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RESEARCH ARTICLE

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Using joint control to teach activities of daily living and vocational tasks to students with autism

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Abstract

The purpose of this study was to assess the efficacy of a self-rehearsal procedure to teach five individuals with autism to follow multiple-step selection of stimuli. Within a multiple probe design across participants, participants were taught to echo the experimenter's instruction, self-echo, and then select multiple pictorial stimuli in order from an array of directly trained and untrained sets of stimuli. Self-rehearsal and selection related to activities of daily living in the natural environment required direct training. Probes of novel multiple-step tasks were conducted. Implications for the role of joint control in developing skills sequences to teach generative responding, conceptual analyses of covert verbal behavior, and designing instructional goals related to transition from formal education settings are discussed.

KEYWORDS

activities of daily living, autism, joint control, multiple probe, vocational tasks

1 | INTRODUCTION

According to Skinner (1957), listener behaviors are specifically conditioned to reinforce the behavior of the speaker. Schlinger (2008) expanded Skinner's definition, suggesting that listening also involves subvocal verbal behavior. In other words, a listener who is said to understand a speaker is engaging in covert verbal behavior such as echoic, tact, and intraverbal behavior with respect to the verbal discriminative stimulus. For instance, in order to follow the instruction, "get me the soup ladle, a bowl, and a lid" a student might echo the three requested items and continue to self-echo while searching for the items and tacting the items as they are retrieved. This example illustrates joint control. Lowenkron (1998) described joint control as ''the effect of two discriminative stimuli acting jointly to exert stimulus control over a common response topography'' (pp. 328–329). Joint control occurs when at least two of the speaker's own verbal stimuli control, or bring to strength, a subsequent response. In the example above, the ongoing self-echoic "soup ladle… soup ladle… soup ladle" controls the selection response at the moment the tact "soup ladle" is emitted; the two verbal operants jointly control the selection response. While searching the kitchen, the student will tact present items and select them when the tact and echoic occasion the same response topography, bringing to strength the selection of each item.

Much of the time these mediating verbal behaviors occur covertly. While it is possible to analyze functional relations and teach a student to follow multi-step directions without focusing on mediating events like self-echoics, doing so could foster generalization and abstraction (Lowenkron, 2004). Learning to echo a speaker and then self-echo is a problem-solving strategy that supports effective responding when the opportunity to respond is delayed from the time the verbal discriminative stimulus is presented (e.g., nonidentity delayed match to sample; Lowenkron & Colvin, 1992). In two experiments, Vosters and Luczynski (2020) utilized an analysis of joint control to teach participants to rehearse multiple-step instructions including selection of multiple stimuli from a field as well as instructions that included autoclitic frames (e.g., put the [object] on the [object]). They demonstrated a functional relation between the rehearsal of the instructions and tacts of the objects on the one hand and correct selection or manipulation of the objects on the other. In other words, the researchers directly taught covert sources of stimulus control suggested to bring the overt responses to strength via joint control.

Evaluating procedures that target foundational repertoires and problem-solving skills is essential for developing more effective instruction for children and young adults with autism. Behavioral skills training for individuals with autism has largely ignored the role of mediating verbal behaviors, focusing instead on teaching nonverbal behaviors via repeated practice, modeling, and similar interventions (Bryant & Fox, 1995; Leaf et al., 2015). While these studies show that repeated practice of the skills needed to maintain employment are critical for generalization and fluency in the completion of activities of daily living (ADLs) and vocational tasks, they do not provide educators with teaching techniques based upon conceptual analyses of skill deficits such as deficient self-echoics. As shown in Vosters and Luczynski (2020), applying teaching techniques that allow for recombination of operant behavior to form novel behaviors provides a significant opportunity to teach students with autism to behave in novel ways based on previously learned skills. This conceptual model, combined with the teaching techniques described for joint control, indicates that teaching skills in isolation as a first step, followed by teaching joint control, may teach students to engage in behaviors that have significant implications for employment skills and ADLs.

