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# The Role of Joint Control in the Manded Selection Responses of Both Vocal and Non-vocal Children with Autism

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In the present study, joint-control training was applied when teaching manded selection responses to children with autism. Four vocal children with autism participated in the first experiment, two males (ages seven and eight) and two females (ages seven and nine). The results showed that it was only after object-word naming was trained under joint control that the symmetrical performance of manded selection responses appeared with no additional training. Four non-vocal children with autism participated in the second experiment, two males (ages six and seven), and two females (ages twelve and thirteen). These results also showed that it was only after the joint tact/self-mimetic/sequelic control training that the symmetrical performance of manded selection responses appeared with no additional training.

*Key words:* joint control, listener's behavior, manded selection responses, match-to-sample, autism.

The origin of manded selection behavior is currently a topic of debate in behavior analysis. Horne and Lowe (1996) suggest the term "bi-directional relations" or "name-object symmetry" to describe this speaker-listener relation. These terms imply the reversibility of the "name-object" and "object-name" relations. For example, training people to emit a name to an object engenders the untrained emergence of a selection response to that object given its name and vice versa (Horne & Lowe, 1996, pp. 208–209). That is, a listener can select a cup from an array of objects as the result of learning to tact "cup" or vice versa. Perhaps the occurrence of these bi-directional relations involve emergent or derived relations. That is, direct reinforcement or training for speaker relations alone can result in new or additional listener relations (Horne & Lowe, 1996, p. 208).

The first experiment is based on a thesis completed by the author, and supervised by Barry Lowenkron, that was submitted to the Department of Psychology at California State University, Los Angeles in partial fulfillment of the requirements for the Master of Science degree in Psychology. The second experiment is based on a dissertation completed by the author, and supervised by Julie S. Vargas, that was submitted to the Department of Advanced Education at West Virginia University in partial fulfillment of the requirements for the Doctor of Education degree in Educational Psychology. The author gratefully acknowledges Barry Lowenkron and Julie S. Vargas for their helpful support, and the author also thanks Robert W. Allan for his invaluable comments on an earlier version of the manuscript.

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*Problems with "Bi-directional Relations"*

While the term "bi-directional relations" describes the speaker-listener induction process, it does not answer the question of the origin of the manded selection behavior, or how transfer occurs. Many empirical studies have shown that training object-name relations does *not* necessarily lead to the emergence of name-object relations, or more specifically, training the speaking of words does not lead to the emergence of selecting correct objects for words heard (Guess, 1969; Guess & Baer, 1973; Lee, 1981).

For Skinner (1957) the process of learning to speak is quite different from the process of learning to listen (p. 195), an assertion that is well supported by experimental work. For example, Guess and Baer (1973) taught two children to use –s in their productive language (which was tact training since the objects were present) and –es in their "receptive" language (selection training). They taught two other children to use –es in their "receptive" language (selection training) and –s in their productive language (tact training). During reversal probes, results showed that "three of the four children did not generalize clearly from receptive training with one class of plurals to correct productive use of that class, nor did productive training of the other class of plurals lead to correct receptive responses to that class."

*Conditional Discrimination*

Manded stimulus selection like much verbal behavior involves conditional discriminations. However, simple discriminative control is not sufficient to account for many speaker-listener relations because of the multiple layers of control involved (Lowenkron, 1991). For example, when a listener selects a cup from an array of items when manded by the speaker "give me the cup," the listener's behavior is under the control of both the verbal stimulus ("cup") and the nonverbal stimulus (the cup). Simple discrimination does not address the question of how these two stimuli combine to evoke a proper selection response.

Manded stimulus selection clearly involves a conditional discrimination, but alone conditional discrimination also fails to explain how two stimuli combine to evoke a proper selection response. One form of conditional discrimination involves a sample and a comparison stimulus: when shown a blue square as a sample, then selecting the blue square among the comparison stimuli of a blue square and a red square; similarly selecting a cup among the comparisons of a cup and a spoon in the presence of the spoken word "cup."

There are two types of matching tasks described as conditional discriminations: relational matching (or identity matching) and arbitrary matching (or generalized matching). In the simplest form of relational (identity) matching, the sample and the comparison share identical features, for example, selecting a blue comparison in the presence of a blue sample. In arbitrary (generalized) matching, the sample and the comparison do not share identical features, for example, selecting a circle in the presence of a blue sample. In both examples selecting a comparison is strengthened in the presence of the sample, with the identity relations between colors in the first being ignored in the second (Carter & Eckerman, 1975; Cohen et. al., 1981; Lowenkron, 1991). However, considering manded selection solely as a conditional discrimination fails to address the differences between identity matching and arbitrary (generalized) matching (Lowenkron, 1991).

### *Equivalence Relations*

Horne and Lowe (1996) used the concept of equivalence to interpret *emergent* or derived speaker-listener relations. Previously untaught object-object listener behavior was said to emerge or be derived as the result of object-word training (Sidman & Tailby, 1982; Saunders, 1989; Sidman, 1990; Dugdale & Lowe, 1990; Sidman, 2000). Equivalence includes three types of relations among stimuli: reflexivity, symmetry, and transitivity. Reflexivity refers to the phenomena of identity. Symmetry refers to reversibility, and the training of reflexivity and symmetry often engenders the relation of transitivity.

Equivalence theory and research have generated considerable interest among behavior analysts because they would seem to be a basis for interpreting a wide range of novel environment-behavior relations. To some, these emergent relations seem to provide an understanding of how we learn language. For example, according to Dugdale and Lowe (1990) many language-based functions seem to reveal emergent equivalence relations, such as reasoning, acquisition of language, learning of arbitrary relational concepts, and symbolic activity (p. 115).

Although many untrained/unreinforced relations can be interpreted in terms of equivalence, naming the relations symmetrical or reflexive or transitive does not explain how these relations come about. Using manded selection as an example again, equivalence relations would assume that the selection response is the product of name training. That is, training the object-name relation (e.g., saying "cup" in the presence of a cup) would engender the symmetrical name-object relation (e.g., selecting cup when hearing "cup"). However, what happens when the symmetrical name-object behavior does not occur? In other words, if selection responses do not occur after tact training or vice versa, what are the variables that might account for this problem? Saunders (1989) stated that when equivalence relations do not occur, it is possibly due to the use of procedures other than those used in the stimulus equivalence studies. Although procedural problems might account for instances when symmetry does not occur, it is also possible that other variables can account for both the occurrences and non-occurrences of symmetrical relations. It is a sort of logical fallacy to describe this phenomenon of bi-directional responding as an instance of symmetry, and to then use the notion of symmetry as an explanation of bi-directional responding. The same problem is relevant to reflexivity and transitivity. It is the position here that symmetry is not an explanation, but rather exactly what needs to be explained.

