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The Effect of Joint Control Training on the Acquisition and Durability of a Sequencing Task

Allison DeGraaf, California State University, Los Angeles and California Unified Service Providers, L.L.C
Henry D. Schlinger, Jr., California State University, Los Angeles

Gutierrez (2006) experimentally demonstrated the effects of joint control and particularly the role of response mediation in the sequencing behavior of adults using an unfamiliar language. The purpose of the current study was to replicate and extend the procedures used by Gutierrez by comparing the effects of joint control training with the effects of a prompt-and-fade procedure on the acquisition of a sequencing task. The effects of each procedure on delayed sequencing behavior were also tested. Ten undergraduate students participated in 2 experiments. The results indicated that all participants acquired the sequencing response in fewer trials and maintained accurate delayed responding when the component responses necessary for joint control were directly taught. Finally, when the self-echoic mediation component was blocked, accurate responding deteriorated in 8 of 10 participants.

Key words: joint control, echoic, tact, verbal behavior

Lowenkron (1984, 1988, 1989, 2006a) developed a model to explain complex behavior in humans, especially linguistic behavior involving object-word relations. This model, termed ''joint control,'' uses established behavioral principles to account for the behavior of the listener in a verbal episode. Consider the following example. In the context of an office, an individual is asked to retrieve a red pen. Immediately after the instruction, he echoes it (''red pen''). As the individual scans the room, he repeats the name of the object either out loud or to himself (self-echoic behavior). When the individual sees a red pen, the sight of it evokes saying ''red pen'' as a tact, and the topography of this response matches the topography of the self-echoic, ''red pen.'' The joint occurrence of these two controlling stimuli evokes a correct selection response (picking up the red pen). He repeats the name so as not to ''forget'' what it is that he is searching for. When he encounters the specific object, the next rehearsal of the response now occurs under joint control of both the sight of the pen (tact) and the previous rehearsal (self-echoic). The individual is now saying the name of the object as joint self-echoic/tact behavior. Therefore, joint control occurs when one specific response form occurs jointly under two sources of stimulus control (Lowenkron, 2006a).

Previous research has demonstrated the necessity of the self-echoic response by training collateral overt rehearsal responses in order to make the self-echoic mediation response observable (Lowenkron, 1984, 1988, 1989; Sidener & Michael, 2006). Lowenkron (1988) taught children a matching-to-sample task in which they were trained to make directly observable hand signs (i.e., coding responses) that corresponded with the shapes of four sample stimuli. Next, each shape appeared briefly on a projection screen followed by an interval with no shapes present. The children were taught to maintain the hand sign unchanged over a delay of 4 to 10 s between the removal of the sample stimulus and the presentation of the comparison. This delay interval was increased until the accuracy of the matching task deteriorated to chance level performance. Then, all four

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Address correspondence to Henry D. Schlinger, Jr., Department of Psychology, California State University, Los Angeles, 5151 State University, Dr. Los Angeles, CA, 90032-8227. (e-mail: hschlin@calstatela.edu).

shapes appeared on the screen and the children had the opportunity to select the correct comparison stimulus from an array of known stimuli. The coding response resulted in correct selection responses for both known and novel shapes and incorrect responding in its absence. Lowenkron (1989) further demonstrated the crucial role of the coding response when he conducted a systematic replication of his two previous studies. Once again, he found that generalization of relational matching-to-sample responses to novel stimuli was dependent on bringing the selection of the comparison stimulus under joint control. In other words, the stimulus control relations that comprised joint control had to be in effect for correct generalized responding to occur.

More recent studies have evaluated the self-echoic component of joint control without training collateral overt responses in order to make the tasks more authentic. For example, Lowenkron (2006b) illustrated the importance of both the tact and the self-echoic component of joint control for generalized responding in another selection-based task with children. In the first experiment, self-echoic behavior was held constant while tact training was manipulated. Six subjects were trained to perform a conditional discrimination task that involved selecting six different stimuli from an unfamiliar three-word description referring to color, shape, and border features (e.g., leaf–trap–clip). The subjects were also trained to echo the sample description prior to and while selecting the comparison shape, which was the rehearsal response necessary for joint control. Acquisition of the selection behavior was slow and the children were unable to tact the items using the three-word description following conditional discrimination training. These results suggest that the selection responses were unmediated, and therefore not occurring under joint control. Next, the participants learned to tact the individual features of each stimulus separately, followed by the stimulus in its entirety using the three-word description, and finally novel combinations of the stimuli using the three-word description. Repeated testing showed that generalized responding did not occur when the subjects were presented with new combinations of colors, shapes, and borders until an extensive tact repertoire was acquired.

In the second experiment, tact behavior was held constant while the role of the self-echoic was manipulated. Similar to first experiment, three subjects were taught a selection task, however, familiar names were used for two sets of stimuli (e.g., green–tree–lines). Following conditional discrimination training, correct generalized responding occurred and the participants were able to correctly tact the stimuli. Unfamiliar names were used in a third set of stimuli and generalization results were similar to those of the first experiment. Next, the rehearsal (or self-echoics) that occurred while the subjects searched for the correct item among six comparison stimuli was prevented. Rehearsal prevention was accomplished by training the participants to read numbers that appeared on the computer screen at the same time as the comparison stimuli. Preventing the self-echoic rehearsal impeded correct selection when stimuli with familiar names were used. The results demonstrated that both the tact and the self-echoic are necessary for generalized stimulus selection. In other words, high levels of generalized responding required joint control.

