multiple control; that is, each component of the compound stimulus must individually strengthen a class of responses and, when presented together, serve to strengthen a single response. This characterization may not include instances in which the elements of a compound antecedent verbal stimulus do not serve an evocative function, a condition previously evaluated in experimental research on compound stimulus control.

A robust literature has examined compound stimuli when the individual elements do not have any conditioning history. This literature has frequently used compound stimuli to assess stimulus blocking or overshadowing by individual elements of a compound stimulus. In one example, Farthing and Hearst (1970) presented pigeons with a successive discrimination task that included compound color-line tilt stimuli. For all birds, the discriminative stimulus (S^D) was a compound blue hue and vertical white line and the extinction stimulus was a compound green hue and horizontal white line. The pigeons were assigned to one of three groups: (a) training with the compound, (b) pretraining with the hue only, or (c) pretraining with the line tilt only. Training with the compound allowed for the assessment of stimulus overshadowing, and pretraining of the individual elements was used to assess the role of stimulus blocking. Birds in groups 1 and 2 showed exclusive control by color, consistent with stimulus overshadowing and blocking, respectively. For the final group, control by line tilt was shown for all pigeons, although only exclusively for two of the four pigeons.

Compound stimuli with no prior history have also been used frequently in research on stimulus equivalence (Markham & Dougher, 1993; Stromer & Stromer, 1990). In one example, Stromer and Stromer (1990) presented compound sample stimuli comprising a tone and hue (AB). Undergraduate participants were required to match the compound stimulus to an arbitrary line drawing (AB–D). A total of four targets were trained (A1B1–D1 and A2B2–D2; A1C1–E1 and A2C2–E2) before equivalence probes of individual components were conducted. The results showed the emergence of equivalence classes for all related elements (e.g., A–B, D–D, A–E, C–E). These findings may suggest that elements of a compound antecedent stimulus may separately evoke some target response, even when no conditioning history to individual elements exist.

In the study by Stromer and Stromer (1990), the authors presented compound stimuli that included elements that were different stimulus modalities (i.e., auditory and visual), referred to as *intermodal* compound stimuli (Groskreutz et al., 2010; Koegel & Schreibman, 1977; Lovaas et al., 1971). Additional research has included compound stimuli that include elements from the same stimulus modality (i.e., *intramodal*; Broomfield et al., 2008; Farthing & Hearst, 1970; Reed et al., 2011). When intramodal compound stimuli are used, visual stimuli are most common (Broomfield et al., 2008; Eckerman, 1967; Farthing & Hearst, 1970; Reed et al., 2011; Stromer et al., 1993). To the authors' knowledge, no prior research has evaluated control by elements of intramodal auditory stimuli (i.e., compound stimuli that include two separable elements, both of which are auditory), which would be relevant to several verbal operants, particularly the intraverbal. The current study serves as an extension of research on compound verbal stimuli in the intraverbal relation. Specifically, two antecedent verbal stimuli with no prior history were presented as a compound verbal stimulus evoking a single response. After mastery of the baseline relation (AB–C), additional tests of stimulus control topography were conducted, including the divergent intraverbal relation (C–AB), reverse relation (BA–C), individual elements (A–C, B–C), and competing stimulus arrangements (e.g., A1B2–C).

Method

Participant, Setting, and Materials

Alice was a 6-year-old girl with autism spectrum disorder (ASD). She had previously received behavior analytic services in a clinical setting for approximately two years, although these services were disrupted by the COVID-19 pandemic. The current study was executed as part of a university-based research program and not during clinical services. Alice's performance on the Expressive Vocabulary Test – 2nd Edition (Williams, 2007) and Peabody Picture Vocabulary Test – 4th Edition (Dunn & Dunn, 2007) was at the 4th and 16th percentile, respectively. Alice's performance on the Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP; Sundberg, 2014) was consistent with an emerging level 3 learner. She communicated using full sentences, although her intraverbal repertoire was less developed compared to tact and listener response domains. Alice was included in this study as she exhibited deficits in describing complex scenes and past events. For example, when shown a brief video clip, Alice would only tact the movie or character name. This protocol aligned with the caregivers' reported goals for Alice to share information about others. At the time of the study, she could accurately respond by listing three characteristics of herself and the first author when asked "tell me about you" or "tell me about [author]." Alice showed a pronounced interest in characters from animated movies, so these targets were included in the current study (see Table 1).

All sessions took place in an individual room in a university-based laboratory. The room was approximately 2.6 m x 2 m and included a child-sized table and chairs, toy shelf, and one-way mirror. Window blinds were pulled over the one-way mirror to reduce distraction. Alice sat diagonally from the experimenter and a secondary observer sat behind Alice or in the adjoining observation room. An additional playroom, approximately 5.9 m x 3.4 m, was used for longer breaks throughout her appointment and included several playsets, games, and a large table.