*Joint Control*

Joint control (Lowenkron, 1984, 1988, 1989, 1991, 1998; Lowenkron & Colvin, 1992, 1995) refers to selection responses that occur under the control of two verbal operants; a self-echoic and a tact. For example, when a teacher asks a student to select a cup from an array of ten items, a self-echoic on the part of the student is evoked by the spoken sample ("cup" in the phrase "Give me the cup"). Upon seeing the cup, the additional verbal operant (tact) is evoked by the comparison (the cup), and these two verbal operants then jointly evoke the selection response.

Lowenkron (1988) illustrated joint control by training children with developmental disability to use hand signs to perform a generalized identity-matching task. They were first taught to use the hand signs for four shapes. Next, each of the four shapes would appear in the center of a projection screen and the children were taught to maintain their hand signs over the delay intervals. Then, all four shapes appeared on the corners of the screen after the time delay. As a result of this training, these children were able to make the sign to whatever shape comprised the current sample and then maintain the sign until the comparisons were presented. When all of these components were performed correctly, the children produced an identity matching of the samples and the comparisons.

However, after the identity matching, the occurrence of generalized identity matching did not occur with the transfer-set shapes (another four shapes). Then, each of the hand signs was trained to the corresponding transfer-set shape. Once children acquired hand signs (i.e., tacts) to the novel shapes, the identity matching performance immediately generalized to these stimuli. This illustrates the concept of joint control and shows that the manded selection response was evoked by one stimulus (the sample) and preserved by rehearsal (self-duplic), and the rehearsal (self-duplic) was combined with the control of an additional second stimulus (the comparison). In addition, as the participant held the hand sign and matched it to the comparison stimulus, the comparison stimulus could also exert tact control. Thus, the manded selection responses in this experiment were under joint self-duplic and tact control.

With joint control, the manded selection response is not directly evoked by multiple variables that contribute to its response strength, but it is evoked by the occurrence of joint control over some other topography, such as the topography rehearsed as duplic (Lowenkron, 1998, p. 331). Joint control is not limited to just joint mimetic/tact control. Joint control is an event that is independent of any particular stimulus but is specific to the relation between stimuli. It is this feature that permits joint control to serve as the basis for generalized responding (Lowenkron, 1998, pp. 331–332). Joint control offers a promising answer to the question of the origin of the manded stimulus selection responses. Equivalence relations might offer a necessary procedure for a listener's behavior, but are not sufficient. Furthermore, joint control does not require any new principles or explanations for the behavior of the listener. It simply restates and demonstrates a critical feature of verbal behavior: multiple causation. As stated by Skinner (1957), there is "a different type of multiple control, in which functional relations, established separately, combine possibly for the first time upon a given occasion" (p. 229).

## EXPERIMENT 1

In the first experiment, the notion of joint control was applied to the analysis of word-object symmetry in the selection behavior of four vocal children with autism. The dependent variable for this study was the emergence of untrained/unreinforced manded stimulus selection responding. The independent variable was the acquisition of joint tact/self-echoic responding. In the initial phase of training the children learned to tact (object-word) each of four pictures, to echo their names when spoken by the experimenter, and to select the correct picture in response to these spoken names (word-object). When this training did not generalize to novel pictures, the participants learned to emit the names of the novel pictures and were retested for accurate selection. In subsequent training, picture-selection was brought under joint control such that when given a picture's name to rehearse (i.e., echo), participants subsequently selected only the pic-