Tu (2006) evaluated the emergence of untrained/unreinforced selection responses in four children diagnosed with autism. The participants were initially taught to echo one- or two-syllable names that corresponded to four different pictures, and to tact the pictures. Next, the participants were instructed to select a specific picture from the array of four. When generalized responding did not occur with novel stimuli, the participants were taught to echo and tact the names of the new stimuli as well as rehearse the name after the experimenter spoke it. Training and testing occurred with two more sets of stimuli, and the participants continued to emit the correct selection response only after emitting the self-echoic rehearsal response that they had learned during joint control training. In a second experiment, the emergence of untrained/unreinforced selection responses in four nonvocal children diagnosed with autism was evaluated. Procedures were similar to those of the first experiment, however, the participants were trained to emit hand signs instead of echoics. Again, results indicated that correct selection occurred only after the participants were trained

to emit a rehearsal response, which, in this case, was a hand sign.

Gutierrez (2006) illustrated the role of response mediation and joint control in a problem-solving task. He taught 6 adult women a generalized sequencing task within the context of an unfamiliar language, Mandarin Chinese, using joint control procedures. The participants were taught to echo the names of the pictures, tact the pictures, and arrange them in a specified sequence. Because the self-echoic component of joint control is covert but is presumed to be a necessary component, it can only be inferred by blocking this response. As the participants were arranging the sequence, they were asked to echo the sequence out loud in order to demonstrate the mediation response (self-echoic) component of joint control. The effects of blocking this mediation on performance were then examined by requiring the participants to sing a nursery rhyme after they were given the instruction to arrange the pictures in a random 6 out of 12 trials. Blocking the self-echoic mediation response resulted in diminished accuracy of responding in all 6 participants.

The purpose of this study was to replicate the procedures used by Gutierrez (2006) by experimentally demonstrating the effects of joint control and particularly the role of response mediation on sequencing behavior of adults using an unfamiliar language. The effect of blocking the rehearsal component of joint control on responding was examined with several procedural modifications. Also, the rate of acquisition of the sequencing response during joint control training (i.e., tact and self-echoic) was compared with the rate of acquisition during training using prompt-and-fade procedures. Furthermore, the present research extended Lowenkron (1989) by testing the effects of each procedure on delayed sequencing behavior. Therefore, the present research sought to answer the following questions. First, would the rate of acquisition of the sequencing task be affected when the response is brought under joint control? Second, what effect would the additional stimuli that comprise joint control have on responding when there is a delay between the instruction and the opportunity to respond? Finally, would responding be affected when the self-echoic component of joint control is blocked?

Several modifications were made to the procedure used by Gutierrez (2006) in order to increase clinical practicality. The current study replicated the joint control training procedure and the rehearsal-blocking phases as described by Gutierrez. However, in the current study, a prompt-and-fade training procedure was added to serve as a basis of comparison for joint control training, which was conducted with a separate set of stimuli in order to prevent history effects. Second, each set of stimuli used by Gutierrez consisted of the same picture cards in four different sequencing combinations. However, in the current study, participants were randomly presented with any 1 of the possible 24 sequencing combinations (without repeat) for every trial. Therefore, instead of generalization tests, delay probes were conducted to assess response strength following each training condition. Third, tokens that were later exchanged for United States currency were used as reinforcers. Fourth, the mastery criterion for the echoic responses was one correct response as opposed to three. Finally, during the rehearsal-blocking phase, verbal prompts (e.g., ''begin counting now'') were used to signal the onset of a blocked trial instead of the presence of a red cup and a different incompatible response was used to block the rehearsal component of joint control.

EXPERIMENT 1: METHOD

Participants and Setting

Five individuals participated in this experiment. Four were male and one was female. All were undergraduate students at California State University, Los Angeles (CSULA). Participants were selected based on their availability to participate in this study and their lack of familiarity with the Mandarin Chinese language, as well as with joint control research.

Training took place in the Behavior Analysis Laboratory on the campus of CSULA. The experimenter sat diagonally across from the participant at a table. Each student participated in one session, lasting about 1 hour.

