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COVERT VERBAL MEDIATION IN ARBITRARY MATCHING TO SAMPLE

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Covert verbal mediation was examined in an arbitrary matching-to-sample (MTS) preparation with a high-verbal group (college students) and a low-verbal group (adults with intellectual disabilities). Arbitrary relations were established between nonsense words, visual symbols, objects, and hand signs. Task difficulty was balanced for the groups based on errors during acquisition. All participants experienced a hand sign condition, and three MTS conditions each with a unique configuration of the comparison array: fixed location, random location, and all symbols the same. The same symbol condition was designed to impede a participant's ability to label individual symbols. The results showed that disrupting labeling adversely affected MTS performance for high-verbal participants, but not for low-verbal participants. The data suggest that high-verbal participants depended on mediating verbal behavior and joint control to assist them in finding the correct comparison stimulus. Low-verbal participants could not benefit from verbal mediating variables and likely relied on unmediated contingencies, or some form of nonverbal mediation. For the high-verbal group, 19 different putative emergent relations were identified as occurring at various stages of acquisition between the sample stimulus and the selection response. These emergent relations likely provided supplementary sources of stimulus control that participated in evoking MTS selection behavior.

Key words: covert verbal mediation, emergent stimulus–stimulus relations, joint control, matching to sample, multiple control, verbal behavior

Sidman's (1971) original work on stimulus equivalence provided a conceptual foundation and research methodology for the empirical investigation of complex behaviors. The study of equivalence and resulting emergent relations has since produced a rich body of data and remains at the forefront of behavior analysis. However, despite a sizable collection of research, a consensus on the variables responsible for the emergence of new behavioral relations remains elusive (Dougher, Twohig, & Madden, 2014).

Since the pioneering work of Sidman, the study of stimulus equivalence and emergent relations has produced four similar, but distinct, conceptual frameworks that strive to provide an account of emergent stimulus–stimulus relations. The four frameworks include: (1) Sidman's (1994) equivalence theory, (2) Hayes, Barnes-Holmes, and Roche's (2001) relational frame theory (RFT), (3) Horne and Lowe's (1996) naming theory, and (4) Lowenkron's (1998) joint control account. A major distinction between these theories involves the role of a participant's mediating verbal behavior as a causal variable in emergent stimulus–stimulus relations.

Both Sidman (e.g., Sidman, 1994; Sidman & Tailby, 1982) and Hayes (e.g., Hayes et al., 2001; Quinones & Hayes, 2014) generally maintain that verbal mediation is not relevant to the emergence of new relations or relational frames. These researchers tend to not identify, discuss, or account for potential overt or covert mediating verbal behavior in their matching-to-sample (MTS) research with verbal participants. For example, in the study by Quinones and Hayes (2014) on ambiguous relational networks, the results obtained with college students were attributed to the experimenter-manipulated contingencies. With the exception of a brief mention of the possible role of rule-governed behavior, participant verbal behavior between the sample stimulus and the selection response was dismissed as a relevant source of stimulus control.

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By contrast, Horne and Lowe (1996) and Lowenkron (1998), who base their positions on Skinner's (1957) analysis of verbal behavior, argue that overt and covert verbal and nonverbal mediating behaviors play an important role in the development of equivalence classes, relational frames, and emergent relations. In support of their view, several studies have demonstrated a participant's self-verbal behavior can affect performance on various complex tasks (e.g., DeGraff & Schlinger, 2012; Greer & Longano, 2010; Horne, Lowe, & Randle, 2004; Lowenkron, 1991, 2006; Miguel, Petursdottir, Carr, & Michael, 2008; Randell & Remington, 1999; Sidener & Michael, 2006; Wulfert, Dougher, & Greenway, 1991).

Stewart, McElwee, and Ming (2013) objected to Horne and Lowe's (1996) focus on mediation, stating "the fact that naming and joint control both require an additional mediational process to explain derived stimulus relations in comparison to RFT can be seen as a weakness of the former" (p. 143). Similarly, Stromer (1996) expressed concern about Horne and Lowe's verbal mediation account. The objection to mediating verbal behavior is typically due to the private nature of these variables. Nonetheless, if they play a causal role they arguably should be taken into account (Skinner, 1974).

Covert verbal mediation must be at least indirectly quantified to identify its role in complex behavior. Direction can be found in the early research on *overt nonverbal* mediating behavior. Ferster and Skinner (1957) initially defined mediating behavior as "Behavior occurring between two instances of a response being studied (or between some other event and such instance) which is used by the organism as a controlling stimulus in subsequent behavior" (p. 729). For example, Sidman (1960) noted "The subject will often adopt a posture in which his whole body or part of it maintains a constant position relative to the correct container. Such mediating behavior may enable the subject to select the correct container even after the lapse of a considerable amount of time" (p. 375).

Several studies have been conducted on various types of overt nonverbal mediating behavior with pigeons, monkeys, and rats (e.g., Blough, 1959; Eckerman, 1970; Hodos, Ross, & Brady, 1962; Laties, Weiss, Clark, & Reynolds, 1965; Laties, Weiss, & Weiss, 1969; Schoenfeld & Cumming, 1963; Shimp & Moffitt, 1977; Wilson & Keller, 1953). For example, in Blough (1959), pigeons that emitted differential stereotypic behavior during different delay conditions demonstrated more correct responding than pigeons that did not engage in such behaviors. In addition, if pigeons emitted the wrong mediating behavior, they typically emitted the wrong response. Blough concluded "behavior during the delay interval seemed to determine the matching response" (p. 156). This line of research is important to the current study because it demonstrates that overt nonverbal mediating behaviors can provide discriminative stimuli for matching responses.

Parsons and colleagues (Parsons & Ferraro, 1977; Parsons, Taylor, & Joyce, 1981; Polson & Parsons, 1994) extended the animal research on mediating behavior to humans. For example, in Parsons et al. (1981), kindergarten children were trained on a delayed MTS task under three conditions. In the differential condition, children were required to emit a specific collateral behavior during the delay interval based on each sample stimulus (a bright light or a dim light). In the common condition, the same response was required for both sample stimuli, and in the nondifferential condition, either response was reinforced, regardless of the sample stimulus. The results showed that "subjects who reliably engaged in sample-specific collateral behavior…rapidly learned the conditional discrimination. Subjects who engaged in identical or nonspecific collateral behavior…either failed to acquire the discrimination or did so incrementally over a number of sessions" (pp. 259-260). These findings, along with the animal data, demonstrate that overt nonverbal mediating behavior can function as causal variables affecting subsequent behaviors in a MTS preparation.

Lowenkron (1984, 1988, 1989) further extended this line of research in a series of experiments in which participants were taught overt responses designed to mediate generalized identity matching (e.g., rotating an arrow, hand signs, use of a compass). For example, in a study examining the role of *overt verbal* mediation, Lowenkron (1988) taught four children with intellectual disabilities to use a hand sign to tact (label) a sample shape. Participants were then taught to maintain that hand sign

over a delay and to tact a matching comparison stimulus with the same hand sign. In a generalization test in which participants did not receive hand sign tact training, they only reliably matched the novel stimuli when the comparisons were present; if the sample was removed with a delay before the comparison selections appeared, participants matched at chance level (25%). However, as soon as the participants learned hand signs to tact the novel shapes, generalized matching appeared immediately. Lowenkron (1988) concluded that generalized delayed matching was dependent on these overt verbal mediating responses because the responses preserved the identity relation during generalization tests.

Sundberg and Sundberg (1990) also noted a mediating effect of hand signs while examining the distinction between sign language training and icon selection training with adults with intellectual disabilities. In that experiment, various arbitrary verbal relations were established following what Michael (1985) defined as topography-based verbal behavior and selection-based verbal behavior. In topography-based verbal behavior, a speaker emits a different response form for each referent (e.g., spoken words, hand signs), whereas in selection-based verbal behavior, the speaker emits the same response form (e.g., pointing, exchanging) to indicate a specific stimulus (e.g., icon selection apps, PECS). The participants in Sundberg and Sundberg were trained on both topography-based and selection-based verbal behavior, and then tested for emergent transitivity. The results showed that topography-based training with hand signs produced some transitivity in the equivalence tests, whereas selection-based training produced none. These results were replicated and extended by Wraikat, Sundberg, and Michael (1991), who also showed that low-verbal participants demonstrated some transitivity in the topography-based conditions, but none in selection-based conditions.

The Sundberg and Sundberg (1990) and Wraikat et al. (1991) data support Lowenkron's (1988) findings that topography-based verbal behavior can produce response products that function as causal variables that may participate in evoking other forms of verbal behavior, including MTS stimulus selection in transitivity tests. Reflecting on the Sundberg and Sundberg data and his own, Lowenkron (1991) suggested that even for the low-verbal participants the selection-based response in arbitrary MTS "depended on mediation by a topography-based behavior" (p. 126).

