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The Role of Rehearsal in Joint Control

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Behavior analysts have offered accounts of the behavior involved in matching to sample and delayed matching to sample. But until recently have not offered a behavioral analysis of generalized matching-to-sample. The concept of joint control, however, seems especially suited to such an analysis The present study used a joint-control procedure to train five adult women to acquire a generalized sequencing behavior using an unfamiliar language. After joint-control training the participants were able to produce untrained picture sequences, and blocking the mediating response during the sequencing task resulted in a reduction in the number of accurate sequences. These results clearly support response mediation as a precurrent to various kinds of complex human behavior.

Key words: rehearsal, joint control, mediating responses, blocking, generalized matching, naming

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The present study examined the role of response mediation in complex human behavior. Matching, where a constant relation exists between the sample and the comparison stimuli, has been explained in terms of cognitive constructs (Zental, Edwards, Moore, & Hogan, 1981), and the application of a rule (Bucher, 1975). Behavioral accounts have also addressed matching when the comparison and sample stimuli share no formal relation such as identity. Cohen, Brady, & Lowery (1981) studied response mediation in a variety of matching tasks. In the first, pigeons were trained to emit sample-specific behavior (e.g., DRL 3 or FR 16) that was related to specific sample key stimuli. These response-produced stimuli from these behaviors then served as discriminative stimuli for the selection of one of the two comparison keys. For example, the color green evoked key pecking appropriate to an FR 16 schedule, after which the comparison stimuli were displayed and the bird learned to peck a comparison key with a horizontal line. The color orange evoked pecking appropriate to a DRL 3 sec schedule, after which the vertical line was the correct comparison. In addition, they were trained to emit the same sample-specific behaviors to the stimuli when displayed in the reverse. In the presence of a horizontal line the bird pecked appropriate to an FR 16 schedule after which the bird pecked the green key. And in the presence of the vertical line, the bird pecked appropriate to a DRL 3 schedule and then pecked the orange key.

The significance of these results was seen when the birds were required to emit the same sample-specific behavior but select comparison keys that were not previously trained. For example, they pecked on an FR16 schedule in the presence of the green-sample key and were then required to peck either a green or an orange comparison key. Up to that point they had not been required to peck comparison keys that shared the same identity as the sample keys. One bird responded with 95 percent accuracy during this identity task without previous training, meaning that the bird pecked the green comparison when shown a green sample, rather than pecking the orange comparison when shown the green sample, due to having acquired the sample-specific behavior for the green key. A control group that were not trained to emit the sample-specific behavior were used to determine whether stimulus mediation without joint control was just as effective in promoting accurate responding during the same task. The results ranged from 28-66% accuracy, with seven out of the ten values falling at exactly 50%, showing that accurate responding in some arbitrary and relational matching was controlled by sample-specific behaviors taught to the birds.

Parsons, Taylor, & Joyce (1981) trained kindergarten children to select different comparison keys after pressing corresponding collat-

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eral keys when distinct levels of sample key brightness were displayed. With a bright sample the children learned to select a red collateral key *above* the sample key. With a dim sample they learned to select a red collateral key *below* the sample. During the next phase of the experiment, once they selected the correct collateral key, two comparison keys were illuminated to the left or right of the sample key, and reinforcement was contingent on selecting the correct comparison key. With a bright sample the children learned to select the red collateral key above the sample and then select the comparison key illuminated with the same level of brightness, *after a one second delay.* With a dim sample, they learned to select the red collateral key below the sample and then select the comparison that was illuminated with the same level of brightness as the sample, *after a one second delay*. Children who were differentially reinforced for pressing the correct collateral key in the presence of the corresponding sample key brightness acquired discriminative behavior producing accurate comparison key selections during this delayed matching-to-sample task. Later, when the experimenter told the children not to touch the red buttons, prohibiting their sample-specific behavior, the frequency of accurate comparison key selections decreased.

The above examples are limited by the number of sample-comparison relations trained, and their analyses do not constitute explanations of more complex behavior such as the generalized identity matching inherent in much human problem solving. Lowenkron (1998), however, recently offered *joint control* as, "a discrete event, a change in stimulus control that occurs when a response topography evoked by one stimulus and preserved by rehearsal, is emitted under the additional control of a second stimulus" (p. 332).