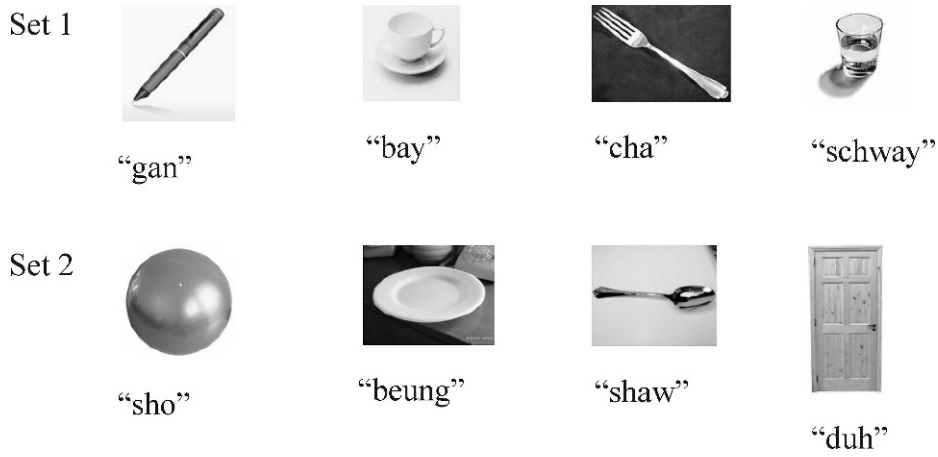

Figure 1. Sets of stimuli. Pictures of objects with their Chinese Mandarin names (spelled phonetically). Partially adapted from Gutierrez (2006).

Materials

Eight Mandarin Chinese names spoken by the experimenter served as sample stimuli. Eight 5 cm × 5 cm picture cards that corresponded to the spoken names served as comparisons. Comparison pictures (pen, fork, cup, glass of water, ball, plate, spoon, and door) were divided into two sets of four pictures (see Figure 1). Each set of pictures was randomly displayed on the table in front of the experimenter and the participant. For the first set of blocked trials, saying the American English alphabet served as an incompatible behavior. For the remaining sets of blocked trials, counting backwards from 100 served as an incompatible behavior. A digital timer was used to time the latency between the instruction and the opportunity to respond during the delay probes. Small white pieces of paper that were each worth $0.25 (i.e., tokens) were delivered contingently on independent correct sequences during the training phases. The tokens were exchanged for currency at the conclusion of each experimental session.

Procedure

Phase 1 (baseline). The four pictures of Set 1 were randomly displayed in front of the participant. The experimenter delivered the instruction, ''I want you to put the pictures in order,'' and then the experimenter named 1 of the possible 24 picture sequences from Set 1 (i.e., ''pen, cup, fork, water'') using their Mandarin Chinese names. Both correct and incorrect sequences were followed by ''okay.'' Sequences were randomly chosen from a list of all possible sequences. Each participant was presented with three trials in which sequences were randomly chosen from a list of all possible sequences.

Phase 2 (prompt-and-fade training). The purpose of this phase was to evaluate the rate of acquisition using a prompt-and-fade procedure as a basis for comparison with the joint control training procedures. First, the experimenter named a four-item sequence from Set 1 one at a time. The experimenter began with a 0-s prompt delay and immediately arranged the pictures on the table in the order named. Next, the experimenter repeated the four-item sequence and allowed 3 s for the individual to respond. Immediately following an incorrect sequence, or if 3 s elapsed, the experimenter provided verbal prompts by repeating the sequence and model prompts by arranging the pictures in the correct order. This process continued until the participant made an independent correct response. The correct response (arranging the correct sequence) resulted in the delivery of one token. Training continued until the participant made three consecutive correct arrangements of the four pictures in Set 1.

Phase 3 (delay probes). A minimum of four probes were conducted using Set 1 pictures following Phase 2 to test the effects of the prompt-and-fade training procedure on delayed sequencing responses. The purpose of the probes was to determine the point at which the previously mastered sequencing response began to deteriorate. The experimenter named the four-item sequence of Set 1 one at a time, allowed *n* s to pass, and then instructed the participant to arrange the pictures. The duration of the delay intervals started at 3 s, and increased by multiples of 3 s. Both correct and incorrect sequences were followed by ''okay.''

Phase 4 (baseline with Set 2). Procedures were identical to Phase 1, except Set 2 pictures and their corresponding Mandarin Chinese names were used.

Phase 5 (joint control component training). The purpose of this phase was to train the prerequisite components necessary for joint control training. First, participants received echoic training, in which they learned to repeat the spoken Mandarin word presented by the experimenter. The names of the four pictures of Set 2 were used but no pictures were displayed. The experimenter said the name of the picture in Mandarin Chinese and had the participant repeat the name by providing a verbal instruction. (i.e., ''Say___''). Correct echoic responses were followed with one token. Incorrect responses were followed with ''No,'' and the name of the picture was repeated along with the verbal prompt to echo the name. The experimenter continued to present one of the four names in random order until the participant emitted one correct response for each of the four names. Second, the participants received tact training. The experimenter held up each picture one at a time and delivered a verbal instruction (i.e., ''What is it?''). The correct response was prompted immediately on the first tact trial for each picture. Correct tacts resulted in the delivery of one token. Incorrect responses were followed by ''No'' and an echoic prompt. The picture and the verbal instruction were re-presented to ensure that the response was under control of the picture rather than the echoic prompt. The experimenter continued to present the four pictures in random order until the participant emitted three consecutive correct tacts for each picture in Set 2.

Phase 6 (joint control training). The purpose of this phase was to require an echoic response in the midst of the sequencing response so as to produce the verbal mediation necessary for joint control. First, the experimenter instructed the participant to repeat the sequence upon hearing the experimenter say it. If the participant made an error, the experimenter repeated it until an accurate echoic response occurred. The participant was further instructed to continue to repeat the sequence. While the participant was repeating the sequence, he or she was required to arrange the pictures on the table in the order named. If the participant made an incorrect response, the experimenter repeated the steps of the procedure. This process continued until the participant made an independent correct response. Correct responding (arranging the pictures in the specified sequence) resulted in the delivery of one token. Training continued until the participant made three consecutive correct arrangements of the four pictures and the corresponding sequences of spoken terms for each of the sequences in Set 2. Verbal prompts were faded until the participant was able to respond to the spoken sample by repeating it with no prompting.