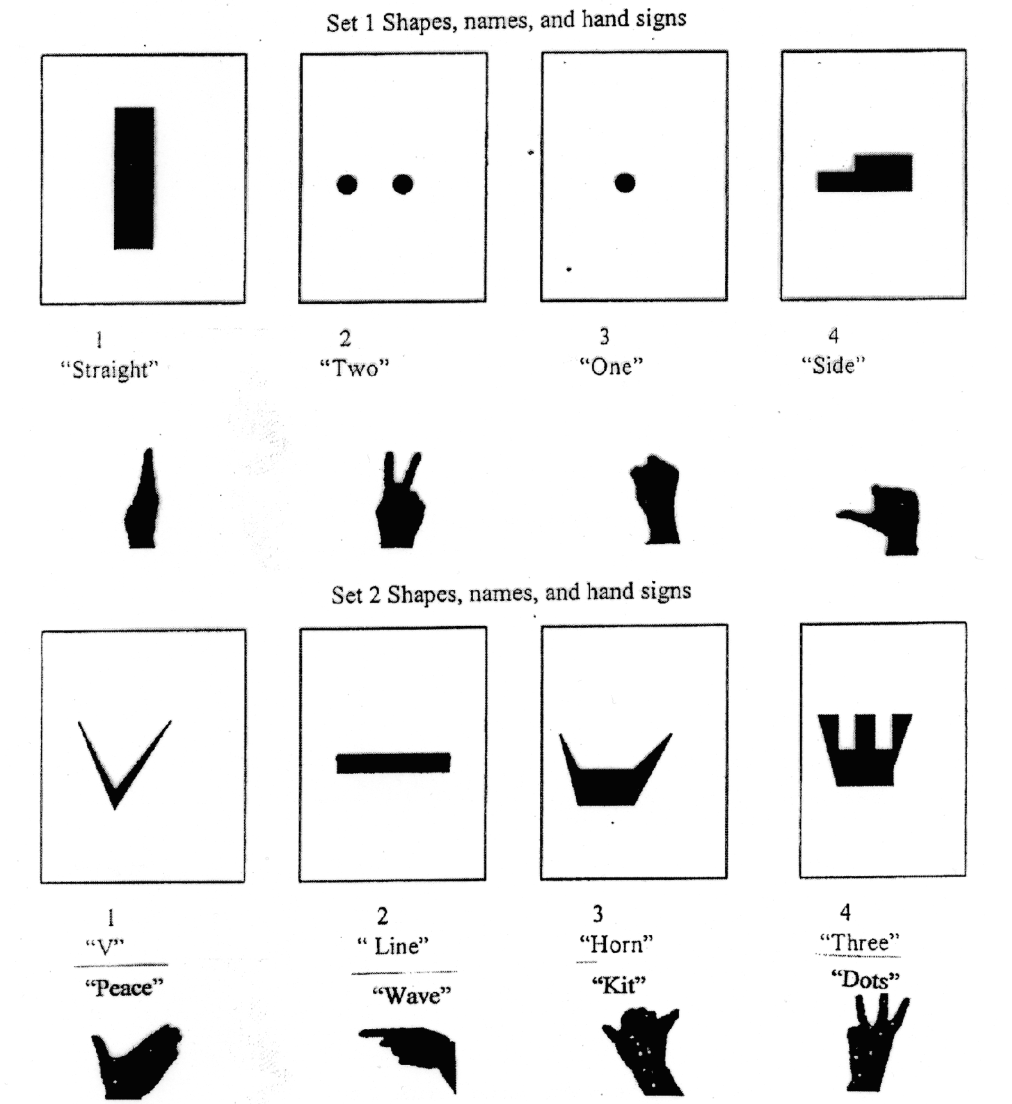


**Fig. 1.** Shapes, names, and hand signs for the experiment. Partially adapted from Lowenkron (1988). Double names for bottom row were given for Participant 4 after he scored 100% on Baseline Test (Set 2) with top row names.

ture that (jointly) evoked a tact (object-word) with the same topography that the participant was rehearsing. Thus, the word-object selection performance included the object-word (tact) relation, and as a result, in subsequent tests of generalization with novel stimuli, word-object/object-word symmetry was seen.

## Method

### *Participants*

A total of four participants, two males (ages seven and eight) and two females (ages seven and nine) participated in this experiment; all were diagnosed with Autistic Disorder. These four were selected based on their demonstrated skill at imitating vocalizations in response to the experimenter's model. Three participants could produce two-syllable words; one could only produce one-syllable words. All had used the Picture Exchange Communication System (PECS) during the past year.

### *Materials*

Training materials included verbal requests by the experimenter that served as spoken

Table 1
Outline of Training/Testing Procedures and Stimulus Set (Experiment 1)

| Procedure | Stimulus Set |
|---|---|
| 1. Baseline test | Set 1 pictures |
| 2. Echoic and tact training | Set 1 pictures |
| 3. Generalization test | Set 1 pictures |
| 4. Joint control training | Set 1 pictures |
| 5. Baseline test | Set 2 pictures |
| 6. Brief joint control training | Set 1 pictures |
| 7. Echoic and tact training | Set 2 pictures |
| 8. Brief joint control training | Set 1 pictures |
| 9. Generalization test | Set 2 pictures |
| 10. Baseline test | Set 3 pictures |
| 11. Brief joint control training | Set 2 pictures |
| 12. Echoic and tact training | Set 3 pictures |
| 13. Generalization test | Set 3 pictures |

Table 2
Correct Responses out of a Possible Eight (Experiment 1)

| | Participant AL | | Participant SC | | Participant AD | | Participant IL | |
|---|---|---|---|---|---|---|---|---|
| Set 1 | Baseline | Generalize | Baseline | Generalize | Baseline | Generalize | Baseline | Generalize |
| Self-echoic | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 |
| Selection | 1 | 1 | 2 | 2 | 0 | 6 | 2 | 0 |
| Set 2 | Baseline | Generalize | Baseline | Generalize | Baseline | Generalize | Baseline | Generalize |
| Self-echoic | 3 | 3 | 0 | 8 | 0 | 8 | 0 | 8 |
| Selection | 3 | 3 | 0 | 8 | 0 | 8 | 0 | 8 |
| Set 3 | Baseline | Generalize | Baseline | Generalize | Baseline | Generalize | Baseline | Generalize |
| Self-echoic | 0 | 4 | 0 | 7 | 0 | 8 | 0 | 4 |
| Selection | 0 | 4 | 0 | 7 | 0 | 8 | 0 | 4 |

samples. In addition, 12 black and white (5 cm x 5 cm) Mayer-Johnson pictures served as comparisons for the three participants who could produce two-syllable words. An additional 12 pictures served as comparisons for the one participant who could only produce one-syllable words. These 12 were randomly divided into three sets of four, a training set (Set 1) and two testing/transfer sets (Sets 2 and 3).

The pictures were presented on the table in front of the participant and the experimenter. A 20 cm x 28 cm x 5 cm binder, with two strips of Velcro, was used to secure the pictures arranged into two rows of two. The pictures were randomly placed in these four positions.

*Reinforcers*

Participants were given choices of items (e.g., praise, food, drink, toys, tokens, or play activities) as reinforcers. The experimenter presented icons for 5 to 6 reinforcers for the subjects to choose from prior to each of the training sessions.

*Setting*

Training took place in the participant's home environment. The experimenter sat next to the participant at a table. During all testing sessions, two observers sat behind the participant to independently record the participant's performance, and all sessions were videotaped.

*Reliability*

The two observers marked "+" for correct responses and "–" for incorrect responses. Inter-observer reliability was assessed as:

$$\frac{A}{A + D} \times 100$$

where A is the agreements and D is the disagreements. The coefficients were 90% or higher.

## Procedure

*STEP 1—Baseline Test (Set 1)*

Set 1 pictures were presented four at a time on the binder. With each presentation, the experimenter said to the participant "Give me ___(and said the name of the picture)." Both correct and incorrect selections were followed by the verbal feedback "Thank you." Each of the four pictures was tested on two trials. If the participant selected the wrong picture on 3 of the first 4 trials, the experimenter stopped the testing and that participant was not used in the experiment. If the participant made correct selections on at least 3 of the first 4 trials, then testing continued for a total of 8 trials.

*STEP 2—Naming Training (Echoics and Tacts)*

*Echoic Training.* The names of the Set 1 pictures were used. No pictures were presented. The experimenter said the name of one picture while gesturing for the participant to repeat the modeled name after the experimenter said it. (To execute this prompt, the *echoic-gesture prompt,* the experimenter waved her hand repeatedly with the palm towards her, in a circular motion toward and away from herself.) Accurate repetitions of the modeled name (i.e., the participant echoed the name of the picture twice after the experimenter said it) were followed by reinforcement. If the participant gave an incorrect response, the experimenter said, "No," and then repeated the name of the picture and again prompted the participant to repeat the name. Training continued until each participant made three correct repetitions of the modeled name. Reinforcement was provided for every correct response.