Stimuli included pictures of cartoon characters on a white background printed on 5.1 cm x 7.6 cm laminated cards. These stimuli were used as tact prompts during training. A laminated token board was present on the table during all sessions.

Dependent Variables and Response Measurement

Unprompted correct responses were defined as Alice emitting the target response within 5 s of the antecedent verbal stimulus. Prompted correct responses were defined as Alice emitting the target responses within 5 s of the presentation of a prompt. Each target response was defined before the study and Alice was required to emit the entire response. Target responses were single words except during divergent intraverbal probes (see below), during which Alice was required to emit the entire response as it was presented during training. For example, when instructed "tell me

Table 1 Target list and alphanumeric notation

Set	Relation	A	B	C
Set 1	1	Who has a friend named Gus Gus?	Who is a maid?	Cinderella
	2	Who has a friend named Donkey?	Who is an ogre?	Shrek
Set 2	3	Who has a friend named Fozzie?	Who is a frog?	Kermit
	4	Who has a friend named Mike?	Who is a scarer?	Sully
Set 3	5	Who has a friend named Sally?	Who is a race car?	Lightning McQueen
	6	Who has a friend named Mickey?	Who is a duck?	Donald
Set 4	7	Who has a friend named Edna?	Who is a superhero?	Elastigirl
	8	Who has a friend named Alfredo?	Who is a rat?	Remy

Notation system includes the letter and relation number (e.g., Who has a friend named Gus Gus is A1).

about Shrek," Alice was required to respond, "He has a friend named Donkey and is an ogre." The primary dependent measure was the percentage of unprompted correct responses, which was calculated by dividing the number of unprompted correct responses by the total number of trials within a session, multiplied by 100. The mastery criterion was set at two consecutive sessions with 100% unprompted correct responses.

Preference Assessment and Token Economy

Before participating in the current study, a Reinforcer Assessment for Individuals with Severe Disabilities (Fisher et al., 1996) was conducted with Alice's caregiver. A Multiple Stimulus Without Replacement (DeLeon & Iwata, 1996) preference assessment was then conducted. Items identified through these assessments were available in the experimental room, and Alice was allowed to mand for items during breaks following each session.

A token board was used during all sessions. Alice had used this same token system during all aspects of her instructional programming for more than one year at the time of this study. The number of tokens required to complete the board varied across sessions depending on the number of trials in the session (i.e., if a session had six trials, token-exchange opportunities were made available after six tokens were accrued). After the token board was filled, Alice received a 2-min break and access to a preferred tangible item. Preferred tangible items were restricted to breaks following token-exchange opportunities and could not be removed from the session room to reduce the likelihood of satiation.

Experimental Design

A multiple-probe design (Horner & Baer, 1978) across four instructional sets was used to evaluate the effects of compound intraverbal training on unprompted correct responding. After responding met the mastery criterion in one panel, post-training probes were conducted with the mastered targets and pre-training probes were conducted for the targets in the subsequent panel before the independent variable was applied. Once responding in all four sets met the mastery criterion, remedial training was conducted (see Table 2 for the training sequence).

General Procedure

Each target set included two compound intraverbal targets. During initial training, compound antecedent verbal stimuli included two components: "Who has a friend named [character's friend] and is a [character type/occupation]." Table 1 shows the target list and alpha-numeric notation. To begin all sessions, the experimenter secured ready behavior (i.e., looking at the experimenter, hands on the table, and sitting in her seat) before presenting the target antecedent verbal stimulus.