An example of joint control during a generalized matching task is as follows. A listener is shown the following array of numbers and a speaker says, "Find 3914061."

3914061	3914062
4609813	3914063
3469061	36946142
3914064	39140142

The listener emits an echoic response, "3914061," followed by several rehearsal responses, "3914061." In addition, the listener sees the number, 3914061, and says, "3914061" (as a tact or textual response). The listener's simultaneous acquisition of two sources of stimulus control, joint echoic and tact/textual control, is reported when the listener points to the number 3914061 as a descriptive autoclitic (Skinner, 1957, pp. 313–316).

Lowenkron (1984) taught five children 3.5 to 5.5 to select a comparison stimulus based on the state of a sample. They were first taught to rotate an arrow card to point in the same direction as a sample stimulus. The rotation of the arrow card then served as a mediating response, allowing them to select the comparison stimulus pointing in the same direction as the arrow card. Interestingly, when the arrow cards were removed some children began to point their fingers in the direction the arrow card would have pointed, and those children continued to select the correct comparisons. In the second part of the study new participants were not taught the rotation of the arrow card and the accuracy of generalized relational matching was low.

Later, joint control was used to explain correct performance in a delayed-matching task (Lowenkron, 1988) where the sample stimuli were removed and followed by a time delay before the comparisons were displayed. Four teenagers with IQs below 40 were taught to emit hand signs after a sample stimulus was displayed. They were then taught to rehearse the hand signs across a time delay, after which comparison stimuli were displayed. The hand signs were first emitted in the presence of the sample stimuli, after which the sample stimuli were removed and the hand signs were rehearsed as self-mimetics. When the comparison stimuli were displayed, the hand sign acquired an additional source of control as a tact. The teenagers selecting the correct comparison stimuli were reporting the acquisition of this additional source of stimulus control. The accurate rehearsal of these hand signs apparently permitted the accurate selection of the comparison stimulus displayed after the time delay.

J. C. Tu used joint control as the basis for training accurate selection-based behavior in a generalized identity task with four individuals diagnosed with autism (J. C. Tu, personal communication, June 12, 2001) [Editor's comment: The Tu study referred to here appears later in this issue of the journal.] The participants first learned to emit different one- or two-syllable words to each of four different pictures, and then to rehearse the word after it was spoken by the experimenter. In addition, they learned to state the names that corresponded to each of the four pictures when shown the pictures. Then, four comparison stimuli were displayed one at a time and the subjects handed the corresponding picture to the experimenter while emitting rehearsal responses. Eventually the number of pictures was increased to an array of four, and the subjects were reinforced for selecting the correct comparison stimulus based on the auditory stimulus of the spoken word. Later they acquired eight additional names that corresponded to eight additional pictures used during two separate generalization tests. During the two generalization tests, the four participants emitted the correct selection response only after emitting the self-echoic rehearsal response that they had learned during joint control training.

Historically, matching-to-sample tasks have been characterized by two paradigms: selection-based behavior and topography-based behavior. Selection-based behavior usually involves the listener pointing to or selecting an item after the display of a sample stimulus, wherein the topography of the listener's behavior is always the same regardless of the sample stimulus displayed (Michael, 1985). In topography-based behavior the listener emits a unique response topography controlled by a particular sample stimulus, and the topography of the listener's behavior always varies based on the sample stimulus displayed. Potter, Huber, & Michael (1997) examined the differences between these two paradigms (1997). Participants were shown *flag-like* patterns as sample stimuli, with comparison stimuli consisting of squares of dot patterns. The flag-like patterns were constructed with the aim of decreasing the likelihood of vocal tacts to such stimuli. Although the study demonstrated little difference between the two paradigms in terms of the accuracy of the performances, during post-session interviews all participants reported using topography-based behavior to perform more accurately during the matching-to-sample task. Very consistent types of statements preceded the selection of correct and incorrect comparison stimuli, showing that highly verbal participants are likely to engage in topography-based responding during selection-based tasks lending further support to Lowenkron's analysis of joint control (1984; 1988; 1998).