Phase 7 (delay probes). A minimum of three probes were conducted using Set 2 pictures following Phase 6 to test the effects of the joint control training procedure on delayed sequencing responses. The purpose of the probes was also to determine the point at which the previously mastered sequencing response began to deteriorate. The procedure was the same as for Set 1. The experimenter conducted the same number of probes with Set 2 that were conducted with Set 1 for each participant.

Phase 8 (rehearsal-blocking). The purpose of this phase was to replicate the findings of Gutierrez (2006) by blocking the verbal response mediation that is thought to account for the occurrence of joint control (Lowenkron, 2006a). The procedure for Phase 8 was identical to baseline, except that a different stimulus set (Set 2) was used. At the beginning of the phase. the participants were told to rehearse an alternative sequence (i.e., saying the American English alphabet or counting backwards from 100) when instructed to do so. They were told not to

stop saying the alternative sequence until the target task was completed. For all of the trials, the experimenter delivered the instruction, ''I want you to put the pictures in order'' and named one of the possible 24 picture sequences from Set 2. Then the participants were immediately given the opportunity to arrange the pictures in the prescribed order. For 6 of the 12 trials, which were chosen at random, the experimenter further instructed the participants to engage in the alternative sequence before the opportunity to respond was given, thereby blocking the previously learned rehearsal response.

Response measurement and interobserver agreement. Each trial was scored on a data sheet created by the experimenter. During baseline, training, delay probes, and rehearsal-blocking trials, each response (placing the four cards on the table in a sequence) was recorded as correct (100%) or incorrect (0%). If the correct sequence was produced, the trial was scored as correct (100%). However, if only one or two of the four pictures were in the correct spot, the trial was scored as incorrect (0%) and was followed with prompts. When an incorrect response occurred (all or some of the pictures were out of place), the prompted responses that followed were considered to be part of the same trial and were not scored. During each training phase, all incorrect responses were followed with prompts until a correct independent response occurred. The first correct response that occurred absent prompts was considered the end of the trial and was also not scored. All of the possible sequences were included on the data sheet to ensure that the experimenter was adequately randomly rotating through possible combinations. Within each phase, combinations were not repeated in subsequent trials, given that only a small number of trials was required to reach the mastery criterion and a total of eight phases were evaluated across each of the 5 participants.

The sessions were videotaped and coded by the experimenter. Three additional observers watched and scored a portion of the trials using the same data sheet as the experimenter in which they scored a ''+'' for correct trials and ''−'' for incorrect trials. The scores from all four observers were used to assess interobserver agreement (IOA) for 25% of the trials for all participants. An agreement was defined as all four of the observers scoring a trial as either correct or incorrect. IOA was calculated by dividing the number of agreements by the total number of trials (agreements + disagreements) and multiplying by 100. A Mean IOA was 100% for all trials.

RESULTS AND DISCUSSION

Participant 1

As illustrated in Figure 2, participant 1 did not arrange any correct sequences during baseline with the pictures from Set 1. In Phase 2 (prompt-and-fade), it took seven trials to reach the mastery criterion. During the first set of delay probes, the participant did not produce a correct sequence when the 3, 6, and 12-s latency occurred between the instruction and the opportunity to respond. Correct sequencing was only demonstrated after the 9-s delay.

This participant also did not arrange any correct sequences during baseline with the pictures from Set 2. During joint control component training, Participant 1 responded correctly to each of the four choices on the first trial. The Mandarin tacts were acquired in 17 trials. In Phase 5, in which a procedure consisting of the components of joint control was used to train the sequencing task, it took 4 trials to reach the mastery criterion. As illustrated in Figure 3, this participant acquired the sequencing response in 3 fewer trials during joint control training. During the second set of delay probes, correct responding occurred after the 3, 6, 9, and 12-s latency.

Following the instruction to engage in the alternative verbal sequence in order to block the self-echoic, Participant 1 correctly produced three out of the six sequences from Set 2. When Participant 1 was not required to block the self-echoic, he correctly produced all 6 sequences (see Figure 4).