Table 2 Sequence of training and probe sessions

Phase	Relations	Number of targets	Trials per session
BL (Sets 1–4)	All*		
Set 1 IV TX	A1B1 + A2B2	2	6
Set 1 Post Probes	A1B1 + A2B2; B1A1 + B2A2; A1; B1; A2; B2; DIV; COMP		
Set 2 IV TX	A3B3 + A4B4	2	6
Set 2 Post Probes	A3B3 + A4B4; B3A3 + B4A4; A3; B3; A4; B4; DIV; COMP		
Set 3 IV TX	A5B5 + A6B6	2	6
Set 3 Post Probes	A5B5 + A6B6; B5A5 + B6A6; A5; B5; A6; B6; DIV; COMP		
Set 4 IV TX	A7B7 + A8B8	2	6
Set 4 Post-IV TX Probes	A7B7 + A8B8; B7A7 + B8A8; A7; B7; A8; B8; DIV; COMP		
Set 4 DIV TX	DIV	2	4
Set 4 Post-DIV TX Probes	B7A7 + B8A8; A7; B7; A8; B8; DIV; COMP		
Set 3 Pre-Component TX Probe	A5B5 + A6B6; B5A5 + B6A6; A5; B5; A6; B6; DIV		
Set 3 Component TX	A5; B5; A6; B6	4	8
Set 3 Post-Component TX Probe	B5A5 + B6A6; A5; B5; A6; B6; DIV; COMP		
Set 3 DIV TX	DIV	2	4
Set 3 Post-DIV TX Probe	B5A5 + B6A6; A5; B5; A6; B6; DIV; COMP		
Set 3 Reverse IV T	B5A5 + B6A6	2	4
Set 3 Post-Reverse IV TX	B5A5 + B6A6; COMP		
Set 2 Pre-DIV TX Probes	A3B3 + A4B4; B3A3 + B4A4; A3; B3; A4; B4; DIV		
Set 2 DIV TX	DIV	2	4
Set 2 Post-DIV TX Probes	B3A3 + B4A4; A3; B3; A4; B4; DIV; COMP		
Set 1 Pre-DIV TX Probe	A1B1 + A2B2; B1A1 + B2A2; A1; B1; A2; B2; DIV		
Set 1 DIV TX	DIV	2	4
Set 1 Post-DIV TX Probe	A1B1 + A2B2; B1A1 + B2A2; A1; B1; A2; B2; DIV, COMP		

BL, baseline; *COMP*, competing stimulus; *DIV*, divergent intraverbal; *IV*, intraverbal; *TX*, treatment. *All relations listed were probed including each element in isolation

Baseline

During baseline procedures, the experimenter presented the antecedent verbal stimulus and Alice was given 5 s to respond. Responses produced no differential consequences. Mastered demands were interspersed after an average of three trials.

Correct responses to mastered demands produced a token and praise. All mastered demands were previously targeted or tested relations to which Alice responded correctly during greater than 90% of opportunities.

Compound Intraverbal Training

Training was conducted using a constant prompt delay procedure and tact prompts. The first two sessions were conducted at a 0-s prompt delay. The experimenter presented the compound antecedent verbal stimulus and immediately presented the tact prompt. Prompted correct responses produced praise and a token. Prompted incorrect responses resulted in the re-presentation of the compound antecedent verbal stimulus and the tact prompt at a 0-s prompt delay until a prompted correct response occurred. All subsequent training sessions were conducted at a 5-s prompt delay. Unprompted and prompted correct responses produced praise and a token. This relation is labeled as the *baseline relation* below.

Stimulus Control Probes

Once the training criterion was met for the baseline relation, stimulus control probes were conducted using procedures identical to baseline for that set. The target relations are shown in Table 2, and an example of the Set 1 baseline relations and subsequent probes are shown in Fig. 1. Each component of the compound antecedent verbal stimulus was presented alone to identify control by individual elements (e.g., "Who has a friend named Gus Gus?"). Probes of the reverse relation were also

Set 1 Targets and Probes

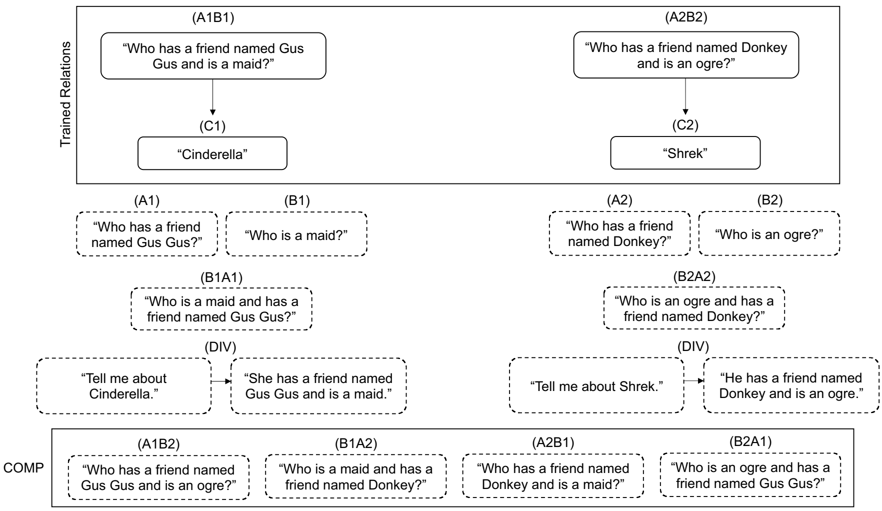

Fig. 1 Set 1 targets and probes. *Note. DIV,* divergent intraverbal; *COMP*, competing stimulus probe