Lowenkron's (1998) analysis of joint control may help to identify some of the behavioral processes involved when topography-based verbal behavior functions as a causal variable in a selection-based task. Joint control occurs when two separate antecedents that evoke the same response topography arise simultaneously. The combination of these variables generates an emerged S^D that can immediately evoke behavior. For example, when looking for a departure gate at an airport, one might first look at the departure board and find the correct gate number (e.g., B85). A self-echoic prompt allows the traveler to retain the terminal and gate number over time, distance, and distractions (if she fails to do so, she may find herself rechecking a departure board). As the traveler passes by gates, she may overtly or covertly tact the numbers (e.g., "there's B81"). Joint control occurs when her self-echoic matches the response form produced by the tact of the numbers. As a result of the confluence of these variables, a new discriminative stimulus (S^D) emerges that evokes selection behavior (going to that gate) followed by reinforcement (successful boarding).

Lowenkron (2006) extended the analysis of joint control to *covert verbal* mediation with two experiments in which at least one of the variables involved a private event. The first experiment attempted to establish generalized matching behavior without the tact component. The results showed that without the tact, novel generalized responding failed to emerge. However, once the tact was established, novel generalized responding occurred immediately. In the second experiment the self-echoic aspect of joint control was disrupted. Participants were required to engage in an incompatible vocal distractor task (reading numbers out loud) following the presentation of the sample stimulus. The results showed that the distractor task impaired performance on tasks that involved a relatively long delay between the sample and comparison stimuli. These data not only replicated Lowenkron's (1984,1988,1989) overt mediation data and those of Parsons et al. (1981), but they also demonstrated how indirect measures could be used to quantify private events

(Palmer, 2011; Skinner, 1953). Subsequent studies have further extended the research on disruption of covert verbal mediators (e.g., Clough, Meyer, & Miguel, 2016; DeGraaf & Schlinger, 2012; Gutierrez, 2006).

The purpose of the current study was to further examine verbal mediation and its effects on the performance of high-verbal (college students) and low-verbal (adults with intellectual disabilities) participants across four separate tasks. One task involved topography-based verbal behavior (hand signs), and three tasks involved selection-based verbal behavior (MTS). In the topography-based condition, arbitrary visual and auditory stimuli were used to establish various relations with arbitrary hand signs. In selection-based training, all participants experienced three conditions. In the fixed-location condition, the comparison stimuli were always in the same position, and in the random-location condition, the position of the comparison stimuli changed after each correct response. In the same-symbol condition, all the symbols in the comparison array looked exactly alike. The goal of this condition was to make it harder for participants to give specific names to each symbol, thereby disrupting covert tacting as a source of control for selection behavior. Exit interviews and talk-aloud procedures were conducted at the conclusion of the study (Ericsson & Simon, 1993; Potter, Huber, & Michael, 1997).

Method

Participants

Eight participants were recruited for the study. Four were adults with intellectual disabilities between the ages of 24 and 52 years, and four were college students between the ages of 21 and 25 years. The participants with intellectual disabilities were identified as the low-verbal group and the college participants were identified as the high-verbal group. All participants are referred to by pseudonyms.

Low-verbal group. The participants in the low-verbal group functioned in the severe to moderate range of intellectual disability and all resided in the same group home. Two were female and two were male. In addition, the participants (1) had moderate to severe deficits in language skills, (2) possessed the manual dexterity for the formation of signs, (3) demonstrated the ability to imitate, (4) demonstrated the ability to follow simple

Table 1

VB-MAPP levels and skills for the participants in the low-verbal group

	Age	General VB-MAPP Level	Mand	Tact	Listener	Imitation	Intraverbal
Molly	52	Level 1: Less than 18 months language level	No mands: Nonvocal, no signs, no selection system	No tacts	Can follow many in-context directions and select at least 10 items on command	Early VB-MAPP Level 2: Can imitate at least 20 actions	None
Jim	38	Level 1: Less than 18 months language level	Can emit at least 4 vocal mands. No signs, no selection system	Can tact at least 6 items	Can follow many in-context directions and select at least 10 items on command	Mid VB-MAPP Level 2: Can imitate at least 30 actions	None
Eric	31	Level 2: Less than 30 months language level	Over 20 vocal mands	Over 50 vocal tacts	Can follow many directions and select at least 50 items on command	Can imitate at least 20 three-step actions	Can emit at least 25 fill-ins
Debra	24	Level 2: Less than 30 months language level	Over 20 vocal mands	Over 50 vocal tacts	Can follow many directions and select at least 50 items on command	Can imitate at least 20 three-step actions	Can emit at least 25 fill-ins

instructions, and (5) had no prior experience with either sign language or an icon communication system.

Table 1 contains the age and approximate verbal skills for each of the participants in the low-verbal group at the outset of the study. In terms of the *Verbal Behavior Milestones Assessment and Placement Program* (Sundberg, 2014), all participants were classified as Level 1 or mid-Level 2 responders, which approximately corresponds with the linguistic abilities of a typically developing 1- to 2-year-old child.

High-verbal group. All the participants in the high-verbal group were female students at Western Michigan University (WMU). All stated that they had sufficient time for the study and that they had no history of sign language or an icon communication system.

Setting

All sessions were conducted in a room containing a table, chairs, and filing cabinets/storage shelves. There was no foot traffic during the sessions and noise was at a minimum. Sessions were conducted 5 or 6 days a week for 4 to 6 weeks.

Low-verbal group. Sessions for the participants in the low-verbal group were conducted in a room of their residential facility. Sessions lasted 10 to 20 min between the hours of 3:00 p.m. and 9:00 p.m.

High-verbal group. Sessions for participants in the high-verbal group were conducted in a room at WMU. Sessions lasted approximately 30 min.

Materials

Symbol boards were created for selection-based responding for both groups and contained a variety of arbitrary symbols in various positions. Each symbol was 4 in. × 4 in. in size, printed on paper, and pasted on 18 in. × 24 in. poster boards placed approximately 2 in. apart (see Appendix A for symbol board samples). Arbitrary hand signs were chosen for topography-based responding (see Appendix B for a description of the hand signs). For two of the participants in the low-verbal group, a variety of objects were used as target nonverbal stimuli for tacting (e.g., LEGO block configurations, wooden cylinders).

Interobserver Agreement

A trained observer collected reliability data on 30% of the trials for the low-verbal group and 28% of the trials for the high-verbal group. Interobserver agreement was calculated by dividing the number of agreements, on a trial-by-trial basis, by the number of agreements plus disagreements, then converting the result to a percentage. Mean agreement for both groups was 98% (range 97% to 98%).

Design

An alternating treatments design (Barlow & Hayes, 1979) was used to compare four conditions for each participant in an A-B-C-D or A-B-C-D-A fashion. In addition, a repeated acquisition design (Boren & Devine, 1968) was used to equate the difficulty of the MTS tasks across the two groups and to mitigate possible sequence effects. Several sessions were run prior to the formal experiment to identify tasks that would be equally difficult for the two groups. The complexity of the tasks, which involved various nonsense words, symbols, objects, hand signs, and array configurations, were manipulated to identify combinations that produced a similar number of errors for both groups.

Each condition of the study was divided into several rounds. A round represented the number of trials until criterion was met. During each round, a specific word or object corresponded to a symbol or hand sign. Trials were conducted until the participant mastered the relation, or until 60 stimulus blocks were presented without meeting the criterion. When the criterion was met, a new round was conducted in the same way, except the same words and objects now corresponded to different hand signs and symbols. This sequence was repeated until it was determined by visual analysis of the data (number of errors per round) that the participants had stopped improving (i.e., there was no downward trend in errors). At this point, the next condition began.

Response Definitions

A correct selection-based response was defined as a point to the target symbol in a comparison array of 2 to 12 symbols (depending on the individual participant) within 5 s of

the presentation of the sample stimulus. A selection-based tact involved pointing to a symbol when an object was presented (e.g., when shown the plastic piece and asked "What's this?", the participant pointed to the corresponding symbol). A selection-based intraverbal involved pointing to a symbol when a spoken word was presented in the verbal frame "Which one is____?" as the sample stimulus (e.g., when asked "Which one is mojam?", the participant pointed to the corresponding symbol).

A correct topography-based response was defined as the participant emitting the corresponding hand sign within 5 s of the presentation of the target stimulus. For a response to be recorded as correct, it must have been a close enough approximation to the desired response that it was easily distinguishable from the other responses in the participant's repertoire. A topography-based tact involved a specific motor response when an object was presented as the antecedent stimulus (e.g., when shown a LEGO block configuration and asked "What's this?", the participant pulled her left ear). A topography-based intraverbal involved a specific motor response when a spoken word was presented in the verbal frame "What is the sign for____?" (e.g., when asked "What is the sign for jihba?", the participant pulled her left ear).

Table 2

An example of three rounds of word–symbol relations for Debra from the low-verbal group

	Symbols			
Round	Window	Horizontal	Square	Triple Square
1	mook	rac	mig	doe
2	doe	mig	jib	dro
3	slo	dro	rook	jib

Note. For Round 1, when presented with the verbal stimulus "mook" the correct selection would be the symbol that looked like a window out of an array of four symbols. The verbal stimulus "rac" goes with the horizontal symbol, etc. For subsequent rounds the same symbols are used but correspond to different nonsense words. Two new nonsense words replaced two existing words each round.