Participant 2

As illustrated in Figure 2, Participant 2 produced one correct sequence during baseline with the pictures from Set 1. In Phase 2 (prompt-and-fade), it took 17 trials to reach

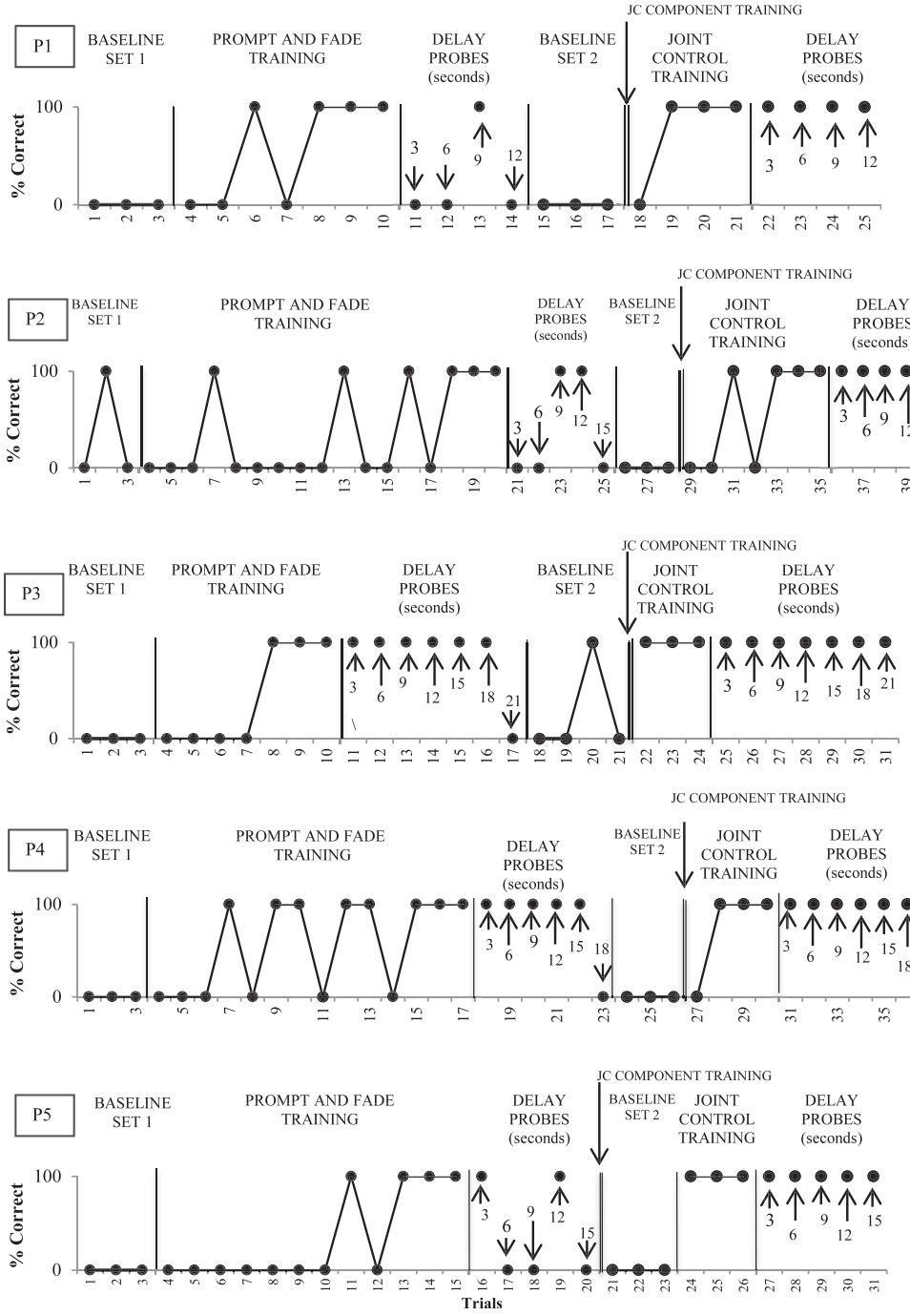

Figure 2. Effects of sequencing training using a prompt-and-fade and joint control procedure on the immediate and delayed sequencing behavior of Participants 1, 2, 3, and 4.

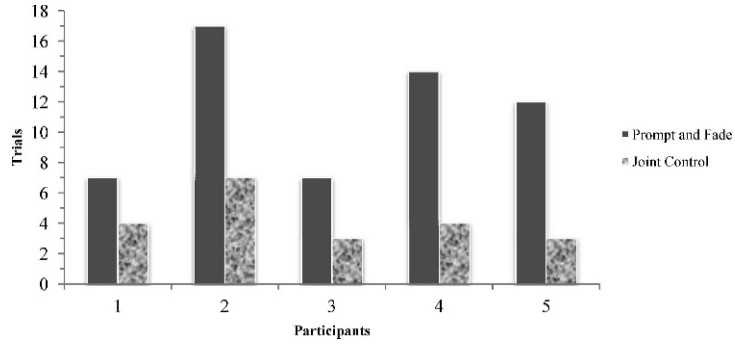

Figure 3. Trials to criterion for the sequencing response during the prompt-and-fade and the joint control training.

the mastery criterion. During the first set of delay probes, the participant did not produce a correct sequence when a 3, 6, 12, 15, and 18-s latency occurred between the instruction and the opportunity to respond. Correct sequencing was only demonstrated after the 9-s and 12-s delay.

This participant also did not arrange any correct sequences during baseline with the pictures from Set 2. During joint control component training, Participant 2 acquired the echoic responses in 5 trials. The Mandarin tacts were acquired in 21 trials. In Phase 6 (joint control), it took 7 trials to reach the mastery criterion. As illustrated in Figure 3, this participant acquired the sequencing response in 10 fewer trials during joint control training. During the second set of delay probes, correct responding occurred after the 3, 6, 9, 12, and 15-s latencies.