conducted, which involved the presentation of the same components of the antecedent verbal stimulus presented in reverse order (e.g., “Who is a maid and who has a friend named Gus Gus?”). These were included to assess for irrelevant stimulus control topographies, such as the order of stimulus elements. Divergent intraverbal (DIV) probes were also conducted and served as the reverse intraverbal (i.e., symmetrical) relation to the baseline relation. The experimenter presented the antecedent verbal stimulus “tell me about [character]” and Alice was required to respond with both trained elements in any order (e.g., “She has a friend named Gus Gus and is a maid”). Competing (COMP) relation probes served as an assessment of stimulus competition. In these trials, a component from each trained stimulus was presented in a stimulus compound. For example, “who has a friend named Gus Gus (A1) and who is an ogre (B2)?” Alice’s response (i.e., Cinderella [C1] or Shrek[C2]) was recorded. Although she could have emitted both responses (e.g., “Cinderella and Shrek”), this was never observed.

Each type of probe was presented in separate sessions with each relation presented twice. For example, probes of the individual elements were intermixed in an 8-trial session that included two presentations of A1, B1, A2, and B2. Separate sessions were conducted for the individual element, reverse, DIV, and COMP probes. The order of these probes was randomly determined, except for the COMP probe, which was always conducted last. Criterion performance was defined as unprompted correct responding at or above 75% in a given probe.

Remedial and Booster Training

Due to inconsistencies in responding during probes across all four sets, training was introduced for an additional relation beginning with either the DIV or individual elements. We began training with the most recently trained set (i.e., Set 4 followed by Set 3, etc.; see Table 2). We chose not to train additional relations following the initial compound intraverbal training until all sets had undergone the initial training as doing so was hypothesized to affect discriminated performances in later sets. Specifically, training the individual elements in the compound or DIV relation may have impacted performance in subsequent training sets. For Sets 1, 2, and 4, remedial training targeted the DIV relation. Set 3 included remedial training of the single components. Set 1 was supposed to be exposed to individual training along with Set 3; however, due to high levels of emergence of the single component relation following training, the DIV relation was trained instead. All relations except for the COMP were probed again before remedial training was conducted. During remedial training, two sessions were conducted at a 0-s prompt delay using echoic prompts. All subsequent sessions were conducted at a 5-s prompt delay. Training continued until two consecutive sessions with 100% unprompted correct responses were observed.

Remedial training for Sets 1–3 began after booster training of the baseline relation (e.g., A1B1 and A2B2); that is, booster training was used to ensure that Alice’s responding in the baseline relation was at the mastery criterion before beginning remedial training. Booster training was identical to the 5-s prompt delay condition during initial training of the baseline relation. After responding met the mastery criterion for this relation, probes were again conducted, followed by remedial training.

Booster training was not conducted for Set 4 as remedial training occurred immediately following post-IV training probes (see Table 2). Once the training criterion was met for the remedial relation (i.e., DIV for Set 4), probes were again conducted. Training of additional relations occurred if low rates of responding were observed during probes as indicated in Table 2.

Interobserver Agreement and Procedural Integrity

An independent data collector was present during 83.7% of training sessions and 54.6% of probe sessions. Trial-by-trial interobserver agreement (IOA) was calculated by dividing the number of trials with an agreement divided by the total number of trials and multiplied by 100. Mean IOA was 100% during training and probes.

Procedural integrity was also recorded by at least one observer during 85.7% of training sessions and 98.2% of probe sessions. Procedural integrity was recorded on a trial-by-trial basis. Percent of trials with integrity was calculated by dividing the number of trials implemented with integrity by the total number of trials in a session, multiplied by 100. Mean procedural integrity was 99.6% (range, 83.3% to 100%) during training and 97.7% (range, 50% to 100%) during probes. Procedural integrity was at 50% during two, four-trial sessions in which the experimenter incorrectly delivered praise following correct responses during probes. A second observer was also present for 81.6% of training and 54.6% of probe sessions, which allowed for trial-by-trial IOA to be calculated for procedural integrity. Mean procedural integrity IOA was 100% during training and 98.3% (range, 50% to 100%) during probes. Procedural integrity IOA was 50% during a single session and occurred when the second observer did not record the experimenter's praise for two correct responses as an integrity error.

Results

The results of compound intraverbal training are shown in Fig. 2. Performance remained at zero levels for all sets with a single target response being emitted in Set 4 during the baseline phase. Responding met the mastery criterion in fewer than ten sessions for all training sets.