Procedure

In general, all participants were exposed to three different selection-based arbitrary MTS tasks involving nonsense words, symbols, and objects, and one topography-based task involving hand signs, nonsense words, symbols, and objects. Each of the participants experienced the four conditions in a different order. The dependent variable was the number of errors made per round in each of the four conditions. Comparisons were made after errors had stabilized using a repeated acquisition design (see Tables 2 and 3 for examples of repeated acquisition training).

Independent variable: Low-verbal group. Two participants in the low-verbal group were taught to select the corresponding symbol when presented with an object and asked "What is this?" They were taught these selection-based tact relations across three different configurations of the comparison array. In a separate topography-based condition, participants were taught to make a specific hand sign when presented with a corresponding object. The other two participants in the low-verbal group were taught to select the corresponding symbol when presented with a nonsense word. They were taught these selection-based intraverbal relations across three different configurations of the comparison array. In a separate topography-based condition, they were taught to make a hand sign when presented with a nonsense word.

All participants in the low-verbal group progressed through three selection-based conditions: fixed location, random location, and all symbols the same (tact disruption). Individualized symbol boards (see Appendix A) were used because the array size differed for each participant (from two to six symbols). In the fixed-location condition, all symbols were distinct and they remained in the same position on the board until mastered. One board was used for each participant for all trials. In the random-location condition, all symbols were distinct, but their position on the board was shuffled after each correct response. Six poster boards were used, each containing a unique arrangement of the same set of stimuli. The six boards were stacked in front of the participants. After every correct response, the experimenter removed the poster board and put it on the bottom of the stack. Thus, the symbol positions repeated every sixth correct response. In the same-symbol condition, all the symbols on the board were identical, and one board was used for all trials for each

Table 3

An example of the word–symbol relations for five rounds for the high-verbal participants

	Symbols											
Round	Vertical	Cross	Stairs	Maze	Window	Square3	Quarter	H	Square	Check	I	Horizontal
1	neeba	peeba	qeeba	reeba	paba	quaida	raca	saba	baba	cafa	daida	haca
2	paba	quaida	raca	saba	baba	cafa	daida	haca	seeba	teeba	veeba	weeba
3	baba	cafa	daida	haca	seeba	teeba	veeba	weeba	taba	waca	vaida	vaca
4	seeba	teeba	veeba	weeba	taba	waca	yaida	vaca	vihba	daca	naiad	pafa
5	taba	waca	yaida	vaca	vihba	daca	naiad	pafa	jafa	hayba	fuba	meeba

Note. The nonsense words listed in each round were the verbal stimuli presented that correlated with the symbols listed at the top of each column. For example, in round one, when presented with the verbal stimulus "neeba" the correct selection was the vertical symbol. When presented with the verbal stimulus "peeba" the correct selection was the cross symbol. The same symbols were used in every round but their correlation to a word changed. For example, in round two it was the verbal stimulus "paba" that correlated to the symbol called vertical.

participant. The same-symbol condition was designed to disrupt self-generated tacts by making all the comparison stimuli exactly the same, and establishing their location as the target source of control.

Participants proceeded through the phases in various orders. Two participants in the low-verbal group started with the fixed-location condition, then progressed through the random- location, same-symbol, and hand-sign conditions. The two other participants started with the hand-sign condition, then progressed through the fixed-location, random-location, and same- symbol conditions, and then repeated the hand-sign condition. Both participants in the low-verbal group who started with the hand-sign condition (Molly and Jim) repeated this condition at the end because it was determined by the experimenters that the condition change may have occurred before the errors stabilized.

A table containing the word–symbol and word–object relations was used to determine the relations for each round (see Table 2 for a sample of word–symbol relations). Because Molly only had two stimulus sets, the relations simply alternated for each round. For example, if "Rook" was related with symbol 1 and "Poe" was related with symbol 2 in round one, then in round two, "Rook" was related with symbol 2 and "Poe" was related to symbol 1. Jim, Debra, and Eric had three, four, and six stimulus sets, respectively. For each round, the symbol or the sign (depending on the condition) was constant, but two new one-syllable nonsense words were rotated into the sets.

Independent variable: High-verbal group. All four participants in the high-verbal group were taught to select the corresponding symbol when presented with a two-syllable nonsense word across three different configurations of the comparison array. Each board contained an array of 12 symbols. They were also taught to make a hand sign when presented with a two-syllable nonsense word in the topography-based condition. The progression through the conditions was the same as that of the low-verbal group.

For participants in the high-verbal group, packs of 10 data sheets were used (designed to accommodate 30 rounds for each participant). For each round, the symbol or the sign (depending on the condition) was constant on the data sheet for all 30 rounds, but eight nonsense words from the previous rounds (four from the last and four from the one before) and four new words were rotated in to create 12 all-new target relations.

Two participants in the high-verbal group went through the conditions in the following order: fixed location, random location, same symbol (tact disruption), and sign. The other two started with the sign condition, then progressed through the fixed-location, random-location, and same-symbol condition, and then repeated the sign condition for the same reason as stated above. A table containing the word–symbol and word–object relations was used to determine the relations for each round for every participant (see Table 3 for a sample of word–symbol relations).

Selection-based pretraining. Pretraining for the selection-based condition started with a symbol board being placed in front of a participant. For the two participants in the low-verbal group who were trained with objects

(the tact relation), the experimenter placed each of the objects on the symbols one at a time while saying "This goes with this." Objects were left on the board for 5 s. For the six participants who were trained using words (the intraverbal relation), the experimenter pointed to each symbol (at a rate of one every 2 s) while saying "This is _____." (e.g., "Biba"). The participant was then told that the experimenter would hold up an object or present a word and the participant would have 5 s to point to the pattern that went with that object. Data collection began immediately after this demonstration.

Topography-based pretraining. Pretraining for the topography-based condition started with a demonstration of each hand sign and a request that the participant imitate the hand sign. This process was repeated five times. Next, if the participants were trained using objects (the tact), the experimenter would point to each object and make the corresponding hand sign while saying "This is this." If the participants were trained using words (the intraverbal relation), the experimenter would make the hand sign for each word while saying "This is ____." (e.g., "Biba"). The participant was then told that the experimenter would hold up an object (if a tact) or present a word (if an intraverbal) and the participant would have 5 s to make the hand sign that went with that object or word.

Fixed-location condition: Selection-based training. The two participants in the low-verbal group who were trained on the tact relation (Molly and Jim) were shown the objects or LEGO block configurations one at a time and their corresponding symbol (as described in pretraining). Next, the experimenter randomly selected one of the items and presented it to the participant along with their symbol board and said "Which one is this?" (object/LEGO). For the other six participants who were trained on the intraverbal relation, the process was the same except instead of an object or a LEGO block configuration, a nonsense word was presented. For the participants in the high-verbal group, if the correct symbol was selected, the experimenter said "yes" and presented the next trial. For the participants in the low-verbal group, if the correct symbol was selected, the experimenter praised the participants (e.g., "Yeah, good job!") and presented the participant with a nickel. If the response was incorrect, the experimenter said, "No, this goes here" or "No, this is ____" while pointing to the correct symbol.

For the high-verbal group, all 12 words were each presented once and then repeated in a different order. This occurred until the mastery criterion was met. When the criterion was met, the round ended and either the session ended or a new round began with 12 new word–symbol relations. Four rounds were conducted for each participant during each session. This process was repeated until the participant's performance stopped improving (i.e., the number of errors had stabilized). For the participants in the low-verbal group, the above procedures were the same; all objects or words were presented (2, 3, 4, or 6, depending on the participant) once and repeated until the criterion was met. However, only one round per day was conducted with these participants.

Random-location condition: Selection-based training. The random location condition was conducted in the same way as the fixed-location condition except that a correct response produced a new trial involving a new symbol board. This new board had the same symbols, but the symbols were in different locations.

Same-symbol condition: Selection-based training. The same-symbol (tact disruption) condition was conducted in a manner similar to the fixed- and random-location condition except all the symbols on the board looked exactly alike.

Hand-sign condition: Topography-based training. The hand-sign condition started with the pretraining on the signs (as described above). After pretraining, the participants were presented with one object or one word and asked "What is the sign for this?" or "What is the sign for ____?" (e.g., "Pog"). As with the previous conditions, all of the objects or words were presented one at a time and then repeated. This process continued until the criterion was met; then, either the session ended or a new round began with new word–sign or object–sign relations. This process was repeated until the participant's performance stabilized. One round per session was conducted with the participants in the low-verbal group and four rounds per session were conducted with the participants in the high-verbal group.

Reward contingency. The participants in the low-verbal group were paid $1.00 per six

min of participation and were given a nickel for each correct response. Participants in the high-verbal group were paid $5.00 per session at the end of each session. All participants or their guardians signed an informed consent form.

Measurement

The first hand sign or the first symbol indicated following the presentation of the target stimulus was recorded. Correct and incorrect responses were recorded on the corresponding data sheets until the mastery criterion for a round was met. At that point, a new round began if time permitted (high-verbal group), or the session ended (low-verbal group).