Another study examined response mediation during a problem-solving task consisting of solving six letter anagrams (Mayzner, Tresselt, & Helbock, 1964). Twelve participants were given six-letter blocks and told "Think out loud" while attempting to sequence the blocks to create a word. They were then given 15 minutes to create a word out of the six-letter blocks. The findings showed that participants were directly affected by the frequency with which certain diagrams, two-letter rearrangements, occurred in the English language. They engaged in a series of mediation responses, 50 to 100 per 15-minute interval, either until time was up or they solved the anagram, providing further support for response mediation in a problem-solving task.

The present study utilized response mediation to train generalized sequencing behavior by typically developing adults within the context of a language foreign to the participants. The first purpose was to demonstrate the utility of response mediation during a problem-solving task, thus providing additional support for Lowenkron's account of joint control in complex human behavior (1984; 1988; 1998). The second purpose was to examine the effects of blocking the mediating response occurring during joint control. It was suspected that this would produce deterioration in the previously mastered complex behavior.

Method

Participants

Six adult females served as participants: a 20-year-old high school graduate (KS), a 22-year-old high school graduate (SA), a 45-year-old high school graduate (CC), a 21-year-old high school graduate (SO), a 32-year-old college graduate, (NRT), and a 45-year-old college graduate, (SM). They were selected based on their lack of familiarity with the Chinese-Mandarin language. Also, none of the participants were familiar with the selection-based, topography-based, or joint-control research areas.

Materials

Four Mandarin Chinese names spoken by the

Table 1
Sequences spoken by the experimenter in each set.

Set 1	Pen, Cup, Fork, Water	Fork, Pen, Cup, Water	Cup, Water, Fork, Pen	Water, Pen, Fork, Cup
Set 2	Pen, Water, Cup, Fork	Fork, Pen, Water, Cup	Cup, Pen, Water, Fork	Water, Fork, Cup, Pen
Set 3	Pen, Fork, Water, Cup	Fork, Water, Pen, Cup	Cup, Fork, Pen, Water	Water, Cup, Fork, Pen

experimenter served as samples, and four pictures (5 cm x 5 cm) corresponding to the four spoken names served as comparisons. The pictures (of a pen, a cup, a fork, and a glass of water) were arranged into twelve different sequences, divided into three sets of four (see Table 1), and randomly displayed 1 cm apart on the table in front of the experimenter and the participant. The children's song "The Wheels on the Bus" served as an incompatible behavior during blocked trials. The experimenter placed a plastic-red Dixie® cup on the table next to the pictures, which instructed the participants to sing the children's song.

Reinforcers

Mint candy and licorice were used as reinforcers for correct responding. A reinforcer sample was conducted prior to each session by displaying the two candies in front of the participants and allowing them to request the particular candy that they wanted to work for during that session.

Setting

Training took place in the experimenter's 4 m x 3 m office which contained a desk, three adult-size chairs, a bookshelf, a filing cabinet, a trashcan, and three windows. In addition, a computer, printer, telephone, and five binders were on the desk during the experiment. The experimenter sat next to the participant at the desk.

Design

An ABC single-subject design was used, with (A) echoic/tact training, (B) joint-control training, and (C) blocked/non-blocked testing.

Procedure

Phase 1: Baseline Test

All four pictures were displayed in front of the participant in a random arrangement. Set 1 sequences were named randomly one at a time. A discrete-trial training format was used in both training and testing sessions. With each trial, the experimenter said to the participant the names of the four-picture sequences from set 1 (i.e., "pen, cup, fork, water") in Chinese Mandarin. The names were recited one right after the other with no pausing. Correct and incorrect selections were followed by "Okay" to signal the completion of a trial. Each of the four-picture sequences was tested on three trials. At this point some participants tried to put the pictures in a sequence and some either stared at the pictures or at me. They really did not know what was expected of them.

Phase 2: Naming Training (Echoics and Tacts)

Echoic training. In this step the participant learned to repeat the spoken word given by the experimenter. The names of the four pictures were used here, but no pictures were displayed. The experimenter said the name of the picture in Chinese Mandarin 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 his hand repeatedly, with palm towards him, in a circular motion toward and away from himself. Correct echoic responses were reinforced with a candy. After an incorrect response, the experimenter said, "No," and then repeated the name of the picture in Mandarin and again prompted the participant to say the name. Training continued until the participant emitted three consecutive correct responses of the modeled name.