Table 3 shows performance during stimulus control probes throughout the study. Although remedial training was conducted with Set 4 targets first, the findings for each target set are presented together in an attempt to avoid confusion. After the mastery criterion was met for the trained relations in Set 1, 100% correct responding on the reverse relation was observed with all other performances at near-zero levels. Prior to remedial training of the DIV relation, performance was below mastery for the baseline relation. This relation was trained to mastery and probes were conducted for a second time. Probe performance showed control by each of the single components, with correct responding occurring at 100% for three of four components. Following DIV training, responding was at or above 75% unprompted correct responses for all relations.

Multiple-Probe Design Across Compound Intraverbal Training Sets

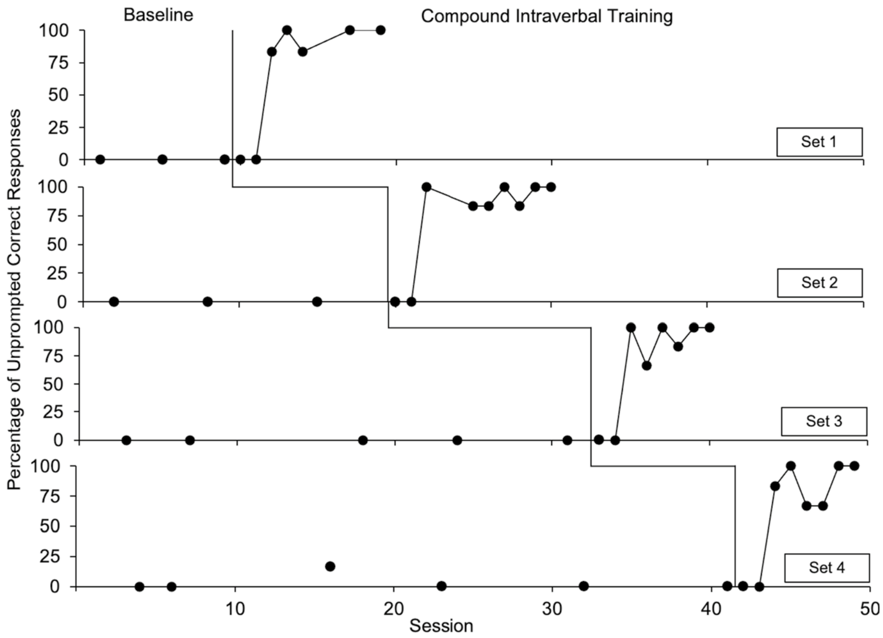

Fig. 2 Multiple-probe design across compound intraverbal training sets. *Note*. Only compound intraverbal training is shown in this figure. All probe outcomes are shown in Table 3 and Fig. 3.

For Set 2, probe performance following initial training met the criterion only for the reverse relation. Before remediation training of the DIV relation began, booster sessions were required to produce responding at the mastery criterion for the baseline relation. Probes following booster sessions showed greater emergence of the single-component relations than previously observed. Performance on the DIV probe remained at 0% correct responses. Remedial training was then introduced for the DIV relation and responding at criterion was observed for all relations except for a single component relation (B4).

Performance following training of the baseline relation for Set 3 showed low levels of emergence with a response bias observed during single-component probes (i.e., Alice only emitted C5 during probes). The baseline relation was exposed to booster training and similar performance was observed during the subsequent probes (pre-component TX). The single-component relations were then trained to mastery and performance during subsequent probes did not increase for the reverse or DIV relations. The DIV relation was subsequently trained and responding remained below the criterion for the reverse relation. Due to no correct responses being emitted during this probe, the reverse relation was trained and responding at 100% was observed during a final probe.

For Set 4, training of the baseline relation resulted in only slight increases during probes. The DIV relation was then trained with an increase in correct responding

Table 3 Percentage of unprompted correct responses during stimulus control probes

Probe	Trained	Reverse	Single component				Divergent
	$A_nB_n + A_{n+1}B_{n+1}$	$B_nA_n + B_{n+1}A_{n+1}$	A_n	B_n	A_{n+1}	B_{n+1}	C_n
Set 1							
Post-IV TX	100	100	0	0	0	50	0
Pre-DIV TX	100	50	100	50	100	100	0
Post-DIV TX	N/A	75	100	100	100	100	100
Set 2							
Post-IV TX	100	75	0	50	50	50	0
Pre-DIV TX	100	50	0	100	100	100	0
Post-DIV TX	N/A	100	100	100	100	50	100
Set 3							
Post-IV TX	100	25	0	0	100	100	0
Pre-Component TX	100	50	0	0	50	100	0
Post-Component	N/A	50	100	50	100	100	0
Post-DIV TX	N/A	0	N/A	N/A	N/A	N/A	100
Post-Reverse TX	N/A	100	N/A	N/A	N/A	N/A	N/A
Set 4							
Post-IV TX	100	25	0	0	50	50	0
Post-DIV TX	N/A	50	0	50	100	100	100

DIV, divergent intraverbal; *IV*, intraverbal; *TX*, treatment; Pre-DIV TX and Pre-Component TX probes were conducted after booster training of the baseline relation

during probes for three of four single-component relations, two of which were at criterion. Responding also increased in the reverse relation, although at sub-criterion levels. Due to experimenter oversight, no additional relations were exposed to remedial training for this target set.