Exit Interview and Talk-aloud Procedure

At the conclusion of the study, exit interviews and talk-aloud procedures were conducted (Ericsson & Simon, 1993; Potter et al., 1997). Three of the participants in the high-verbal group (Gina, Julie, and Erin) were available for the interviews and talk-aloud procedures (the participants in the low-verbal group did not have sufficient language skills for these activities). Each participant was asked a series of questions designed to identify strategies used and the extent of their mediating verbal and nonverbal behavior. Also of interest was the extent to which mediated behavior was correlated with differential performance across conditions, or if any particular type of covert behavior was correlated with differential performance across conditions. A mock session was also conducted. The participants were asked to talk aloud as they were presented a block of stimulus presentations from the experiment. They were instructed to try to overtly vocalize any responses that they may have covertly emitted during the actual experiment (e.g., given the symbol that looked like stairs: "Miba. That sounds like maybe. Maybe I'll go upstairs."). They were also instructed to report any relations for which they did not engage in any consistent and specific verbal behavior.

Results

Low-verbal group. The frequency of errors during the last four rounds of each condition is presented in Figure 1 for Jim, a representative participant from the low-verbal group. Data for each participant in the low-verbal

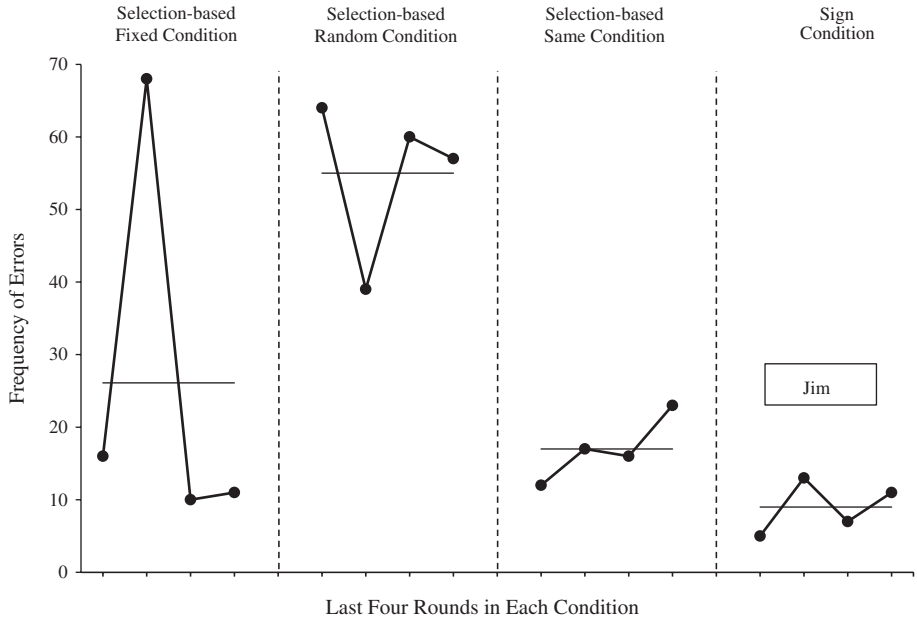

Fig. 1. The frequency of errors and mean lines for each of the last four rounds across three selection-based MTS conditions and one topography-based hand-sign condition for participant Jim from the low-verbal group.

group are presented in Appendix C. During the selection-based fixed-location condition, Jim met the criterion for all relations. However, in the random location condition in which the symbols were in different locations on each trial, his mean frequency of errors more than doubled and he failed to meet the criterion for any of the relations. Thus, Jim acquired conditional discriminations when the comparison symbols were in the same location on each trial, but not when in different locations on each trial.

Jim's best performance of the three selection-based conditions was in the same-symbol condition (tact disruption). These data demonstrate that symbol location rather than symbol topography was the relevant source of control for Jim's selection behavior. Jim's best performance of all conditions was during the topography-based sign condition. One possible explanation for Jim's better performance with hand signs is that the topography-based tasks involved only simple discriminations, whereas all the selection-based tasks involved conditional discriminations.

Figure 2 presents the mean frequency of errors for the low-verbal group's last four rounds of each condition. The group error pattern was similar to Jim's data. For the selection-based tasks, the random-location condition was the most difficult for the participants in the low-verbal group. The fixed-location and same-symbol conditions were easier than the random- location condition. Three of the four participants failed to master any of the relations in the random-location condition, but mastered all of the relations in the fixed-location and same- symbol conditions (see Appendix C).

One participant, Molly, who demonstrated the lowest verbal skills and worked with an array of only two symbols, acquired a peculiar response pattern and failed to demonstrate reliable conditional discriminations in any of the selection-based conditions. However, in the topography-based hand-sign condition, she performed in a manner commensurate with the other participants in the low-verbal group. The mean frequency of errors for the topography-based hand-sign condition for all the participants in the low-verbal group shows that their best overall performance was in the hand-sign condition, whereas their worst performance was in the random-location condition (Fig. 2).

High-verbal group. The frequency of errors during the last 10 rounds of each of the four conditions is presented in Figure 3 for Julie, a representative participant from the high-verbal group. Data for all participants from the high-verbal group are presented in Appendix D. A comparison of the selection-based fixed location and the selection-based random location shows little difference between these two conditions. Thus, unlike Jim from the low-verbal group, Julie was not adversely affected by

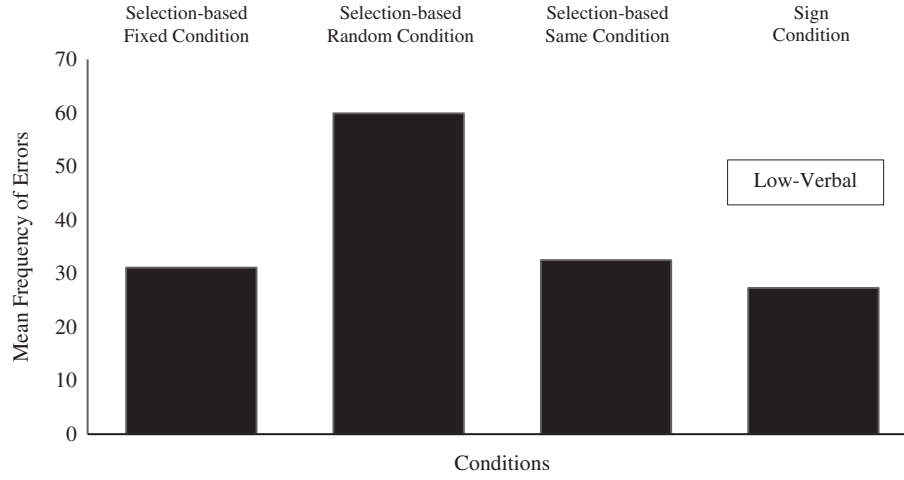

Fig. 2. Mean frequency of errors for the low-verbal group for the last four rounds across the three selection-based MTS conditions and one topography-based hand-sign condition.

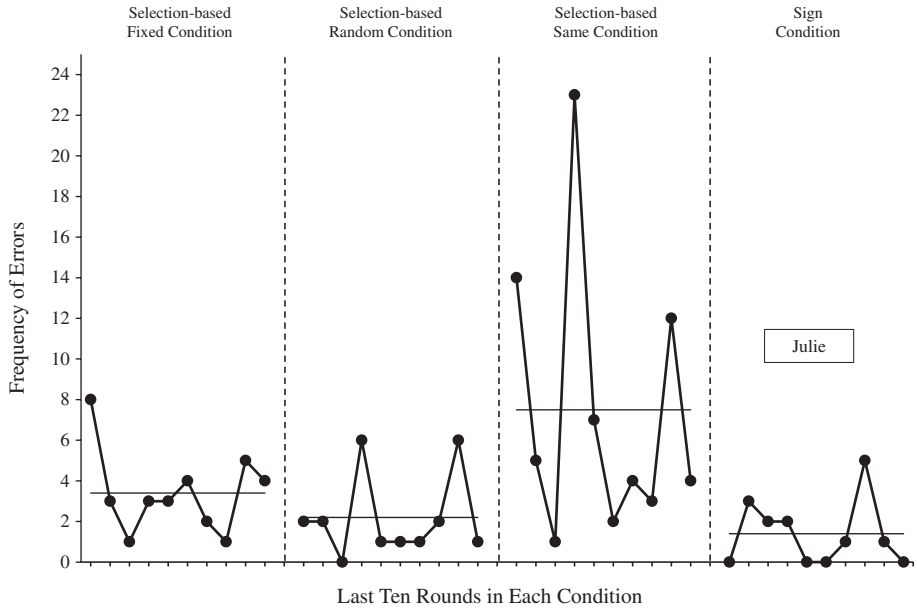

Fig. 3. The frequency of errors and mean lines for each of the last 10 rounds across three selection-based MTS conditions and one topography-based hand-sign condition for participant Julie from the high-verbal group.

randomization of symbol location; in fact, she performed better in the random condition than the other MTS conditions.

However, in the same-symbol condition in which the possibility of tacting the symbols was disrupted by making all the symbols identical, Julie's error rate more than tripled. These data demonstrate that topographically distinct comparison stimuli can affect MTS performance (see also Slattery, Stewart, & O'Hora, 2011). Julie's lowest error rate was for the topography-based hand-sign condition.