Following the instruction to engage in the alternative verbal sequence in order to block the self-echoic, she did not correctly produce any of the six sequences from Set 2. When she was not required to block the self-echoic, she correctly produced five out of the six sequences from Set 2 (see Figure 4).

Participant 3

As illustrated in Figure 2, Participant 3 did not produce a correct sequence during baseline with the pictures from Set 1. In Phase 2 (prompt-and-fade), it took seven trials to reach the mastery criterion. During the first set of delay probes, the participant produced a correct sequence when a 3, 6, 9, 12, 15, and 18-s latency occurred between the instruction and the opportunity to respond. Incorrect sequencing was only demonstrated after the 21-s delay.

Participant 3 arranged one correct sequence during baseline with the pictures from Set 2. During joint control component training, Participant 3 responded correctly to each of the four echoic stimuli on the first trial. The Mandarin tacts were acquired in 16 trials. In Phase 6 (joint control), it took 3

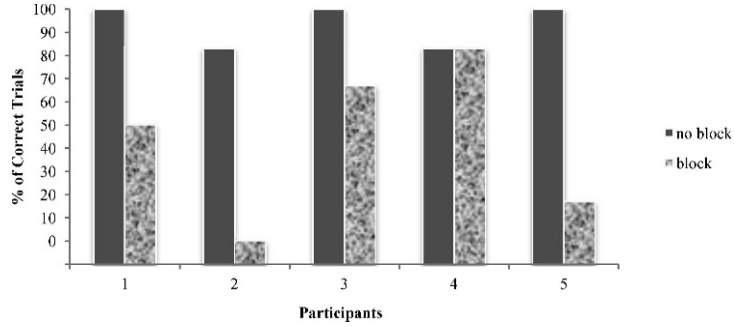

Figure 4. Percentage of correct blocked and non-blocked trials from Experiment 1. The blocked and non-blocked phases have a maximum of 6 correct trials possible.

trials to reach the mastery criterion. As illustrated in Figure 3, this participant acquired the sequencing response in 4 fewer trials during joint control training. During the second set of delay probes, correct responding occurred after a 3, 6, 9, 12, 15, 18, and 21-s latency.

Following the instruction to engage in the alternative verbal sequence in order to block the self-echoic, he correctly produced four of the six sequences from Set 2. When he was not required to block the self-echoic, he produced all six sequences correctly (see Figure 4).

Participant 4

As illustrated in Figure 2, Participant 4 did not arrange any correct sequences during baseline with the pictures from Set 1. In Phase 2 (prompt-and-fade), it took 14 trials to reach the mastery criterion. During the first set of delay probes, the participant produced a correct sequence when a 3, 6, 9, 12, and 15-s latency occurred between the instruction and the opportunity to respond. However, the participant did not produce a correct sequence following an 18-s delay.

This participant also did not arrange any correct sequences during baseline with the pictures from Set 2. During joint control component training, Participant 4 responded correctly to each of the four echoic stimuli on the first trial. The Mandarin tacts were acquired in 21 trials. In Phase 6, in which a procedure consisting of the components of joint control was used to train the sequencing task, it took 4 trials to reach the mastery criterion. As illustrated in Figure 3, this participant acquired the sequencing response in 10 fewer trials during joint control training. During the second set of delay probes, correct responding occurred after a 3, 6, 9, 12, 15, and 18-s latency.

Following the instruction to engage in the alternative verbal sequence in order to block the self-echoic, Participant 4 correctly produced five out of the six sequences from Set 2. When Participant 4 was not required to block the self-echoic, he also correctly produced five out of the six sequences from Set 2 (see Figure 4).

Participant 5

As illustrated in Figure 2, Participant 5 did not arrange any correct sequences during baseline with the pictures from Set 1. In Phase 2 (prompt-and-fade), it took 12 trials to reach the mastery criterion. During the first set of delay probes, the participant did not produce a correct sequence when a 6, 9, and 15-s latency occurred between the instruction and the opportunity to respond. Correct sequencing was only demonstrated after the 3-s and 12-s delays.

This participant also did not arrange any correct sequences during baseline with the pictures from Set 2. During joint control component training, Participant 5 responded correctly to each of the four echoic stimuli on the first trial. The Mandarin tacts were acquired in 16 trials. In Phase 5, in which a procedure consisting of the components of joint control was used to train the sequencing task, it took 3 trials to reach the mastery criterion. As illustrated in Figure 3, this participant acquired the sequencing response in 9 fewer trials during joint control training. During the second set of delay probes, correct responding occurred after a 3, 6, 9, 12, and 15-s latency.

Following the instruction to engage in the alternative verbal sequence in order to block the self-echoic, Participant 5 correctly produced one out of the six sequences from Set 2. When Participant 5 was not required to block the self-echoic, he correctly produced all six sequences (see Figure 4).

EXPERIMENT 2

A second experiment was conducted using procedures similar to Phases 4, 5, 6, and 8 of Experiment 1. The purpose of this experiment was to address the performance of Participant 4, who responded correctly to the same percentage of blocked trials as unblocked trials in Experiment 1. Different distractor tasks were used to block the rehearsal response and account for the occurrence of joint control in an effort to prevent the participants from interspersing the two tasks.