Performance during COMP probes at post-IV training and post-remediation training are shown in Fig. 3. A single response was emitted during three of four competing stimulus probes following mastery of the baseline relation, although responding was generally low. Following remediation training, response biases were less pronounced and total responding during probes was higher than post-IV training for three of four sets. For Set 3, performance following remediation training suggested control by the final component of the antecedent verbal stimulus. This pattern of responding was evident, although less pronounced in the remaining sets.

Discussion

The purpose of the present study was to extend the literature on compound stimulus control in the intraverbal relation. During training of the baseline relation (AB–C), Alice acquired the compound intraverbal targets rapidly for all sets. Nevertheless, subsequent assessments of stimulus control topography suggested that responding had not come under control of both elements of the compound antecedent stimulus.

Responding During Competing Stimulus Probes Across Target Sets

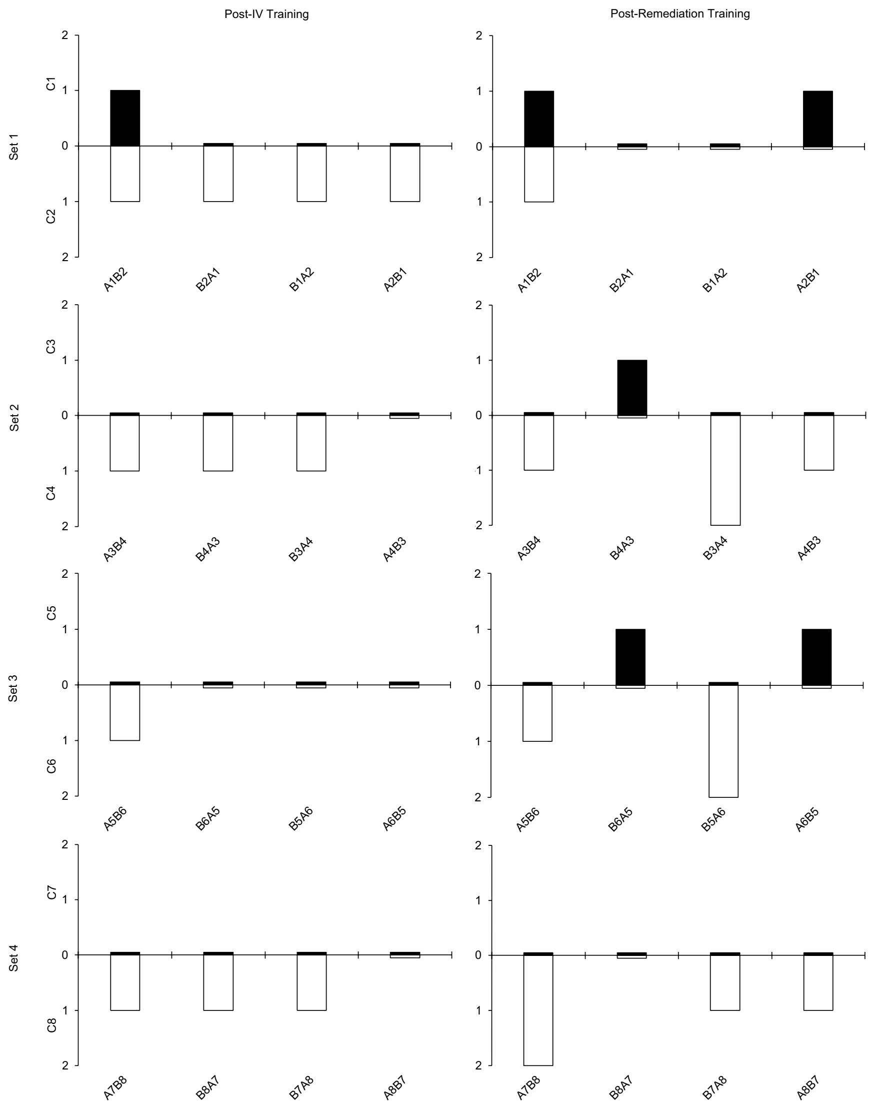

Fig. 3 Responding during competing stimulus probes across target sets. *Note.* Each relation was presented twice at post-IV training and post-remediation training timepoints