Figure 4 presents the high-verbal group's mean frequency of errors for the last four rounds of each condition. The group's error pattern was similar to Julie's data. For the

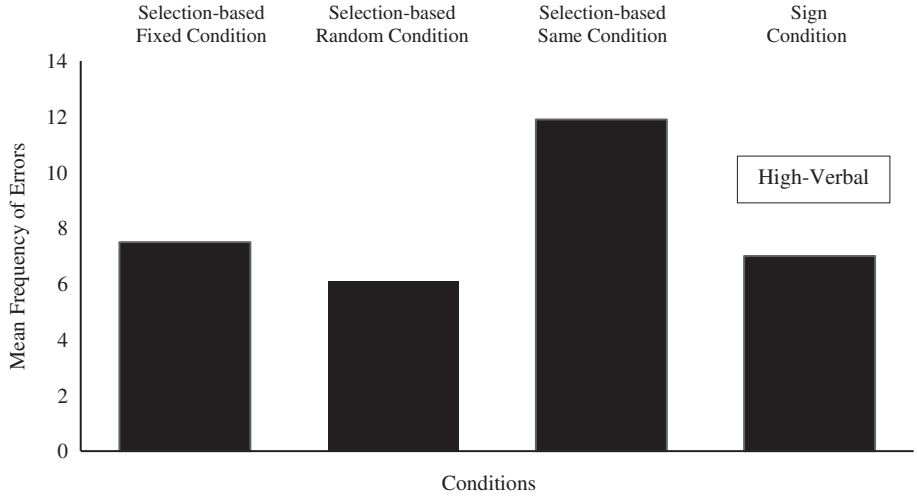

Fig. 4. Mean frequency of errors for the high-verbal group for the last 10 rounds across the three selection-based MTS conditions and one topography-based hand sign condition.

selection-based tasks, performance was similar during the fixed- and random-location conditions. The highest number of errors for three out of the four high-verbal participants occurred during the same-symbol condition (see Appendix D). One participant, Gina, demonstrated approximately the same performance for all the selection-based conditions (although in the exit interview she reported that the same-symbol condition was the hardest). The data for three participants in the high-verbal group (Julie, Erin, and Amanda) suggest that the distinct patterns on each symbol were an important source of stimulus control, regardless of whether the symbol's location was constant. The scores for the four participants in the topography-based condition were approximately equal to their scores in the selection-based fixed- and random-location conditions, but better than their scores in the selection-based same-symbol condition.

Comparisons between groups. The most noteworthy difference between the two groups was their opposite performance on the same-symbol and the random-location conditions. The high-verbal group was adversely affected by the tact disruption in the same-symbol condition, but the low-verbal group was not. However, the low-verbal group was adversely affected by the randomization of the location of the symbols, whereas the high-verbal group was not. These data suggest that different contingencies were operating for high-verbal and low-verbal groups in the selection-based conditions. Interestingly, there was little difference between the two groups in the topography-based hand-sign condition.

Table 4

Protocol analysis questions

1.	Which condition did you find the easiest?
2.	Why do you think that condition was the easiest?
3.	Did you use any general or specific strategies to find the right symbol?
4.	Why did you think there was such variation in scores within a condition?
5.	Which condition did you find the hardest?
6.	What do you think made that condition difficult?
7.	Did you have any trouble using your general or specific strategies to find the right symbol?
8.	Did you have any problem distinguishing visually one position from another on the board during the same condition?

Exit interview and talk-aloud procedure. Each of the three available high-verbal participants were asked a series of questions designed to identify strategies and the extent of mediating verbal and nonverbal behavior during the experimental procedures (see Table 4 for the questions). The participants were then asked to talk aloud as they were presented a sample block of trials from the study.

All three participants reported using the same basic strategy during the fixed and random conditions. The participants created a recognizable name or action for each arbitrary sample word or symbol, and for each comparison symbol. Then they altered the word to a phrase or something that would connect the initial stimulus to a sign or comparison symbol. All three participants indicated that much of the variance in errors between rounds was a result of the extent to which they could come up with names and good connections between the stimuli. For example, when the sample word was "biba" and the symbol was an empty square, the participant would convert the word "biba" to "bebop" and think of the square as a dance floor. The resulting self-generated connection was "Bebop on a dance floor." All three participants identified the same-symbol condition as the hardest because they could not use their strategies to create names for the symbols and come up with a story to connect the sample stimulus with the comparison stimulus. The results of a mock session, in which the participants were asked to talk aloud as they were presented with a block of stimuli, confirmed the strategies reported by the participants. The talk-aloud activity also confirmed the lack of verbal strategies in the same-symbol condition (e.g., "Bocam. Huh, I wonder where that goes").

Discussion

The present study found that disrupting mediating verbal behavior in an arbitrary MTS preparation adversely affected performance for high-verbal participants, but not for low-verbal participants. The participants from both groups acquired similar conditional discriminations, but it is likely that different contingencies were operating for each group. The data suggest that high-verbal participants depended on mediating verbal behavior as supplementary sources of stimulus control for

more efficient MTS selection behavior. Low-verbal participants, however, presumably were not affected by the verbal disruption procedure because their limited verbal abilities precluded them from benefitting from supplementary verbal behavior during MTS acquisition. For these participants, it is more likely that they acquired the conditional discriminations by unmediated contact with the experimenter-manipulated contingencies, or by some form of nonverbal mediation.

The results from the high-verbal group are consistent with previous research demonstrating that the response products of mediating behavior can provide supplemental sources of stimulus control in MTS performance for rats (e.g., Laties et al., 1965), pigeons (e.g., Sidman, 1960), monkeys (e.g., Hodos et al., 1962), children (Parsons et al., 1981), and college students (e.g., Santos, Ma, & Miguel, 2015). In addition, the current study replicates and extends previous research on joint control that showed disrupting mediating verbal behavior impairs performance (e.g., Clough et al., 2016; DeGraaf & Schlinger, 2012; Gutierrez, 2006; Lowenkron, 2006; Sidener & Michael, 2006).

The high-verbal participants brought an extensive history of verbal and nonverbal repertoires to the experimental sessions. As a result of this history and the immediate contingencies, these participants emitted verbal behavior during the trials that produced supplementary S^Ds that occurred along with the programmed contingencies, and putatively participated in evoking MTS selection behavior as a multiply controlled response (Blough, 1959; Michael, Palmer, & Sundberg, 2011). Figure 5 shows an interpretation of how a high-verbal participant's verbal behavior and other sources of stimulus control may interact during the early stages of MTS acquisition. A mediated path to a selection response is presented in the upper panel of Figure 5, and an unmediated path to selection is presented in the lower panel. The mediated path is based on Skinner's (1957) analysis of verbal behavior and Lowenkron's (1998) analysis of joint control. Following the mediated path, a trial begins on the left side of the diagram with the presentation of the arbitrary auditory sample stimulus (e.g., "Beeba") that ultimately functions as a verbal S^D (VS^D_1) with three separate behavioral effects (divergent multiple control).

As shown in Figure 5, two effects are evocative, and one effect is function-altering. The evocative effects are observed by an antecedent's demonstration of an immediate differential increase or decrease of a behavior. One evocative effect of the sample stimulus is demonstrated by an immediate overt or covert echoic verbal response (VR_1). The participants confirmed this effect in their exit interviews. The second evocative effect of the sample stimulus is that it evokes an overt nonverbal scanning response (NVR_1; i.e., looking for the correct comparison stimulus). The consequences for these two behaviors are likely automatic reinforcement related to hearing one's own echoic response, finding the targeted item, or making progress toward solving the MTS problem (Vaughan & Michael, 1982). The third effect of the initial verbal S^D is a function-altering effect that produces changes in the function of other stimuli (Michael, 1995, 2004; Schlinger & Blakley, 1987, 1994). This effect occurs following a few repeated contacts with the MTS reinforcement contingencies in which the presentation of the sample stimulus (VS^D_1) alters one of the stimuli in the comparison array to an S^D function and establishes the other stimuli as S-deltas.

All of the high-verbal participants reported in the exit interviews that they initially repeated the nonsense words (an echoic) and converted them to something more recognizable and easier to distinguish from the others. Figure 5 shows this activity in which the response product of the participant's echoic response may also function as an S^D (VS^D_2) that evokes a self-echoic response (VR_2). The conversion behavior occurs when the echoic response product generates VS^D_3, which evokes a self-intraverbal response (VR_3). For example, upon hearing the sample stimulus "Beeba," one participant reported that over a few trials she converted it to "Baby." The result of this conversion was an emergent self-generated intraverbal relation.

All of the participants also reported giving names to the stimuli in the comparison arrays to make them easier to remember (thus generating additional emergent verbal behaviors and verbal S^Ds). For example, the symbol with framed lines (NVS^D_1) was given the label "window" (VR_4) by the three participants who were available for the exit interview. These exit reports support Horne and Lowe's (1996)

observation that participants performing on MTS tasks often engage in overt or covert verbal behavior about the task and how to perform on it. The current interpretation provides some specifics about what the participants might be talking about and how this talk might affect selection behavior. Figure 5 shows that the response product from this emergent tact generates a verbal S^D (VS^D_6), and it then participates in joint control with the intraverbal relation described below.