Tact training. All four pictures were displayed one at a time. The experimenter held up a picture and gave a vocal prompt. Correct tacts were reinforced with a candy. When the subject did not respond, the experimenter again vocally prompted the name of the picture. If the participant gave an incorrect response, the experimenter said, "No," held the item up, and again prompted the name of the picture. Finally, an additional trial was conducted to ensure that the participant said the name of the picture under the control of the picture (tact) rather than under the control of the experimenter's spoken word (echoic). Training continued until the participant emitted three consecutive correct tacts.

Phase 3: Generalization Test (Set 1 Sequences)

Phase 1 was repeated.

Phase 4: Joint-Control Training

The purpose of this step was to force a tact response in the midst of an echoic stream of repetitions so as to produce joint tact/echoic control. During this phase pictures had been randomly arranged on the table.

a) The experimenter named the four-item sequence one picture at a time.
b) Then repeated the sequence of names while using the echoic gesture, prompting the participant to repeat the four Chinese Mandarin terms (e.g., the terms for book, pen, cup, and water).
c) While participants were repeating the sequence of Mandarin terms, they were also required to arrange the four pictures on the table in the order named.
d) And then to immediately say the sequence of four terms.
e) The correct response (tacting the sequence by saying the four Mandarin terms in the order that they were displayed on the table) was reinforced with a candy. After a statement of the sequence of terms, the experimenter prompted the correct statement and repeated steps b–d.
f) Training continued until the participants made three consecutive correct arrangements of the four pictures and the corresponding sequence of terms for each of the four sequences in Set 1.
g) As practice with the four pictures continued, echoic-gesture prompts were faded until the participants could respond to the spoken sample by repeating it with no prompting.

Phase 5: Baseline Test (Set 2 Sequences)

Since selection training with the Set 1 sequences continued until the performance was errorless, there was no reason for another test of the performance. Therefore, testing of *Set 2 Sequences* began, and the procedure of Phase 1 (Baseline Test) was repeated with the *Set 2 Sequences*.

Phase 6: Rehearsal Blocked (Set 3 Sequences)

During this phase the participants were told the following, "Begin to sing the *Wheels on the Bus* children's song every time a red cup is placed on the table. If you do not know the words to the song, continue to say, *The wheels on the bus* over and over. Do not stop singing until you have sequenced the pictures." At this point the experimenter repeated the procedure of Phase 1 (Baseline Test) with the *Set 3 Sequences*. During this phase 6 of the 12 echoic responses were randomly blocked by having the participants sing the song.

Data Collection

Trial-by-trial data on the number of accurate sequences produced by the participants during each phase of the procedure were collected.

Results

Trial-by-trial data were recorded on all sequences during baseline and generalization tests. As illustrated in Figure 1, KS did not correctly produce any sequences during the baseline test. After learning the names of the four pictures she correctly produced all 12 Set 1 sequences in Generalization Test 1. Since she had no errors during Generalization Test 1, joint-control training and Generalization Test