More specifically, control seemed to be largely exerted by the second component of the compound antecedent stimulus as indicated in the single stimulus probes. For example, following training of the baseline relation in Set 3, Alice only emitted the correct response when the second component of the compound stimulus was presented (i.e., “Who is a racecar?” or “Who is a duck?”), but not the first (i.e., “who has a friend named Sally" or "Who has a friend named Mickey?"). Additionally, the divergent intraverbal did not emerge following baseline training for any set. Due to low levels of control by the individual elements, reverse relation (Sets 3 and 4), and the lack of emergence of the DIV relation following compound intraverbal training, remediation training was introduced for each set. For Sets 1, 2, and 4, remediation training consisted of training the DIV relation (C–BA) and resulted in moderate to high performance across all stimulus control probes. For Set 3, the individual components were trained to mastery. Subsequent probe performance increased in the trained relations but remained at moderate-to-zero levels in the reverse and divergent relations, respectively. Both of these relations required training to produce performance at high levels during stimulus control probes.

Alice's performance during the single component probes suggested that her responding had come under control of the temporal position in the compound antecedent stimulus. Specifically, Alice responded almost exclusively to the second stimulus component following compound intraverbal training. As reported by Farthing and Hearst (1970), a single element may exert control over the response even when prior conditioning histories are identical. The current findings may suggest overshadowing by the temporal location in the compound antecedent stimulus; however, it is also possible that Alice's responding came under control of the character type/occupation since this was always presented second in the antecedent verbal stimulus. Thus, we may conclude that overshadowing occurred; however, the specific source of overshadowing is unknown. Future research might counterbalance the order of elements in the compound antecedent verbal stimulus to better identify the source of stimulus control and overshadowing effects.

A similar pattern of overshadowing by temporal position was observed during competing stimulus probes following remediation training (Fig. 3). Of the 17 correct responses emitted during competing stimulus probes, 14 (82.4%) were controlled by the second element (e.g., A1B2–C2 or A2B1–C1). The finding of overshadowing by temporal position may be unique as most research on restricted stimulus control has included the simultaneous presentation of two visual components (Broomfield et al., 2008; Dube & McIlvane, 1999; Eckerman, 1967; Farthing & Hearst, 1970; Reed et al., 2011; Stromer et al., 1993). The present study extends prior research by including a compound stimulus that includes two auditory components. Inherent to this arrangement is the sequential presentation of the elements of the compound stimulus. In contrast, visual compounds may be presented simultaneously and overshadowing may result from either the stimulus position or a particular element (Dittlinger & Lerman, 2011; Dube & McIlvane, 1999). Nevertheless, the effects of training using a compound antecedent stimulus observed in the current study were similar to the findings of past research suggesting control by only a subset of stimulus elements. Additional research is needed to identify methods to capitalize on the potential benefits of training using compound stimuli. This may serve as an efficient method of training if control by the individual elements is shown. The current findings may suggest that training the DIV may result in the emergence of the single components; however, because training in the current study began with the compound antecedent verbal stimulus, it is unclear whether the patterns of stimulus control observed following training of the DIV were a result of that training alone.

Training of the compound intraverbal relation resulted in variable performance during stimulus control probes except the DIV relation. Indeed, the DIV never emerged in the absence of direct training. This may be unsurprising as even studies that have included single component antecedent verbal stimuli have inconsistently shown the emergence of the reverse (or symmetrical) relation (e.g., trained A–B, assessed B–A; Allan et al., 2015; Dickes & Kodak, 2015); although repeated testing and training may result in the eventual emergence of this relation (Pérez-González et al., 2007). Future research might consider optimal training methods, or additional response requirements, such as differential observing responses (Dube & McIlvane, 1999), that may result in the emergence of the DIV relation.

Training functionally equivalent compound stimuli with no prior history has been studied in the experimental (e.g., Farthing & Hearst, 1970) and stimulus equivalence literatures (e.g., Stromer & Stromer, 1990); however, similar training arrangements have not been evaluated in research on verbal behavior. Moreover, prior experimental research has not included intramodal auditory stimuli. The present study served as an attempt to bridge the experimental and verbal behavior literatures. The current arrangement may be particularly notable in its potential contribution to the refinement of the definition of compound verbal stimulus control by Sundberg (2016) and Eikeseth and Smith (2013). Specifically, that compound verbal stimulus control may not require that the individual elements currently strengthen any given response or class of responses. In hindsight, additional data on responding during baseline, such as recording the specific responses emitted during probes, may have bolstered our argument. For example, errors during baseline probes may have suggested that a particular antecedent verbal stimulus evoked a consistent, albeit incorrect, response. Although it is unclear whether this was the case during baseline, various errors did emerge during the study. As one example, during probes following initial training of the Set 4 targets, Alice emitted the response "Anna" following the antecedent verbal stimulus "Who has a friend named Edna?" This error may have been due to the similarity between the target name "Edna" and "Elsa," which is Anna's sister in the movie Frozen. This additional error analysis may have allowed for even greater analysis of stimulus control topography and may be addressed in future research.