After a small number of exposures to the direct contingencies, the participants reported coming up with a phrase to connect the two stimuli (termed "intraverbal naming" by Horne & Lowe, 1996). Figure 5 shows the covert self-intraverbal response product of VR_3 (saying "baby") generating VS^D_4 (hearing as a self-listener "baby") and evoking a second intraverbal response, VR_5 (saying to oneself "in the window"), with the resulting response product producing VS^D_5. The participants reported that they covertly repeated the phrase "baby in the window," now as a self-echoic (VR_6) producing VS^D_6 as they scanned the comparison array. Upon encountering the comparison stimulus with framed lines (NVS^D_1), the previously acquired and self-generated tact "window" is evoked (VR_4), and the resulting response product generates VS^D_6. When the covert tact and intraverbal both contain the same primary response form ("window"), the instantaneous confluence of these two separate antecedent events

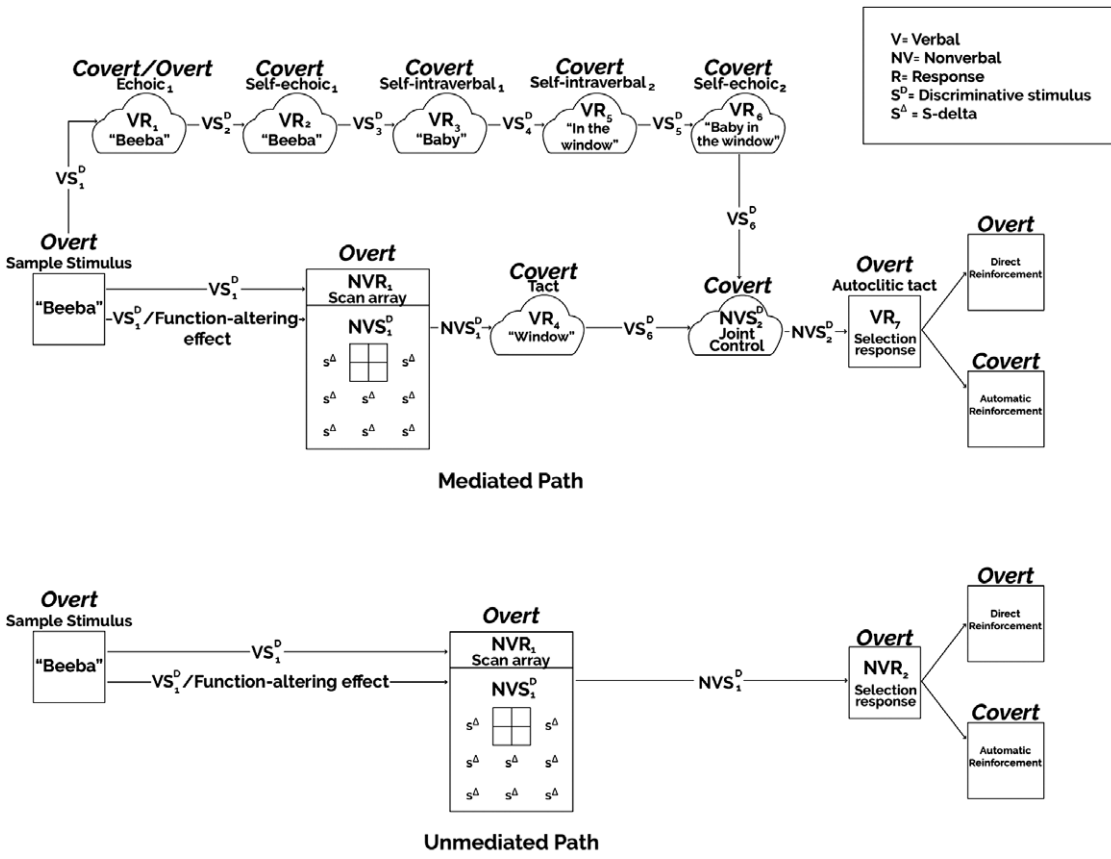

Fig. 5. A mediated path to a selection response is presented in the upper panel, and an unmediated path to selection is presented in the lower panel. The mediated path begins on the upper left side of the diagram with the presentation of the arbitrary auditory sample stimulus (e.g., "Beeba"), and concludes with a selection response and reinforcement. The mediated path contains a sequence of verbal events that set up joint control that evokes a selection response. The unmediated path begins with the same sample stimulus, but shows how the selection response could also be acquired by direct contact with the contingencies, which is likely the path taken by the low-verbal participants.

constitutes the discriminable event (NVS^D_2) identified as joint control (Lowenkron, 1998). This emerged nonverbal event is the similarity of the two response products and tacted (VR_7) as such by the speaker and tagged on to primary tact ("window") as an autoclitic tact of sameness in the form of selection behavior (Lowenkron, 1998). The reinforcement for these mediating behaviors involves a history of both experimenter-manipulated direct reinforcement and putative automatic reinforcement.

Proponents of the RFT and stimulus equivalence accounts often refute a verbal mediational account to explain complex behavior on the basis of the short latency between the sample stimulus and the response (e.g., Saunders & Green, 1996). However, it is important to distinguish between the current emission of a target response and the variables involved in the relevant learning history regarding that response. Eventually, the supplemental stimuli are no longer necessary, and stimulus control is transferred to the target verbal stimulus (i.e., the response is fluent, or memorized). Indeed, the participants reported in the exit interviews that once they learned the connection between two stimuli, they no longer needed their strategies.

When the procedure was changed to the same-symbol condition, disrupting the tact element of joint control impaired performance for high-verbal participants, but not for low-verbal participants. For high-verbal participants when all 12 symbols in the comparison array looked exactly alike, tacting was difficult. Figure 6 shows that without a consistent tact for a comparison stimulus (e.g., "Window"), the second type of covert intraverbal cannot occur (e.g., "Baby in the window"). Although the self-echoic (e.g., "Beeba") and first type of intraverbal (e.g., "Baby") could still occur, without the primary tact, joint control, intraverbal naming, and the secondary autoclitic tact cannot occur, and no help is provided to the high-verbal participant in finding the correct comparison stimulus. At this point, the participants had to switch to the unmediated path that required more trials. This difference is perhaps why the participants reported in the exit interviews that the same-symbol condition was the most difficult.

Autoclitic verbal behavior is critical to joint control, but an alternative interpretation of its specific role is possible. Lowenkron (1998) suggested that the selection response be classified as a descriptive autoclitic. While it seems clear that autoclitic behavior is involved in the sequence of events, it is possible that the autoclitic response is not in the form of selection behavior, but rather it is a critical step in that direction. Consider that in the sequence of events in a joint- control account, the comparison stimulus must control two completely different behaviors, occurring in rapid succession. The exact same static stimulus (e.g., the window) first controls a tact, but then immediately controls selection behavior, in that order only. The nonverbal stimulus cannot evoke the selection response first because without the primary tact, the necessary S^D generated by its response product is not available to combine with the self-echoic ("Baby in the window") and set up joint control. Without joint control, the descriptive autoclitic tact cannot occur (e.g., "That's it!"), both of which are necessary to alter the functional effect of a specific stimulus in the comparison array, such that it sets up the conditional discrimination that ultimately evokes correct selection behavior.

Figure 7 shows this alternative interpretation. When the self-echoic (VR_6) and tact (VR_4) conditions evoke the same response form, thus producing the same response product (VS^D_6), the confluence of these variables generates the onset of joint control (NVS^D_2) and evokes secondary verbal behavior in the form of an autoclitic tact (VR_7) (e.g., "That's it," similar to Sidman, Cresson, & Wilson-Morris', 1974, reported "aha" response). The response product of the autoclitic tact produces VS^D_7. VS^D_7 has both evocative and function-altering effects; namely, it evokes (or maintains) scanning behavior (NVR_2) and alters the function of the window from a nonverbal S^D evoking a tact to a verbal S^D that participates in evoking selection behavior. Thus, it is not until the verbal response product of the autoclitic tact occurs (e.g., self-hearing of "That's it") along with the visual comparison stimulus, that a conditional discrimination is set up and selection behavior is evoked by VS^D_9 as a selection-based intraverbal. This alternative account accommodates the rapid change in the evocative effect of the nonverbal stimulus in the comparison array.

For the high-verbal participants, at least 19 different putative emergent behavioral relations can be identified as occurring at various stages of acquisition between the presentation of the sample stimulus and the selection of a comparison stimulus (Fig. 5). None of these antecedents, behaviors, or consequences were specifically targeted by the experimenters' programmed contingencies. Seven types of verbal behavior putatively emerged for the high-verbal participants during various stages of acquisition: self-echoic$_1$, self-intraverbal$_1$, self-tact, self-intraverbal$_2$, self-echoic$_2$, self-autoclitic behavior, and an overt selection-based intraverbal response. In addition, 11 types of stimulus control were identified as putatively emergent: eight new verbal S^Ds emanating from the response products of the putative covert verbal behavior, two new nonverbal S^Ds evoking the primary and autoclitic tacts, and most importantly, the multiple causation that produced joint control and its resulting S^D evoking an autoclitic tact of sameness. Finally, a new type of consequence putatively emerged in the form of automatic reinforcement related to sameness (e.g., "That's it"). It is also possible that other types of automatic consequences emerged during the experimental activity, including automatic negative reinforcement related to escape (e.g., van Haaren, 2015).