*Tact training.* All four pictures of Set 1 were presented. The experimenter asked the participant, "What is it?" while pointing to one of the four pictures. Correct vocal tacting responses were followed by reinforcement. If the participant did not respond, the experimenter said the name of the picture again and gave the echoic-gesture prompt. If the participant gave an incorrect name, the experimenter said, "No," asked, "What is it?" again, said the name of the picture, and then gestured for the participant to respond. Immediately after the participant accurately repeated the name, the experimenter asked again, "What is it?" thus requiring the participant to say the name under the control of the object (as a tact) rather than under the control of the experimenter's immediately preceding spoken word (an echoic). To complete this step, participants had to tact correctly 4 out of 5 trials with each of the Set 1 pictures before moving on to the next step.

*Giving behavior training.* With one picture from Set 1 on the table, the experimenter first provided the physical prompt, then gradually faded the prompt until the participant was able give the experimenter the picture that was on the table. The same procedure was used with all pictures in a random order.

*STEP 3—Generalization Test (Set 1)*

Step 1 was repeated.

*STEP 4—Joint-Control Training*

The purpose of training in this step was to force a tact control event in the midst of an echoic stream of repetitions so as to produce joint tact echoic control.

a) The four pictures of Set 1 were presented to the participant one at a time.
b) The experimenter said the name of the picture while using the echoic gesture prompt.
c) While the participant was repeating the name of the picture, the experimenter said the name of the picture again and again displayed the prompt.
d) When the participant picked up the named picture, the experimenter immediately asked, "What is it?"
e) The correct response (tacting the picture) was reinforced. If the participant said an incorrect name, the experimenter prompted correct tact behavior and repeated Steps c and d.
f) Training continued until the participant selected each picture correctly on each of 10 trials when the pictures were presented individually, and again when the pictures were presented two at a time, and again three at a time, and finally four at a time.
g) As practice with the four pictures continued, the echoic prompt was faded and participants responded to the spoken sample by repeating it with no prompting by the experimenter.
h) Reinforcement was provided for each correct response.

*STEP 5—Baseline Test (Set 2)*

Because selection training with the Set 1 stimuli continued until the performance was errorless, there was no reason to further test the performance. Testing thus moved on to Set 2, and the procedures of Step 1 (Baseline Test) were repeated with the Set 2 pictures.

*STEP 6—Regain Training-Set Behavior (Brief Joint-control Training)*

The procedures of Step 4, beginning with Step 4f, were repeated with all four pictures presented at once.

*STEP 7—Echoic and Tact Training (Set 2)*

The Set 2 pictures and the Step 2 procedures occurred.

*STEP 8—Regain Training Set 1 Behavior (Brief Joint-control Training)*

Step 6 was repeated.

*STEP 9—Generalization Test (Set 2)*

Step 5 was repeated, except each picture was tested on one trial only.

*STEP 10—Baseline Test (Set 3)*

The procedures of the baseline test were repeated but with Set 3 pictures.

*STEP 11—Regain Set 2 Behavior (Brief Joint-control Training)*

Step 6 was repeated but with Set 2 pictures.

*STEP 12—Echoic and Tact Training (Set 3)*

Set 3 pictures and Step 2 procedures occurred.

*STEP 13—Generalization Test (Set 3)*

Step 10 was repeated.

## Results

Data were recorded on the number of correct self-echoic responses and selection responses during all Baseline and the Generalization tests. All reliability coefficients were above 93%. As illustrated in Table 2, participant AD did not make any correct selections during the Baseline Test (Set 1). However, during the Generalization Test with Set 1 pictures, AD made one correct selection with two of the pictures, and two correct selections with the other two pictures. On each of the correct selections, but none of the incorrect selections, AD also made a correct self-echoic response. After reaching an errorless performance in joint-control training on the Set 1 pictures, AD made no correct selections during the Step 5 Baseline Test with Set 2 pictures. However, after regaining a joint-control performance in Steps 6 and 8 with the Set 1 pictures, as well as learning the names for the novel Set 2 pictures in Step 7, AD made correct selections on all pictures during the Generalization Test with Set 2 pictures in Step 9. And again, AD made no correct selections during the Step 10 Baseline Test with the novel Set 3 pictures, but after regaining joint-control performance in Step 11 with the Set 2 pictures, and learning the names for the novel Set 3 pictures, AD made two correct selections with all Set 3 pictures during the Step 13 Generalization Test (Set 3). As illustrated in Table 2, before each of the correct selections, but none of the incorrect selections, AD made a correct self-echoic response.

The second participant, SC, made one correct selection on two pictures during Baseline Test (Set 1). His performance was the same during the Generalization Test (Set 1). After reaching errorless performance in joint-control training on the Set 1 pictures, SC made two correct selections on one of the four pictures during the Step 5 Baseline Test (Set 2). However, after regaining joint-control performance in Steps 6 and 8 with the Set 1 pictures, as well as learning the names for the novel Set 2 pictures in Step 7, SC made one correction selection on all of the pictures during the Generalization Test with Set 2 pictures in Step 9. And again, SC made no correct selections during the Step 10 Baseline Test with Set 3 pictures, but after regaining joint-control performance in Step 11 with the Set 2 pictures, as well as learning the names for the novel Set 3 pictures, SC made two correct selections for three out of four pictures, and one correct selection for another picture during the Step 13 Generalization Test (Set 3).

After reaching errorless performance in joint-control training on the Set 1 pictures, AL made one correct selection on three of the four pictures during the Step 5 Baseline Test with Set 2 pictures. After regaining joint-control performance in Step 6 and 8 with the Set 1 pictures, as well as learning the names for the novel Set 2 pictures in Step 7, AL made one correct selection on all four pictures during the Generalization Test with Set 2 pictures in Step 9, and no correct selections during the Step 10 Baseline Test with novel Set 3 pictures After regaining joint-control performance in Step 11 with the Set 2 pictures, as well as learning the names of the Set 3 pictures, AL made one correct selection with all four Set 3 pictures during the Step 13 Generalization Test. As illustrated in Table 2 before each of the correct selections, but none of the incorrect selections, AL made a correct self-echoic response during both Generalization Tests (Set 2 and 3). However, self-echoic responses were inconsistent during both the Baseline and Generalization Test for Set 1 pictures. The forth participant, IL, made one correct selection on two of the four pictures during the Baseline Test for Set 1 pictures, but no correct selections during the Generalization Test (Set 1). After reaching errorless performance in joint-control training on the Set 1 pictures, IL made no correct selections during the Step 5 Baseline Test with Set 2 pictures. However, after regaining joint-control performance in Steps 6 and 8 with the Set 1 pictures, as well as learning the names of the novel Set 2 pictures in Step 7, IL made one correct selection with all four pictures during the Generalization Test with Set 2 pictures in Step 9. IL made no correct selections with all four pictures during Step 3, but after regaining joint-control performance in Step 11 with the Set 2 pictures, as well as learning the names for the novel Set 3 pictures, IL made one correct selection with all four pictures during the Step 13 Generalization Test (Set 3). As illustrated in Table 2, before each of the correct selections, but none of the incorrect selections, IL made a correct self-echoic response during both Generalization Tests (Set 2 and 3). However, the self-echoic responses were inconsistent during both the Baseline and Generalization Test for Set 1 pictures.