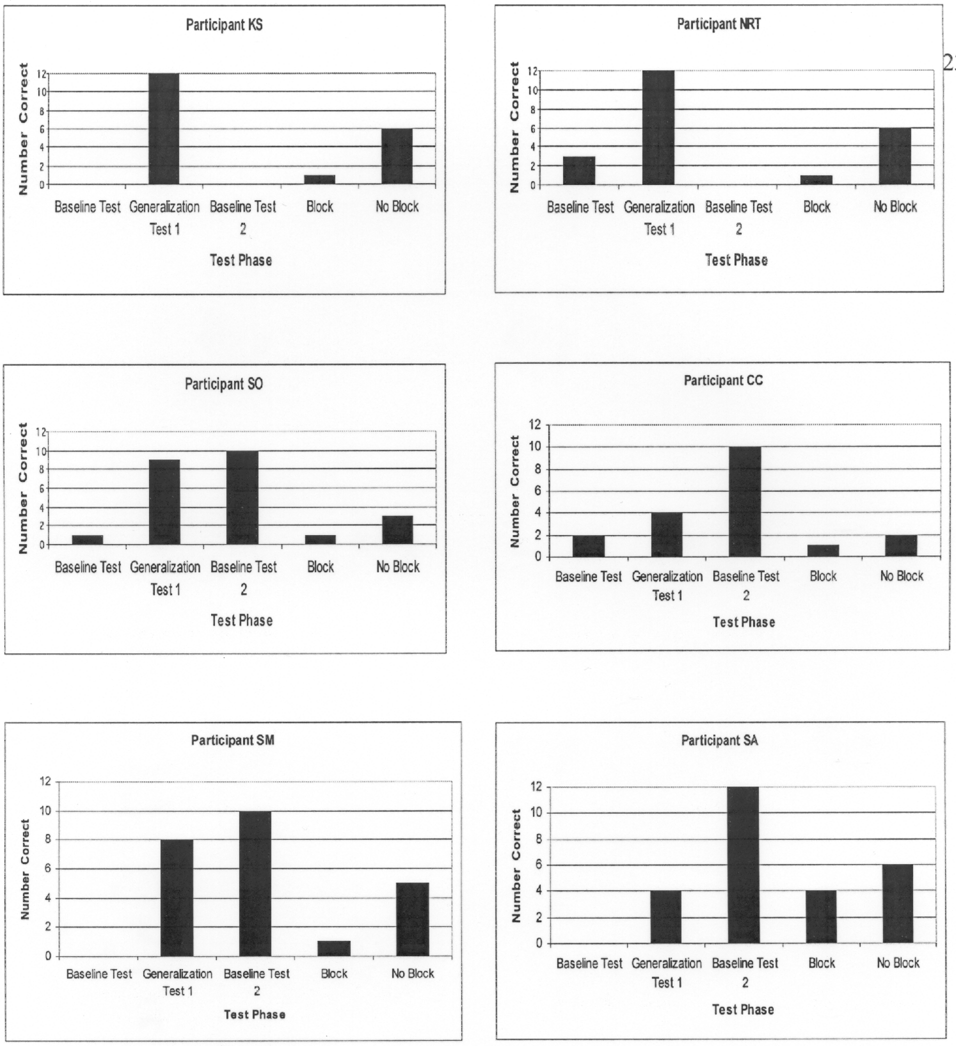

Fig. 1. Performances of six participants across each phase of this study. The block and non-block test phases have a maximum of six correct trials possible.

2 phases were skipped. Following the introduction of the self-echoic block, KS correctly produced only one out of six Set 3 sequences, but upon removal of the block, she correctly produced all six.

NRT correctly produced 3 out of 12 Set 1 sequences during baseline. After learning the names of the 4 pictures she correctly produced all 12 of the Set 1 sequences during Generalization Test 1. Since she had no errors during Generalization, joint-control training and Generalization Test 2 phases were skipped. Following the introduction of the self-echoic block, she correctly produced only one out of six Set 3 sequences, but upon removal of the block, correctly produced all six.

SO correctly produced 1 out of the 12 Set 1 sequences during baseline. After learning the names of the four pictures she correctly produced 9 out of 12 during Generalization Test 1. After reaching errorless performance during joint-control training with the Set 1 sequences, SO correctly produced 10 out of 12 Set 2 sequences during Generalization Test 2. Following the introduction of the self-echoic block she correctly produced only one out of six Set 3 sequences, but upon removal of the block, correctly produced three out of six.

CC correctly produced 2 out of 12 Set 1 sequences during baseline. After learning the names of the four pictures she correctly produced 4 out of 12 Set 1 sequences during Generalization Test 1. After reaching errorless performance during joint-control training with the Set 1 sequences, she correctly produced 10 out of 12 Set 2 sequences during Generalization. Following the introduction of the self-echoic block, she correctly produced only one out of six Set 3 sequences, and upon removal of the block, she correctly produced two out of six Set 3 sequences.

SM correctly produced 1 out of 12 Set 1 sequences during baseline. After learning the names of the 4 pictures, she correctly produced 8 out of 12 sequences during Generalization. After reaching errorless performance with the Set 1 sequences during joint-control training, SM produced 11 out 12 Set 2 sequences during Generalization. Following the introduction of the self-echoic block, she correctly produced only one out of six Set 3 sequences, but upon removal of the block correctly produced all six.