Many of the emergent forms of verbal behavior involved topography-based relations evoked on the way to emitting a selection-based response. This effect provides support for the view that selection-based verbal behavior in a MTS preparation may be dependent on topography-based verbal behavior

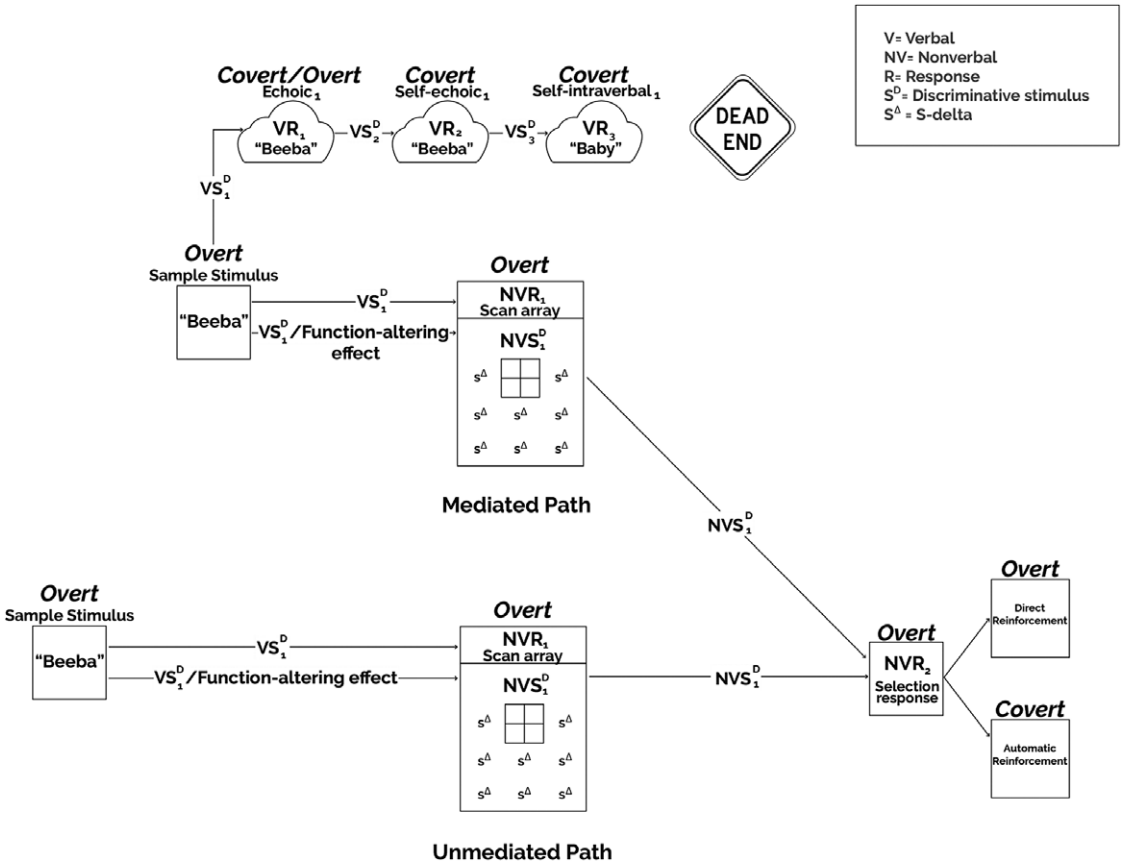

Fig. 6. The same mediated and unmediated paths shown in Figure 5 are presented, but show that without a tact for a specific comparison stimulus, joint control, intraverbal naming, and the secondary autoclitic tact cannot occur. The mediated path comes to a dead end and no help is provided to the participant. At this point, the participant has to rely on the unmediated path.

(Lowenkron, 1991; Polson & Parsons, 2000; Sundberg & Sundberg, 1990; Wraikat et al. 1991). Without a specific response topography, nothing is available to mediate transfer between variables in a selection-based task and participants must rely on the unmediated contingencies or some form of nonverbal mediation.

The high-verbal participants and the low-verbal participants performed similarly in the topography-based hand-sign condition. High verbal participants reported in the exit interviews that this was the easiest condition. Interestingly, all of the low-verbal participants performed better in the topography-based hand-sign condition than in the selection-based random condition, replicating the results of Sundberg and Sundberg (1990) and Wraikat et al. (1991). These findings have clinical implications for the use of sign language versus selection-based icon systems for teaching language to nonvocal intellectually disabled persons.

The results from the current study can also provide some insight regarding the discrepancy between those who easily demonstrate stimulus equivalence, relational framing, and derived relations, versus those who struggle or fail (see *JEAB's* January, 2014 special issue). In general, the lower the verbal and intellectual abilities demonstrated by participants, the more difficult it is to obtain emergent relations, although not impossible, even with nonvocal humans and nonhumans (e.g., Lowenkron, 1984; McIntire, Cleary, & Thompson, 1987; Saunders & Spradlin, 1989; Schusterman & Kastak, 1993; Sundberg & Sundberg, 1990; Swisher & Urcuioli, 2018; Zentall, Wasserman, & Urcuioli, 2014). The current data suggest that it is a participant's mediating verbal behavior that provides valuable supplementary sources of stimulus control that participate in evoking selection behavior and producing emergent relations. These types of self-generated verbal stimuli are less available to low-verbal participants and nonhumans, although even a small degree of verbal or nonverbal mediation may be effective in generating emergent behavior.

A potential limitation of the current study is that the primary behavior of interest is covert and cannot be directly measured. Rather, the role of covert verbal behavior can only be inferred by observing orderly effects in other indirect measures (Palmer, 2011; Skinner, 1953). Another limitation is that it would have been more informative to run the talk-aloud procedure prior to the interview to guard against potential order effects. However, both the reports in the exit interview and the responses during the talk-aloud procedures were consistent with the overt verbal behavior exhibited by the participants during the experiment.

Previously it was noted that there are four different conceptual explanations of emergent stimulus–stimulus relations. Lowenkron's (1998) joint control account and Horne and Lowe's (1996) naming theory both maintain that a participant's mediating verbal behaviors can function as causal variables and should be

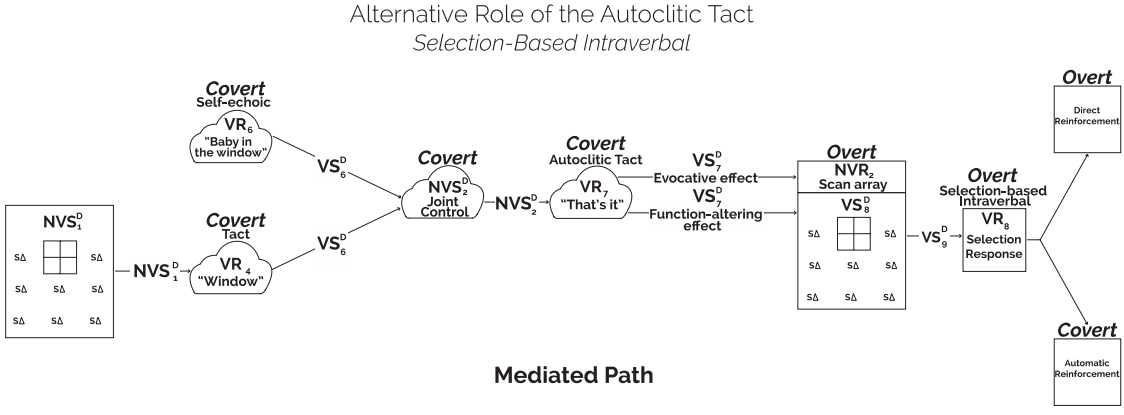

Fig. 7. An alternative interpretation of the autoclitic shows joint control evoking a discriptive autoclitic tact of sameness ("That's it"). The response product of the autoclitic tact alters the function of the stimuli in the comparison array, establishing one stimulus as VS^D8 that along with VS^D7, participates in a conditional discrimination and selection behavior is evoked by VS^D9 as a selection-based intraverbal.

accounted for in the explanation of emergent relations. Proponents of equivalence theory and RFT tend to dismiss the relevance of a participant's mediating verbal behavior as a source of stimulus control when examining emergent relational behavior (e.g., Hayes et al., 2001; O'Hora, Barnes-Holmes, & Stewart, 2014; Quinones & Hayes, 2014; Saunders & Green, 1996; Sidman & Tailby, 1982; Slattery, Stewart, & O'Hora, 2011). However, the current data suggests that verbal participants emit verbal behavior, much of it covert, during the trials. The response products of these self-produced verbal responses can function as verbal S^Ds that evoke other verbal and nonverbal behaviors, including the terminal response. Without an account of the causal role of a participant's verbal mediation, we argue equivalence theory and RFT are incomplete explanations of MTS performance and emergent relational behavior with high-verbal participants.