One example of an intervention targeting deficient duplics (i.e., echoic or mimetic behavior; Blair & Farros, 2019) in this manner was conducted by Causin, Albert, Carbone, and Sweeney-Kerwin (2013). They taught students to self-rehearse object names to guide multiple-stimulus selection. During joint control training, correct rehearsals (hand sign or vocal verbal) were followed by an opportunity to select the stimuli from a 12-stimulus "messy" array while incorrect rehearsals were followed by a 5s time-out from social attention. Correct stimulus selections were reinforced with tangibles or edibles. This procedure proved ineffective at establishing robust generalized multiple-stimulus selections for two of three participants. The experimenters then implemented a procedural modification that involved prompting the echoic and self-echoic or intraverbal and self-mimetic responses but did not involve presenting a 12-stimulus array or a stimulus selection response. Generalization probes were conducted with novel stimulus sets and without a rehearsal requirement. After learning to emit echoic to self-echoic behavior (vocal-verbal participants), or mimetic to self-mimetic rehearsal (one participant who used sign language), all three participants generalized the skill of selecting novel series of items in the prescribed order.

The purpose of this study was to replicate and extend Causin et al. (2013) to multiple-step behavior chains related to ADLs, competitive employment skills, and similar socially significant multiple-step tasks. We evaluated whether prescribed self-rehearsal behavior taught tabletop would generalize to natural environment conditions related to ADLs and vocational skills for students in autism support classrooms.

2 | METHOD

2.1 | Participants

Participants in this study were three males, Eric, Nathan, and Michel, and two females, June and Jessica. All participants had a primary diagnosis of autism and attended classrooms in which they received a majority of their instruction via behavior analytic methodologies including direct instruction procedures (Engelmann & Carnine, 1982) and discrete trial training utilizing Skinner's (1957) analysis of verbal behavior. All participants were able to tact at least 100 common items and select at least 100 items from a field of stimuli. We further screened participants to ensure they emitted three-word echoic phrases (if vocal speech was their primary mode of communication) or imitated at least three consecutive signs (if sign language was their primary mode of communication) and did not accurately select multiple items when asked to do so. Four of the participants responded vocally and one of the participants, Michel, used American Sign Language as his primary response form. All participants' caregivers signed informed consent and this research was approved by the Chicago School for Professional Psychology's institutional review board.

Eric was a 16-year-old male who attended a center-based educational setting for individuals with autism. At the time of the research Eric's instructional targets were tacts of items, tacts of parts and features of objects, vocational tasks, and ADLs based on his transition goals. His VB-MAPP score at the time of the research was 149. Eric was able to learn tacts of common items with two or three days of errorless instruction but required more teaching for items with which he had little previous exposure. He had a generalized echoic and imitative repertoire, and could accurately mand for items present, missing items, some information, and removal of aversive stimuli. He continued to require discrete trial instruction to learn tacts of parts and features due to frequent discrimination errors on these tasks. When Eric learned to tact an item, he could select it from a field without direct teaching.

Nathan was a seven-year-old male who attended public school in an autism support classroom. At the time of the research Nathan's instructional targets were tacts of parts and features of objects, tacts of items, tacts of actions, multiple word echoic phrases, and mand frequency. His VB-MAPP score at the time of the research was 106.5. Nathan could echo multiple words but required echoic training for longer phrases due to a pattern of leaving off the final word or words from phrases. He had a generalized imitative repertoire for single actions and learned mand responses for items present without direct errorless teaching. Nathan also selected from a field any item for which he had learned a tact response.