METHOD

Five undergraduate students (one male and four females) from CSULA participated in joint control training in which they learned to tact the pictures, echo the corresponding

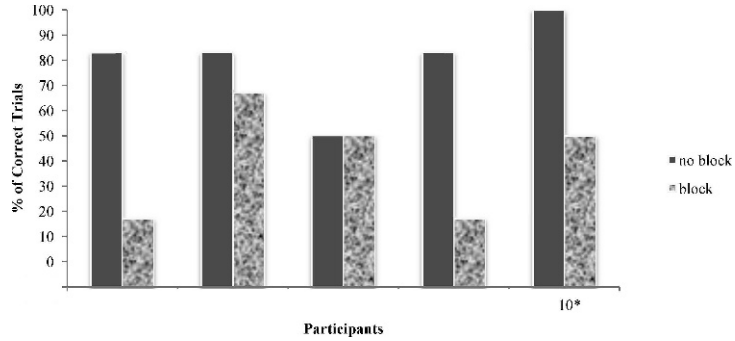

Figure 5. Percentage of correct blocked and non-blocked trials from experiment 2. The blocked and non-blocked phases have a maximum of 6 correct trials possible. A metronome was used with Participants 8, 9, and 10.

names, and arrange the pictures in a specified sequence while vocally rehearsing the sequence using the procedures outlined in Phases 4, 5, and 6 of Experiment 1. Because the participants received course credit for their participation and could not receive monetary compensation, correct responses were followed by praise and a written star. Following joint control training, the participants were randomly told to rehearse an alternative sequence by singing *Happy Birthday* immediately after they were instructed to do so. As in Phase 8 of Experiment 1, 6 of the 12 rehearsal responses were randomly blocked by having the participant repeat the alternative sequence. During this phase, for Participants 8, 9, and 10, a metronome, which emitted a slow pulse, was turned on after the experimenter named the sequence in order to encourage the participants to sing steadily and prevent interspersal of the self-echoics during the song.

The sessions from this experiment were video recorded and coded by the experimenter. Two additional observers watched and scored a portion of the trials using the same data sheet as the experimenter in which they scored a ''+'' for correct trials and ''−'' for incorrect trials. An agreement was defined as all three of the observers scoring a trial as either correct or incorrect. The scores from all three observers were used to assess interobserver agreement for 25% of the trials for all participants. IOA was calculated by dividing the number of agreements by the total number of trials (agreements + disagreements) and multiplying by 100. Mean IOA was 100% for all trials.

RESULTS AND DISCUSSION

Following the instruction to engage in the alternative verbal sequence in order to block the self-echoic, the participants correctly produced one (Participant 6), four (Participant 7), three (Participant 8), one (Participant 9), and three (Participant 10) of the six sequences. When the participants were not required to block the self-echoic, they correctly produced five (Participant 6), five (Participant 7), three (Participant 8), five (Participant 9), and six (Participant 10) of the six sequences (see Figure 5).

GENERAL DISCUSSION

The purpose of this study was to investigate the role of joint control in the performance of a sequencing task. In the first experiment, the rate of acquisition and accuracy of delayed responding was evaluated. Each participant was trained to produce correct sequences with two sets of pictures using two different training procedures. Mandarin Chinese names were assigned to each picture in order to make the sequencing task novel. The effect of these two training procedures on delayed responding was tested using progressive interval lengths. In both experiments, accuracy of responding was evaluated when the rehearsal component of joint control was randomly blocked in 6 out of 12 trials with a response presumed to be incompatible with the self-echoic response involved in the rehearsal component of joint control.

In Experiment 1, all of the participants acquired the sequencing response in fewer

trials when the component responses necessary for joint control were directly taught (see Figure 3). When a prompt-and-fade procedure was used to teach the sequencing response, it took between 7 and 17 trials for the participants to reach the mastery criterion, which was set at three consecutive correct responses. After the participants were trained to tact the objects, echo the names, and rehearse the sequence of a different set of pictures, it took between 3 and 7 trials for the participants to reach the mastery criterion. Therefore, the number of trials required to master the sequencing response according to the aforementioned criterion decreased by an average of 61%. This finding supports the hypothesis that ensuring mastery of joint control components prior to training a complex task may lead to faster acquisition of the task when compared to the rate of acquisition when these responses are not taught. Furthermore, the probability of correct responding increased when responding was under joint control. However, the two interventions were applied across participants in the same order. This may have contributed to more accurate responding when joint control training was applied because, even though a separate set of pictures was used, the participants were able to practice the sequencing task before the joint control training occurred with the second set of pictures.

Delay probes were conducted following each training procedure. The results of these probes were quite different for each participant. Participants 3 and 4 responded accurately when the opportunity to respond was delayed in the majority of the probes and only responded incorrectly when the longest probe (21 and 18 s) was presented. On the other hand, sporadic incorrect responses were observed for participants 1, 2, and 5. In other words, incorrect responding did not seem to be a function of progressively longer delays. A delay in general, regardless of the length, seemed to interfere with accurate sequencing. These inconsistent results can perhaps be attributed to individual differences in repertoires and learning histories. Alternatively, however, it is possible that the mastery criterion described for the sequencing task during the initial training was not sufficient for maintenance of the skill. All of the participants responded correctly in 100% of the delay probes that followed joint control training. These findings, although preliminary, may suggest that the probability of correct responding following a delay increases when the individual engages in self-echoic rehearsal during the delay interval, therefore bringing the response under joint control.