## Discussion

In the Baseline Test (Set 1), the five correct selections made without preceding echoics could be attributed to chance alone because there were only five correct selections made in 32 trials. In Generalization Test 1, the relation between accurate self-echoic performance and accurate selection was in accord with what would be expected if accurate selection does indeed depend on joint-control. For under joint control accurate selections are dependent on the onset of stimulus control over a single topography by both a tact and an echoic. Thus, three of the four participants neither made correct self-echoic responses, nor correct selections during the Step 3 Generalization Test (Set 1), while the one subject (AD) who did make correct self-echoics, showed accurate selections on six of the eight trials in Generalization Test (Set 1). There was no case of an accurate selection without an accurate self-echoic response.

The failure of these same three participants also shows that the bi-directional relation (e.g., name-object and object-word relations) does not routinely occur after the acquisition of tacts. All participants were trained to emit tacts for the pictures in Set 1 (the object-name relation), but only one, participant AD, consistently made accurate selections (the name-object relation). These results imply the necessity for joint control in responding of this sort. As the data in Generalization Tests 2 and 3 indicate, even given tact training, it was only after participants were trained in joint control, with Set 1, that bi-directional responding appeared (in the form of accurate selection). It thus was evident that the acquisition of appropriate tacts and self-echoics to mediate selection behavior was not sufficient to produce bi-directional responding, as in Generalization Test (Set 1), unless these responses are brought under joint tact/echoic control, but once they are, symmetrical responding occurs immediately, as in Generalization Tests (Set 2 and Set 3).

## EXPERIMENT 2

There were two goals for the second experiment: First, to explore the functions of joint control in relation to the "manded selection/ tact" relation; and second, to examine the role of joint control in selection responses of non-vocal children with autism. The dependent variable for this study was the occurrence of untrained/unreinforced name-object symmetry responding (manded stimulus selection). The independent variable was the occurrence of joint tact/self-mimetic (sequelic) responding. The study was designed to examine whether joint control plays a necessary role for the occurrence of untrained/unreinforced manded selection responses of non-vocal children with autism.

### Method

#### *Participants*

A total of four students participated in this experiment, two males (ages six and seven) and two females (ages 12 and 13). All were diagnosed with Autistic Disorder. These four participants were selected based on their limited vocal and selection responses. The level of vocal and selection responses were assessed with the Assessment of Basic Language Learning Skills (ABLLS) (Partington & Sundberg, 1998). The criteria for selection were maximum scores on the following items on the ABLLS: "2" on C 6, "0" on C 7, "1" on D 9, "1" on E 1, "0" on G 1, "0" on H 1, and "1" on Z 2. In general, the participants could follow instructions to touch a common item in various positions but were not able to follow instructions to perform an action out of a structured-teaching context. The participants could imitate no more than two fine motor movements and imitate no more than two sounds on request.

#### *Materials*

Training materials included the eight visual stimuli in Figure 1. These were black and white arbitrary shapes drawn on eight 7.5 cm x 12.7 cm white index cards, selected to match hand signs, and arranged into two sets of four. The first set served as the training set (Set 1), and the second served as the testing/transfer set (Set 2).

#### *Reinforcers*

Correct responses resulted in receipt of a flower sticker with velcro on the back which could be attached to a 12.7 cm x 15.2 cm laminated card. The participants could exchange these sticker for edibles (e.g., candies, cookies, popcorn, drinks, etc.), activities (play with computer for up to 5 minutes, etc.), or tangibles (e.g., toy figures, cards, etc.).

#### *Setting*

Training took place in each participant's home. The experimenter sat next to the participant at a table, and testing objects were placed on the table in front of the experimenter and participant. During all testing sessions, two observers sat behind the participant to independently record the participant's performance, and all sessions were videotaped. These two observers were also used for calculating reliability. Each participant participated in the training and testing for half an hour per day, and the time frame for the completion of this experiment ranged from five to eleven days.

*Reliability*

The two observers marked "+" for correct responses and "–" for incorrect responses. Inter-observer reliability was assessed as:

$$\frac{A}{A + D} \times 100$$

where A is the agreements and D is the disagreements. The coefficients were all 90% or higher.

*Overview of the Experimental Design*

Procedures were the same for all testing steps (steps 1, 3, 7, 10, and 11a.). They were conducted with two observers sitting behind the participant. During joint-control training (Step 6), because training continued until the participants' performances were errorless, no test was necessary after this step. In addition, joint-control training was always conducted with Set 1 shapes, and generalization tests and follow-up generalization tests were always conducted with Set 2 shapes.

## Procedures

*STEP 1—Baseline Test (Set 1)*

Set 1 pictures were presented four at a time on the table. With each trial, the experimenter said to the participant "Give me ___ (shape)." Both correct and incorrect responses were followed by verbal feedback "Thank you." Each of the four pictures was tested on two trials.

*STEP 2—Tact Training*

To develop control over the selection of comparison stimuli by the participant's hand signs, a 7.62 cm x 7.62 cm card with shape 1 of the Set 1 shapes was held approximately 12 inches in front of the comparison (shape 1). Physical prompting was used initially to evoke hand signs and gradually faded. As soon as the participant made the hand sign on the card, the distance between the card and the comparison was gradually decreased to 6 inches in front of the comparison (shape 1). As soon as the participant made the correct hand sign, the card was completely removed. Shapes 2, 3, and 4 of the Set 1 shapes were trained in the same fashion. Correct hand signs were reinforced with stickers. Any changes in hand signs before touching the comparison stimulus were followed by a verbal "try again" from the experimenter. The comparison stimulus was removed from the tabletop and the trial repeated. These comparisons were then presented one at a time in a random fashion. Training continued to a criterion of 5 correct trials out of 5 for each comparison in a single session.