What emerges in an arbitrary MTS preparation with high-verbal participants are new self- speaker and self-listener behaviors, along with joint control. These emergent behaviors and their sources of control interact with the experimenter-manipulated contingences and evoke selection behavior as a multiply controlled verbal response. Skinner's (1957) analysis of verbal behavior along with Lowenkron's (1998) analysis of joint control provide a plausible and parsimonious account of emergent stimulus–stimulus relations. In addition, a verbal behavior account allows for a more precise identification of the causal variables that underlie emergent behaviors, thereby engendering more effective language assessment and intervention programs for individuals experiencing language disorders.

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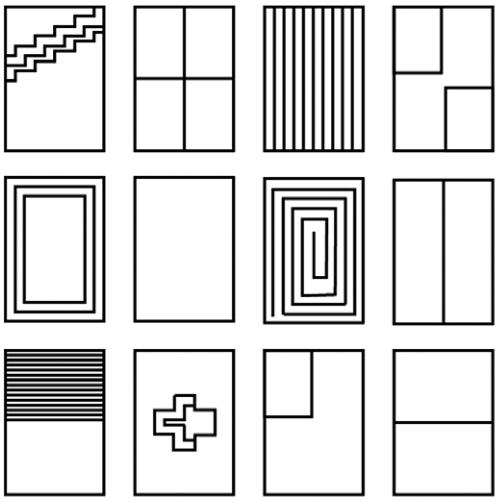
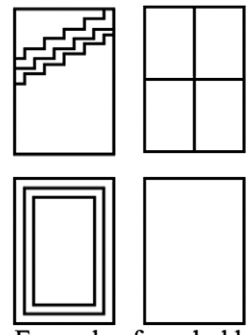
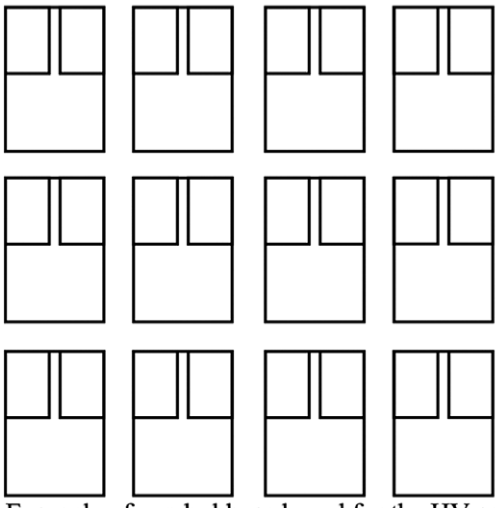
Appendix A: Examples of symbol boards used with low-verbal and high-verbal participants.



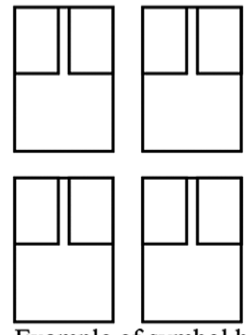
Example of symbol board used for HV group (fixed or random condition)



Example of symbol board used for LV participant Debra (fixed or random condition)



Example of symbol board used for the HV group same symbol condition (tact disruption condition)



Example of symbol board used for LV participant Debra for the same symbol condition (tact disruption condition)

Appendix B: Words and signs used with low-verbal and high-verbal participants

Word lists for the two low-verbal group participants in the word–sign and word–symbol conditions.

Debra	Eric			
po	po	mac	pig	so
rook	slo	jack	jig	doe
flo	blo	pac	rig	
clo	crow	zook	mig	
sac	tro	rac	flo	
bo	mook	dro	sook	

Word lists for the two low-verbal group participants in the word–sign and word–symbol conditions.

mo	jim	rook	jook
zig	sac	zoo	sike

Signs for participants in the low-verbal group.

Molly	Jim	Debra	Eric
pat head with right hand	pat head with right hand	pat head with right hand	pat head with right hand
touch nose with right finger	touch nose with right finger	touch nose with right finger	touch nose with right finger
	open one palm forward	slap table with right hand	open one palm forward
		lift right elbow (90° from body)	slap table with right hand
			lift right elbow (90° from body)
			put right fist into left palm

Final word list for participants in the high-verbal group.

paba	kaba	taba	saba	baba	daba	haba
laba	maba	naba	buba	cuba	duba	fuba
beeba	keeba	deeba	heeba	bihba	kihba	dihba
fihba	bayba	cayba	dayba	fayba	jeeba	leeba
meeba	neeba	hayba	jayba	layba	mayba	baca
daca	haca	jacaa	naca	faca	laca	maca
payba	nayba	rayba	sayba	hafa	peeba	queeba
reeba	paca	raca	quaca	soca	baida	caida
daida	haida	seeba	teeba	veeba	weeba	taca
waca	yaca	vaca	huba	juba	muba	nuba
jaida	laida	maida	naiad	luba	quba	puba
ruba	hihba	jihba	lihba	mihba	paida	quaida
raida	saida	bafa	cafa	dafa	nihba	
pihda	rihda	taida	quihba	yaida	zaida	

Signs for participants in the high-verbal group.

slide right hand down left arm from elbow to hand
raise left arm and point
touch nose with right finger
open one palm forward
pet imaginary animal
put right fist into left palm
slap table with right hand
life right elbow (90° from body)
hook index and middle fingers of both hands to each other
tap underneath chin with right hand
circle index fingers of both hands around each other
cover mouth with right hand

Appendix C: Errors for each of the last four rounds per phase for low-verbal group

Phase	Participant				
	Molly	Jim	Debra	Eric	Grand Mean
Fixed	16	16	9	11	
	69	68	14	27	
	4	10	35	55	
	69	11	25	59	
	$\overline{x}$ = 39.5	$\overline{x}$ = 26.1	$\overline{x}$ = 20.8	$\overline{x}$=38	$\overline{x}$ = 31.1
Random	12	64	95	64	
	68	39	63	69	

Phase	Participant				
	Molly	Jim	Debra	Eric	Grand Mean
	15	60	72	75	
	62	57	67	76	
	$\overline{x}$= 39.3	$\overline{x}$= 55	$\overline{x}$= 74.3	$\overline{x}$=71	$\overline{x}$=59.9
Same	64	12	20	10	
	64	17	36	42	
	59	16	32	3	
	74	23	14	34	
	$\overline{x}$= 65.3	$\overline{x}$= 17	$\overline{x}$= 25.6	$\overline{x}$=22.3	$\overline{x}$=32.5
Sign	18	29			
	1	54			
	25	33			
	5	2			
	$\overline{x}$= 12.3	$\overline{x}$= 29.5			$\overline{x}$=20.9
Sign	18	5	30	88	
	58	13	51	45	
	13	7	8	22	
	61	11	33	25	
	$\overline{x}$= 37.5	$\overline{x}$= 9	$\overline{x}$= 30.5	$\overline{x}$= 45	$\overline{x}$=30.5

Appendix D: Errors for each of the last 10 rounds per phase for high-verbal group

Phase	Participants					
	Amanda*		Gina	Julie	Erin	Grand Mean
Fixed	Last 10	Prior 10	Last 10	Last 10	Last 10	Amanda's Last 10
	13	7	13	8	2	
	22	19	6	3	10	
	17	10	9	1	6	
	21	16	8	3	5	$\overline{x}$=9.5
	22	7	1	3	5	Amanda's Prior 10
	39	4	8	4	0	
	4	14	1	2	4	
	33	9	37	1	5	$\overline{x}$= 7.5
	11	12	8	5	2	
	7	13	13	4	12	
	$\overline{x}$= 18.9	$\overline{x}$= 11.1	$\overline{x}$= 10.4	$\overline{x}$= 3.4	$\overline{x}$=5.1	
Random	12		14	2	13	
	19		8	2	5	
	6		21	0	6	
	16		5	6	0	
	8		8	1	7	
	3		3	1	0	
	7		16**	1	2	
	2			2	1	
	7			6	5	
	7			1	4	
	$\overline{x}$= 8.7		$\overline{x}$= 10.7	$\overline{x}$= 2.2	$\overline{x}$=4.3	$\overline{x}$=6.1
Same	10		13	14	34	
	14		13	5	14	
	2		4	1	17	
	22		15	23	18	
	17		19	7	23	
	6		6	2	17	
	15		6	4	11	
	7		7	3	13	
	17		11	12	14	
	17		1	4	19	
	$\overline{x}$= 12.7		$\overline{x}$= 9.5	$\overline{x}$= 7.5	$\overline{x}$=18	$\overline{x}$=11.9

Phase	Participants				
	Amanda*	Gina	Julie	Erin	Grand Mean
Sign	30	8	0	5	$\bar{x}$=7
	10	6	3	7	
	13	5	2	3	
	21	3	2	13	
	9	12	0	5	
	12	9	0	1	
	3	8	1	10	
	6	11	5	19	
	6	2	1	3	
	7	9	0	11	
	$\bar{x}$= 11.7	$\bar{x}$= 7.3	$\bar{x}$= 1.4	$\bar{x}$= 7.7	

*The first cell includes the errors from participant Amanda's last 10 rounds and from the previous 10 rounds of the fixed phase. Both group means are included for this phase.**Only seven rounds were conducted for participant Gina during the random phase.