June was a 14-year-old female who attended public school in an autism support classroom. At the time of the research, June's instructional targets were mands for missing items using interrupted behavior chains relevant to her transition goals and preferred activities, tacts of verb–noun combinations, tacts of items related to her transition goals, tacts of parts and features, and site word identification. The site word identification involved both reading the printed word aloud (textual behavior) and selecting the printed word from a field of other words. June's VB-MAPP score at the time of the research was 136.5. June still required errorless teaching for some common items due to errors of discrimination (e.g., calling a broom a mop) or items to which she had little previous exposure. She acquired mands for items present with a single teaching trial or after learning to tact the item. She required direct teaching to mand for missing items and to tact parts and features of items. June also selected items from a field without direct teaching once she mastered a tact response for the item.

Jessica was a 14-year-old female who attended public school in an autism support classroom. At the time of the research, Jessica's instructional targets were manding for actions and for items that were present, echoing words and phrases, tacting common items and actions, following common one-step directions (e.g., show me drying, show me squeezing), identifying body parts receptively (e.g., touch your elbow), and completing ADLs related to transition goals. Her VB-MAPP score at the time of the research was 86. Jessica could echo multiple words but required vocal shaping for some single word responses due to poor articulation. She required direct teaching to learn mands for items and actions. She would occasionally require direct teaching of selecting items from a field of stimuli after having learned the tact of the item.

Michel was a 15-year-old male who attended a public school in an autism support classroom. At the time of the research, Michel's instructional targets were mands for actions and for items that were present, tacts of common items and actions, following one-step directions, and motor imitation to pre-teach sign language responses if he was unable to imitate the sign during assessment. Michel's VB-MAPP score at the time of the research was 93. Michel had a history of slow acquisition of skills across verbal operants and other instructional goals. His primary response form at the time of the research was American Sign Language and a selection-based system that he used during sessions with a speech and language pathologist. All of Michel's tact responses were signs. Michel could often select items from a field without direct teaching after mastering a tact response for the item, but this performance was inconsistent and thus sometimes directly taught.

2.2 | Settings and materials

The first author (henceforth referred to as the "experimenter") conducted all sessions. The experimenter was a BCBA who had worked as a consultant in autism support classrooms for 10 years. The experimenter had previous experience teaching joint control to students with autism based on the procedures described in Causin et al. (2013).

The experimenter conducted baseline, cold probes, and joint control training in the classroom where the participants received the majority of their instruction. All of the participants had baseline, cold probes, and joint control training conducted at a desk where they typically were taught mand training and language instruction via discrete trial training.

The experimenter conducted generalization probes in natural environment settings in the buildings where the participants typically received mand training and language instruction (i.e., the "contrived" environment). The classrooms had been arranged for one-to-one instruction or dyadic instruction. The experimenter stood next to the participant or sat across from the participant, kept the immediate area free of extraneous stimuli, and kept preferred items and activities out of the participant's reach. The seating was arranged to be comfortable and appropriate for the participant. Probes for generalization were conducted in a Practical Assessment Exploration System (PAES®) Lab where skill instruction related to competitive employment and ADLs was implemented with middle and high school students. PAES® is a vocational skills training curriculum that utilizes converted classroom space to replicate competitive work environments, assess student's skillsets related to employment, and teach skills using materials common to workplace environments (Practical Assessment Exploration System [PAES], n.d.) Additional natural environment settings included a free time areas in two classrooms in which materials related to leisure skills were readily available and an area of a middle school classroom used to teach ADLs. The latter area also came equipped with a sink and mirror that were used for teaching hygiene tasks such as tooth brushing, shaving, and applying deodorant. Relative to the classroom setting in which baseline, cold probes, and joint control training took place, the naturalistic environments were less controlled in that they contained a greater number of items, including more potential preferred items and activities that the participants could access without adult mediation.

Stimuli used in the classroom settings for multiple-step selection were two-dimensional (2D) picture cards described below, while items to be selected in the generalization settings were 3-dimensional (3D) objects that were more typical of the tasks that were targeted for instruction (e.g., personal care items such as toothbrush, comb, and toothpaste, to prepare for a bedtime routine).