*STEP 3—Post-tact Test*

The purpose of this step was to determine whether manded selection would appear after tact training. This step was identical to Step 1 and occurred immediately after the tact training. Then, the experiment stopped temporarily until the next day. An identical test (Post-tact Test 2) was given to the participant again at the beginning of the next session (on the following day). Thus, each of the four pictures was tested on two trials to ensure that the newly established tact and selection responses did not extinguish under the testing condition. During the testing step, no reinforcement followed the selection responses.

*STEP 4—Mimetic and Sequelic Training*

*Mimetic training*. In this step, the experimenter first showed the hand sign for shape 1 (Set 1) in the absence of the printed shape and verbal instructions. A physical prompt was used to prompt the participant to mimic the experimenter's hand sign. The physical prompt was faded until the participant mimicked the experimenter's hand sign and held it for up to 5 seconds. All four hand signs of the four shapes in Set 1 were trained similarly. Then the hand signs were presented randomly. Correct mimetic responses were reinforced, and incorrect responses were followed by a verbal "no" and the trial repeated. Training continued to a criterion of five correct trials out of

Table 3
Outline of Training/Testing Procedures and Stimulus Set (Experiment 2)

| | Procedure | Stimulus Set |
|---|---|---|
| 1. | Baseline test | Set 1 pictures |
| 2. | Tact training | Set 1 pictures |
| 3. | Post-tact test | Set 1 pictures |
| 4. | Mimetic/sequelic training | Set 1 pictures |
| 5. | Post-mimetic/sequelic test | Set 1 pictures |
| 6. | Joint control training | Set 1 pictures |
| 7. | Baseline test | Set 2 pictures |
| 8. | Tact training | Set 2 pictures |
| 9. | Mimetic/sequelic training | Set 2 pictures |
| 10. | Generalization test | Set 2 pictures |
| 11a. | Follow-up generalization test | Set 2 pictures |
| 11b. | Brief joint control training | Set 1 pictures |
| 12. | Generalization test | Set 2 pictures |
| 13. | Follow-up generalization test | Set 2 pictures |

five for each hand sign in a single session.

*Sequelic training*. In this step, the experimenter said the name of the shapes in the absence of the shapes. For example, “straight” for shape 1 (Set 1) (see Figure 1). Mimetic prompts were used here and faded until the participant made the correct hand sign and repeated it upon hearing the experimenter say the name of the shape. All four hand signs to the four shapes in Set 1 were trained in the same way. Then the vocal stimuli of the names of the shapes were presented randomly. Correct sequelic responses were reinforced, and incorrect responses were followed by a verbal “try again” and the trial repeated. Training continued to a criterion of five correct trials out of five for each shape in a single session.

*STEP 5—Post-mimetic/sequelic Test*

The purpose of this step was to determine if manded selection responses would occur after mimetic and sequelic training. This was identical to Step 3, and occurred immediately after the mimetic/sequelic training. The experiment stopped here until the next day. An identical test (Post-mimetic/sequelic Test 2) was given again on the following day.

*STEP 6—Joint-control Training (Set 1)*

The purpose of this step was to force a tact in the midst of a self-mimetic rehearsal response so as to produce joint tact/self-mimetic or sequelic control.

a) The four shapes were placed on the table one at a time.
b) The experimenter said to the participant “Give me ___ (name of the shape).”
c) The participant was prompted mimetically to make the hand sign of the shape, match the sign to the shape, then hand the picture of the shape to the experimenter.
d) The experimenter immediately asked, “What is it?”
e) Correct tact responses were followed by stickers.
f) Incorrect tact responses were followed by a verbal “try again” and the same trial was repeated.
g) Training continued until the participant selected each shape correctly on each of the five trials when shapes were presented individually, and again when the shapes were presented two at a time, and again three at a time, and four at a time.

*STEP 7—Baseline Test (Set 2)*

Because selection response training with the Set 1 stimuli was continued until the performances of the participants were errorless, there was no reason to further test the performances. Training and testing thus were moved to Set 2 shapes, and the procedure of Step 1 was repeated here but with the Set 2 shapes. However, for participant 4, the spoken names to Set 2 shapes were changed because he scored 8 out of 8 when using the original spoken names. Thus, for participant 4, this step was repeated using new spoken names.

*STEP 8—Tact Training (Set 2)*

This step was identical to Step 2, except that Set 2 shapes were used.

*STEP 9—Mimetic and Sequelic Training (Set 2)*

This step was identical to Step 4, except that Set 2 shapes were used.

*STEP 10—Generalization Test (Set 2)*

This step was identical to Step 7. If selection responses were lower than 50% at Step 10, the experiment was designed to move onto Step 11b, 12, and 13. However, if selection responses were higher than 50% at Step10, the experiment would stop at Step 11a.

*STEP 11A—Follow-up Test (Set 2)*

This step was identical to Step 10, and was given to the participant a week after Step 10. Because during Step 10 participant 2 made selection responses in the absence of tact responses and participant 3 made selection responses in the absence of both tact and sequelic responses, the comparisons were placed 5 feet away from participants 2 and 3 during this step.

*STEP 11B—Brief Joint-control Training (Set 1)*

If generalization did not occur in Step 10, a brief joint-control session with Set 1 shapes would occur.

*STEP 12—Generalization Test 2 (Set 2)*

This step was identical to Step 10.

*STEP 13—Follow-up Test (Set 2)*

This step was identical to Step 10, and occurred a week after Step 12.

## Results

Two observers recorded the number of correct manded selection, tact, and sequelic responses during all steps. All reliability coefficients were above 91%. Trials-to-criteria data were collected during the training steps. However, because the training criteria for all training steps were specifically defined, data analysis focused only on the testing steps. The experiment stopped at Step 11a for all participants.

As illustrated in Table 2, participant 1 made one correct selection out of eight during the Baseline Test with Set 1 shapes. During the first Post-tact Test (Set 1), one correct selection out of eight occurred, but not the same one initially made. On the next day, three correct selections during the Post-tact Test 2 (Set 1) occurred. After mimetic training, two correct selections out of eight during the Post-mimetic/sequelic Test (Set 1) occurred, and one correct selection out of eight the next day during the Post-mimetic/sequelic Test 2 (Set 1). None of the correct selections were accompanied by tact or sequelic responses. That is, the hand sign did not match the shape. nor was it made immediately upon hearing the name of the shape. Prior to the joint-control training, correct selection responses of this participant occurred only eight times out of 40 opportunities.