Despite the initially promising findings, the results of this study must be interpreted in light of several limitations. First, performance on the single component probes for Sets 1 and 2 increased following pre-DIV training. This may have been the result of booster training of the compound intraverbal relation (AB–C) for the set or exposure to the single component training in Set 3. Future research might include additional and intermittent probes to allow for the measurement of potential effects of trainings across sets. Additionally, the present study included a single participant which limits the generalizability of the findings. It is unclear how participant variables such as age, diagnosis, or intraverbal repertoire may impact the development of control by compound antecedent verbal stimuli. To note, although restrictive stimulus control (i.e., stimulus overselectivity) is prominently studied in children with ASD (Ploog, 2010), the finding of restrictive stimulus control is not unique to ASD (Broomfield et al., 2008; Dickson et al., 2006; Dube & McIlvane, 1999; Lovaas et al., 1971; Reed et al., 2013). Future research may consider how restrictive stimulus control may be implicated in the acquisition of various verbal repertoires, including in individuals who are not diagnosed with ASD.

Future research should also consider arranging targets to require conditional discrimination performances (see *compound conditional discrimination*; Eikeseth & Smith, 2013; Sundberg, 2016). In the current study, each element of a compound (e.g., "who has a friend named Gus Gus and is a maid?") strengthened a single response (e.g., Cinderella). Future research might arrange for elements of the compound antecedent stimulus to be included in other compounds to ensure the learner's performance is truly under convergent, rather than simple, control. Lastly, the arrangement of probing procedures may have affected acquisition of the target relations. Although research has found that probe frequency does not affect acquisition (Reichow & Wolery, 2009), it is possible that detection of changes in the probed relations were delayed because probes were only conducted following mastery. Additionally, because probes served to assess the acquisition of trained and untrained relations, probes were conducted under extinction conditions. It is possible that the lack of reinforcement during probing procedures may result in extinction of the target response. Future research should consider how procedural characteristics and the timing of probes may facilitate or hinder performance, an area for which there is little guidance in the extant literature.

The results from the present study suggest several possible areas of future research. First, this study evaluated the effects of the presentation of a two-component compound antecedent verbal stimulus on control by the individual components and related stimulus control topographies. Interestingly, research on compound stimulus control has typically only included two-component compound stimuli. Additional research might attempt to identify the potential overshadowing or blocking effects when a compound stimulus includes three or more components. Moreover, the vast majority of research on restrictive stimulus control has included selection-based response topographies in a two-stimulus array (Dube & McIlvane, 1999; Rieth et al., 2015). The limitations of two-choice arrangements have been described elsewhere (Sidman, 1987) and remain relevant here. Verbal behavior researchers may be particularly poised to extend this literature by moving beyond selection-based response topographies and instead including topographically distinct responses characteristic of tact, intraverbal, and textual relations (among others). Doing so will continue to require the systematic assessment of stimulus control topography, which may be bolstered by error analyses of topographically distinct responses.

The current study served as a demonstration of intraverbal training using compound antecedent verbal stimuli with novel elements. Subsequent analyses of stimulus control topography suggested overshadowing by temporal position and no emergence of the corresponding DIV relation. Nevertheless, the participant eventually showed high levels of responding under most probe conditions. This study attempted to serve as a bridge between the experimental and verbal behavior literatures to examine the potential sources of stimulus control when using intramodal auditory compound stimuli. Although we believe this to be a unique contribution to the study of verbal behavior, we also recognize the many readers of TAVB already researching and writing about verbal stimulus control and the intraverbal with much greater sophistication than we are presently able (e.g., Axe, 2008; Eikeseth & Smith, 2013; Michael et al., 2011; Palmer, 2016; Sundberg, 2016 to name a few). Accordingly, we look forward to future research and discussion on stimulus control and verbal behavior in the pages of the journal.

Declarations

Competing Interests Tom Cariveau currently serves on the editorial board for *The Analysis of Verbal Behavior*. All other authors declare that they have no conflict of interest.

Ethical Approval and Informed Consent This research was approved by an Institutional Review Board and informed consent was obtained before participation began.

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