SA did not produce any correct Set 1 sequences during the baseline test. After learning the names of the 4 pictures she correctly produced 4 out of 12 during Generalization. Subsequently, after reaching errorless performance with the Set 1 sequences during joint-control training, she correctly produced all 12 of the Set 2 sequences during the Generalization Test 2. Following the introduction of the self-echoic block SA correctly produced four out of six Set 3 sequences, and upon removal of the block, she correctly produced all six.

Discussion

The purpose of this study was to investigate the importance of response mediation in complex human behavior. During the study the production of accurate sequences diminished when the participants recited a children's song, designed to block mediating behavior. Prior to the blocking all participants were producing sequences with at least 80% accuracy. After the introduction of blocking, five of the six produced sequences with only 17% accuracy. The remaining participant, SA, produced sequences with 67% accuracy. The difference in accuracy between the performances of SA and that of the remaining participants may have been related to the fact that SA recited the song very slowly, which possibly allowed her to rehearse the sequences covertly. Several times the experimenter had to remind SA to keep singing.

During non-blocked trials with Set 3 sequences, accurate responses increased across all participants. Four of the six increased to a level of 80% accuracy or higher. The resurgence of accurate sequences after cessation of blocking constitutes some support for the claim of response mediation as a precurrent behavior for correct selection-based responding (Parsons et al., 1981).

The remaining two participants, SO and CC, returned to an accuracy level of only 50% and 33% respectively. After the study was completed, SO explained that she had begun to confuse the name of one of the four pictures with a name from her native German language. The German name for a cup sounded very similar to the Mandarin-Chinese name for a fork. Coincidentally, pictures of a cup and a fork were used in both the sequences during all phases of this study. These variables led SO to emit correct echoic but incorrect tact behavior, causing her to produce inaccurate sequences. SO's behavior in this study further supports Lowenkron's analysis of joint control (1984; 1988; 1998) by demonstrating the necessity of *two* sources of stimulus control during complex human behavior such as a problem solving task.

When blocking ceased, CC's decrease in accuracy may have been due to inaccurate echoic responses emitted by CC during testing phases. As the study progressed, she began increasingly to emit inaccurate echoic responses. On several occasions, she combined two of the names spoken by the experimenter and created a new name that was not trained during echoic or tact training. As a result of these inaccurate echoics she began to emit inaccurate tacts. With these inaccuracies of the tact and echoic behavior, the accuracy of the Set 3 sequences emitted during the final phase of the study diminished by 50%, providing further support for the necessity of joint stimulus control during complex human behavior.

This study also suggested how joint control could be used to identify and train prerequisite behavior in typically developing adults during problem-solving tasks. Knowing that production of accurate sequences was dependent upon two sources of stimulus control allowed the experimenter to identify specific skill deficits in the participants: SO had a deficit in tacting and CC had a deficit in echoing. The identification of such deficits could lead to remedial echoic and tact training for these two participants. Most importantly, this study demonstrated that joint tact-echoic stimulus control was important for accurate generalized sequences. In addition, the results when blocking occurred clearly implied the importance of the rehearsal response in joint control.

Future studies could evaluate the importance of the tact repertoire in behaviors that are jointly tact-echoic controlled. Furthermore, the effect of blocking on verbal operants other than the tact and echoic repertoires in complex behavior should be evaluated. For example, how does blocking affect behavior that is under joint tact *mimetic* control? Also, future research could examine how response mediation affects the acquisition of listener behavior across different languages. In addition, joint control's role in problem solving needs to be examined across languages.

A limitation of this study is the lack of reliability data resulting from the camcorder's production of faulty videotapes. Due to this technical fault the experimenter was unable to obtain reliability data using secondary observers. Although interobserver reliability data were not available it is nevertheless reasonable to believe that the data collected were somewhat accurate because consistent trends in the data were recorded across participants within each phase of the experiment. Further, the experimenter clearly observed all participants struggling to produce accurate sequences and often commenting on the difficulty of the task while they were singing the children's song. In addition, the experimenter observed the participants fluently produce sequences when they were not required to sing the song.

The role of joint control in complex human behavior has been demonstrated across a variety of different research contexts (e.g., generalized matching-to-sample tasks and delayed matching-to-sample tasks). Applications based on these findings, as well as on the results of other studies on joint control, can provide educators with tools for identifying and training prerequisites to problem solving.

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