After reaching an errorless performance (5 out of 5) in joint-control training on the Set 1 shapes, participant 1 made no correct selections during the Baseline Test with Set 2 shapes and no tact or sequelic responses. However, after tact and mimetic/sequelic training on Set 2 shapes, participant 1 made correct selections (8 out of 8) with all four Set 2 shapes during the Generalization Tests (Set 2) without joint-control training on Set 2 shapes. And again 8 out of 8 correct selections with all four of the Set 2 shapes were made during the follow-up Generalization Test the next day. In the Generalization Test (Set 2) and the follow-up Generalization Test, all correct selection responses were accompanied with correct tact and sequelic responses. After the joint-control training on Set 1 shapes, selection responses of this participant on Set 2 shapes were occurring at an errorless level.

Participant 2 made three correct selections out of eight during the Baseline Test with Set 1 shapes (see Table 2), but this performance was

Table 4
Correct Responses out of a Possible Eight (Experiment 2)

| | Participant 1 | | | | | Participant 2 | | | | | Participant 3 | | | | | Participant 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Set 1 | BL | PT-1 | PT-2 | PS-1 | PS-2 | BL | PT-1 | PT-2 | PS-1 | PS-2 | BL | PT-1 | PT-2 | PS-1 | PS-2 | BL | PT-1 | PT-2 | PS-1 | PS-2 |
| Self-mimetic | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Selection | 1 | 1 | 3 | 2 | 1 | 3 | 0 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 0 | 2 | 0 | 0 | 2 | 0 |
| Sequelic | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Set 2 | BL | GT-1 | GT-2 | | | BL | GT-1 | GT-2 | | | BL | GT-1 | GT-2 | | | BL | BL | GT-1 | GT-2 | |
| Self-mimetic | 0 | 8 | 8 | | | 0 | 0 | 0 | | | 0 | 0 | 0 | | | 0 | 0 | 4 | 4 | |
| Selection | 0 | 8 | 8 | | | 1 | 8 | 8 | | | 2 | 8 | 8 | | | 8 | 0 | 4 | 4 | |
| Sequelic | 0 | 8 | 8 | | | 0 | 8 | 0 | | | 0 | 0 | 0 | | | 0 | 0 | 8 | 8 | |

Note: BL = Baseline test, PT-1/2 = Post-tact test 1/2, PS-1/2 = Post-mimetic/sequelic test 1/2, GT-1/2 = Generalization Test 1/2.

not repeated after tact training during the Post-tact Test (Set 1). On the next day, two correct selections out of eight occurred during the Post-tact Test 2 (Set 1) and one correct selection on both the Post-mimetic/sequelic Test (Set 1) and the Post-mimetic/sequelic Test 2 (Set 1). None of the correct selections was accompanied by tact or sequelic responding. Similar to the first participant, prior to the joint-control training, correct selection responses occurred only seven times in the 40 trials.

After reaching an errorless performance (five out of five) in joint-control training on the Set 1 shapes, participant 2 made one correct selection out of eight during the Baseline Test with Set 2 shapes with no tact or sequelic responses. However, after tact and mimetic/sequelic training on Set 2 shapes, participant 2 made eight out of eight correct selections on Set 2 shapes with correct sequelic responses on all selections during the Generalization Test (Set 2). These responses were not accompanied by tact responding. In the follow-up Generalization Test with Set 2 shapes, participant 2 continued to make eight out of eight correct selections on Set 2 shapes; however, none of the selection responses was accompanied by tact or sequelic responding. Nevertheless, after the joint-control training, selection responses of this participant were occurring at an errorless level. Again, joint-control training was given only for Set 1 shapes.

Participant 3 made one correct selection out of eight during the Baseline Test with Set 1 shapes (see Table 2). During the Post-tact Test (Set 1), two correct selections out of eight occurred and one was the same one made during the Baseline Test (Set 1). On the next day, two correct selections out of eight occurred during Post-tact Test 2 (Set 1). Participant 3 made two correct selections out of eight in the Post-mimetic/sequelic Test (Set 1) and no correct selections in the Post-mimetic/sequelic Test 2 (Set 1). None of the correct selections were accompanied by tact or sequelic responding.

After reaching an errorless performance (five out of five) in joint-control training on the Set 1 shapes, participant 3 made two correct selections during the Baseline Test with Set 2 shapes with no tact or sequelic responding. However, after tact and mimetic/sequelic training on Set 2 shapes, this participant made 8 out of 8 selections on Set 2 shapes with no tact or sequelic responding during both the Generalization (Set 2) and the follow-up Generalization test with Set 2 shapes. Selection responses of this participant were occurring at an errorless level immediately after the joint-control training.

Participant 4 made two correct selections out of eight during the Baseline Test with Set 1 shapes (see Table 2), but made no correct selections during either Post-tact Test 1 or Post-tact Test 2 with Set 1 shapes. Two correct selections out of eight occurred during the Post-mimetic/sequelic Test (Set 1), but no correct selections during Post-mimetic/sequelic Test 2 (Set 1). None of the correct selections were accompanied by tact or sequelic responding. Like the other three participants, prior to the joint-control training, correct selection responses rarely occurred.

After reaching an errorless performance (five out of five) in joint-control training on the Set 1 shapes, participant 4 made eight out of eight correct selections during the Baseline Test with Set 2 shapes when the experimenter used the original spoken names for these shapes. It is not clear why selection responses were occurring during this step where both the spoken sample and the comparisons were untrained and unreinforced in the past. However, when the experimenter used new spoken names for the same shapes (Set 2), Participant 4 made no correct selections during the Baseline Test with Set 2 shapes. After the tact and mimetic/sequelic training on Set 2 shapes with new spoken names, this participant made four out of eight (50%) correct selections on Set 2 shapes in Generalization Test (Set 2). In this step, four out of four correct selections on two of the Set 2 shapes occurred, with correct tact and sequelic responding. In the same step, Participant 4 made four out of four correct sequelic responses to the spoken names of the Set 2 shapes; however, the tact responses were incorrect, and incorrect selection responses on these two shapes occurred. The same responses occurred with participant 4 during the follow-up Generalization Test with Set 2 shapes.