Of course, there is no way to objectively measure whether the participants were in fact rehearsing the sequence at a covert level during the prompt-and-fade training and test phases. During the delay probes, it is possible that Participants 3 and 4 were rehearsing the sequence even though they had not received direct training to do so. Furthermore, reinforcement was not available during these probes, so it is possible that these two participants were receiving automatic reinforcement for correct performance, in that responding correctly produced its own reinforcing consequences. None of the participants received tact or echoic training for the pictures in Set 1; however, they may have incidentally acquired the tact and echoic responses for this set of pictures. For example, it has been suggested that as humans contact complex environments, accuracy of selection responses will be enhanced if self-echoic rehearsal occurs. The selection response that occurs under joint control may be inadvertently reinforced and eventually spread throughout the individual's repertoire (Lowenkron, 1998). Although overt tact or echoic responses were not observed and no direct prompting or reinforcement was provided for these responses, automatic reinforcement for correct sequencing responses may also have aided in the acquisition of the response during the initial training. Future research could test for the emergence of tacts during and following the prompt-and-fade procedure. Another way to possibly control for this limitation is to use naïve participants who have limited verbal repertoires, such as children or individuals with developmental disabilities.

The results of Experiments 1 and 2 replicated Gutierrez (2006) by showing that for 80% of participants, accurate responding deteriorated when they said the alphabet (Participant 1), counted backwards from 100 (Participants 2, 3, 4, and 5), or sang *Happy Birthday* (Participants 6, 7, 8, 9, 10), which

was designed to block the mediating self-echoic behavior. Participants 3, 4, and 7, however, responded correctly to a high percentage of blocked trials. These results may be due to the fact that, based on anecdotal observations, these participants engaged in the distraction task slowly and rhythmically and were therefore able to intersperse the blocking response with mediation responses. Participant 8 responded correctly to a low percentage of unblocked trials (50%). She demonstrated a weak echoic repertoire and required many prompts to echo the sequence correctly during joint control training. Lowenkron (2006b) emphasized that both of the tact and self-echoic components of joint control are necessary for generalized responding to occur. When he taught children to select stimuli with unfamiliar names (i.e., absence of tacts) while engaging in response mediation (self-echoics), acquisition was slow and generalization was poor. On the other hand, when he taught children to select stimuli with familiar names (i.e., existing tacts), but blocked the response mediation, selection accuracy deteriorated. Therefore, joint control can also be used to identify deficits in either of the prerequisite skill areas. For example, if an individual is having difficulty mastering a complex task, such as the one mentioned above, it might be beneficial to test for a tact and/or echoic repertoire. If one or both of the repertoires are missing, remedial training can be provided.

Because some correct responding occurred during trials in which the rehearsal was ''blocked,'' it may be possible to attribute the results of these trials to the nature of the distraction responses, which was different than the distraction response required by Gutierrez. The two responses used in the first experiment may not have been completely incompatible in that the participants may have been able to intersperse the sequence with counting backwards or saying the alphabet. However, in the second experiment when a different distractor task (i.e., singing *Happy Birthday*) was used along with a metronome, correct responding during the ''blocked'' trials still occurred. Also, given that the participants were adults with extensive verbal repertoires, it is possible that correct responding during blocked trials resulted from the use of an alternative strategy. For example, Participant 8 reported that she attempted to ''visualize'' the sequence while she was arranging the cards. That is, correct responding may have been a function of ''imagining.''

The results of the current and previous research on joint control have a number of applied implications for language-training programs for children with autism or other learning disabilities (Sidener, 2006). That is, it may be a necessary prerequisite to directly train and reinforce the components of joint control (tact, echoic, and mediation responses) in order for complex selection or sequencing responses to be acquired quickly and efficiently. For example, if a teacher gives a complex conditional instruction, such as, ''put the ball in the closet and close the door,'' the child may be more likely to respond to the response chain correctly if the child has been taught to emit the tacts, echoics, and rehearsal required to bring the instructed task under joint control. Therefore, the child should be taught to tact both of the actions that occur in the response chain, echo the instruction given by the teacher, and continue to rehearse the instruction until the response chain is completed.

In conclusion, the present research provides further evidence of the important role of joint control in complex human responding by demonstrating that the introduction of supplementary stimuli that control a given response may lead to a sudden and drastic change in response strength (Skinner, 1957). Although the training that used the prompt-and-fade procedure eventually led to correct responding, responses that were trained under joint control resulted in fewer errors, faster acquisition, and more accurate maintenance, even when a delay interval was introduced. The study also provided indirect evidence for the existence of the self-echoic component of joint control by showing that the inaccurate responding was consistent when the participants were required to engage in an incompatible behavior; therefore blocking or preventing any response mediation from occurring. Finally, this research demonstrated that the prerequisites required for joint control might be necessary for complex behavior requiring conditional discriminations.

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