## Summary

This study looked at applying joint control to the analysis of name-object symmetry in the manded-selection responses of four non-vocal children with autism. In the initial phase of training the children were taught to tact four shapes by using arbitrary hand signs, to mimic hand signs shown by the experimenter, and to give the hand signs in response to their corresponding spoken names. All four participants were able to do this. It was expected that this training would not lead to name-object relations (or the manded-selection responses), which it did not. In subsequent training, shape-selection responses were brought under joint control such that when given an object's name to rehearse (i.e., self-mimetic), participants were trained to select only the object that (jointly) evoked a tact (object-name) with the same topography as the one being rehearsed. All four participants learned to select under joint-control training. Interestingly, for two of the participants, joint-control self-mimetic/tact training was necessary for correct selection, but self-mimetic responses did not appear overtly in the Generalization Test (Set 2). In subsequent tests of generalization with novel stimuli, the untrained/unreinforced name-object symmetry occurred immediately. These data imply that joint-control training based on verbal behavior principles supplied the missing links for the selection responses of non-vocal children with autism.

## Discussion

The results clearly show that prior to the joint-control training, selection responses did not occur spontaneously even after tact training or mimetic/sequelic training. In the Generalization Test (Set 2), the relationship between accurate selection responses, and sequelic and tact responses performed by participant 1 and 4, were in accord with what would be expected if accurate selection did indeed depend on joint control. In the same step, the correlation between accurate selections and accurate sequelics performed by participants 1, 2, and 4 could be an indication that sequelics served as mediating responses in participants' selections.

For participant 3, although the selection responses in the Generalization Tests were not accompanied by overt tact or sequelic responding, these responses were still occurring at 100% accuracy in both Generalization Tests, and with the comparisons placed 5 feet away. These accurate selections were dependent on his errorless performance in joint-control training (Step 6). The bi-directional relation did not occur after acquisition of tacts, mimetic, or sequelics, but only after these responses were brought under joint control. While for participants 1, 2, and 4, sequelic responding served as mediating responses in their selection responses, participant 3 was able to make accurate selections without overt mediating responses.

## GENERAL DISCUSSION

As the data from both experiments suggest, training under joint control provides a simple and parsimonious method to produce generalized symmetrical responding in children with autism. In addition, these experiments show that the listener's behavior need not be described using cognitive concepts. Rather, it can be interpreted and studied as behavior, which is clearly more accessible and more easily defined than cognition.

Two explanations might account for the differences observed in the participants' performances in both experiments. First, the sequelic responding by participant 3 might have been covert during selection. Second, the sequelic responding might overlap with other operants when the size of the operant unit changed as a result of the joint-control training. These possibilities are discussed below.

### *Covert Responding*

It is often observed that typically developing children and adults make accurate selections without overt mediating responses. For example, when children or adults first learn to read, they often move their lips silently, and sometimes even respond at an audible level. As they become more fluent, their lips move less and less, or they begin to read in complete silence. At this point, reading has become covert. A similar process may be involved in manded-selection responding. Selection responses may first be accompanied by overt mediating responses as was observed with all participants in the first experiment, and with participants 1, 2, and 4 in the second experiment. Selection responses performed by participant 3 were similar to the selection responses seen in typically developing children and adults, that is, in the absence of overt mediating responding. The same can be said about the selection responses made by participant 2 in the second experiment during the follow-up generalization test (Set 2) when accurate selections were made in the absence of tact and sequelic responding.

Future studies might focus on exploring the role of self-echoics and/or self-mimetics in joint-control training procedures. This could be demonstrated by blocking self-echoic responses while selecting a new set of items after joint-control training of a first set of items. For example, a participant could be taught to engage in self-echoic responding while selecting a cup from an array of four items under joint-control training. Engaging in self-echoic responding while selecting, for example, a pen as a new item would be expected in the subsequent generalization tests. At this time, the self-echoic responding could be blocked by asking the participant to repeat the word "apple." If performance was unaffected, it would be clear that covert self-echoics were not occurring. If performance deteriorated, then the importance of self-echoics (either overt or covert) would have been be demonstrated.

### *Functional Units and Overlapping Controls*

Another explanation for the differences observed in the participants' performances could involve a change in the size of the operant (Skinner, 1957, pp. 76–77). Overlapping controls or the combining of units is often observed in many daily activities. For example, when a child first learns to dress, shirt and pants might be put on separately. As greater *fluency* develops, the dressing routine becomes a large operant instead of a chain of small operants.

The overlapping of tact and sequelic controls could be the result of joint-control training. In the present study, a problem ("Give me the ___") was first introduced to the participant and then each component of the solution (e.g., tact and echoic, or tact and sequelic) was taught, but this did not result in the problem being solved. Then when these components were taught jointly, the problem was solved immediately. A single unit of behavior was not sufficient to solve a problem. However, when multiple units of behavior overlapped as seen in the joint-control training, the available behavior *was* sufficient. Multiple control in both verbal and non-verbal behavior in problem solving could also be observed in other types of problem solving. For example, a blacksmith may have composed a poem such as "up high, down low, up quick, down slow. And that's the way to blow" (Skinner, 1969, p. 139) to facilitate effective behavior or in discussing effective behavior with other blacksmiths. "By occasionally reciting the poem, possibly in phase with the action, he could strengthen important characteristics of his own behavior. By recalling it upon a remote occasion, he could reinstate an effective performance." (p. 139). The same can be observed in the selection responses of the participants in this study. The joint-control training combined several verbal operants to evoke the selection responses when the problem "Give me the ___" was given to the participants.

Future studies should also focus on exploring the role of joint control in complex behavior such as problem solving, memory, and rule-governed performances. One set of solutions of a math problem could be taught to a participant using the joint-control training procedures (training components of identified skills as verbal rules jointly), and generality with respect to other problems could then be tested.

*Applied Implications*

Devany et al. (1986) suggested that training in equivalence-class formation or similar behavioral processes should assist in language acquisition and vice versa (p. 254). These two experiments indicated that joint-control training can produce results similar to those attributed to equivalence training. However, joint-control training is a simpler and shorter procedure, and requires no special equipment for training or testing.

The present work shows that joint-control training is a simple and parsimonious procedure for insuring generalized symmetrical responding in both vocal and non-vocal children with autism. However, one should not assume that bi-directional responding will occur spontaneously in children with autism. Training tact responses is not sufficient to produce manded-selection responses; only after joint-control training did bi-directional responding occur. Furthermore, acquisition is much quicker using joint-control training than with traditional teaching methodologies. All of the participants were able to complete these studies during a surprisingly short period. They were able to acquire four selection responses in two or fewer 30-minute sessions, and the responding generalized to two to four novel stimuli in another two or fewer 30-minute sessions. Specifically, in the second experiment, the results showed that non-vocal children with autism were able to acquire at least six to eight selection responses in less than a week. Thus, by combining joint control with verbal behavior principles, practitioners will have a more effective teaching technology for children who do not emit vocal sounds.

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