For all participants the initial multiple-step selections taught in the joint control teaching phase included 7.62 cm × 12.7 cm pictures of items for which the participant could engage in a tact response based on previous teaching or assessment. These stimuli were common items selected from Language Builder card sets or identified through a Google image search. The stimuli were items that the participants encountered frequently in their home and school setting. An example of a set of stimuli to be taught would be a picture of a couch, a picture of a phone, and a picture of an apple. Each participant's list of mastered tact responses was reviewed and sets of stimuli for teaching and for probes of novel stimuli were selected from these lists. Sets of stimuli for probes of novel joint control responses were separated from the larger set so they were not inadvertently mixed in with sets of stimuli to be used in the teaching phase. Sets of stimuli used in the teaching phase were selected from the list and kept with the student's other instructional target materials in plastic bags. Twenty sets of stimuli, consisting of three stimuli per set, were identified for each participant to be used in the teaching phase.

Stimuli used in the natural environment settings were items commonly used in ADLs, or items that were relevant to participant's transition goals. An example of items used in the natural environment setting were items necessary to set a table such as plates, cutlery, cups, and napkins. These stimuli were selected because they served a dual purpose of being relevant to ADLs and employment in food service. Sets of stimuli were also selected based on their relevance to leisure skill activities such as a paint brush, easel, a cup to rinse brushes in, and toys the students played with independently such as balls, puzzles, action figures, iPad, plug and charger, a marble racer, and a miniature basketball hoop, scoreboard, and net. Sets of stimuli were not arranged thematically except in the generalization settings. Stimuli were also selected based on their relevance to ADLs such as toothbrushes, shaving cream, safety razor, deodorant, Q-tips, shampoo, soap, band aids, and washcloth. In order to obtain potential targets to teach, caregivers were asked to complete a questionnaire regarding what multiple-step skills they would like their child to learn. If materials necessary for those socially significant activities were unavailable in the experimental setting, the experimenter chose multiple-step tasks from the participant's transition goals in their individualized education plans (e.g., ADLs, skills related to competitive employment).

2.3 | Experimental design

A concurrent multiple baseline across participants with probes of novel sets of stimuli design was used to evaluate the effects of the joint control teaching procedures on making multiple-step selections of stimuli from a messy array and following multiple-step directions in the natural environment (Carr, 2005).

Once baseline responding was stable, the intervention was introduced for the first participant. Following multiple probe design logic, the intervention for each subsequent participant was introduced following a demonstration of stable baseline prior to and during the intervention phase for the previous participant. Mastery criteria were evaluated through a first trial cold probe of novel selection of stimuli. Cold probe criteria were used because the research took place in an applied setting where instructors have little exposure to more rigorous behavior analytic data collection methods (Lerman, Dittlinger, Fentress, & Lanagan 2011). When responding to novel stimuli during cold-probe trials showed a stable increasing trend, cold probe procedures were implemented in the natural environment (generalization settings). Mastery criteria for target sets of stimuli were two consecutive correct multiple-step selections during cold-probe trials. Novel sets of stimuli were considered mastered on the first correct multiple-step selection during cold-probe trials. Novel stimuli sets were considered mastered on the first correct multiple-step selection because unlike the target stimuli sets, these sets had never been directly taught as multiple-step selection responses. These mastery criteria were utilized across all the phases of research. The left panel of Figure 1, which was adapted from Causin et al. (2013), provides a flow chart for the cold probe procedure.

2.4 | Response measurement

The dependent variable was the cumulative number of emergent multiple-step selections of picture stimuli and novel multiple-step directions followed in natural environment settings during cold probe sessions. In each phase, the experimenter recorded the participant's selection of multiple stimuli from a field of objects or pictures. For example, following the experimenter instruction, “give me the book, the pen, and the jacket,” a correct response would be recorded if the participant handed those items to the experimenter in the order in which they were requested within 20 s.

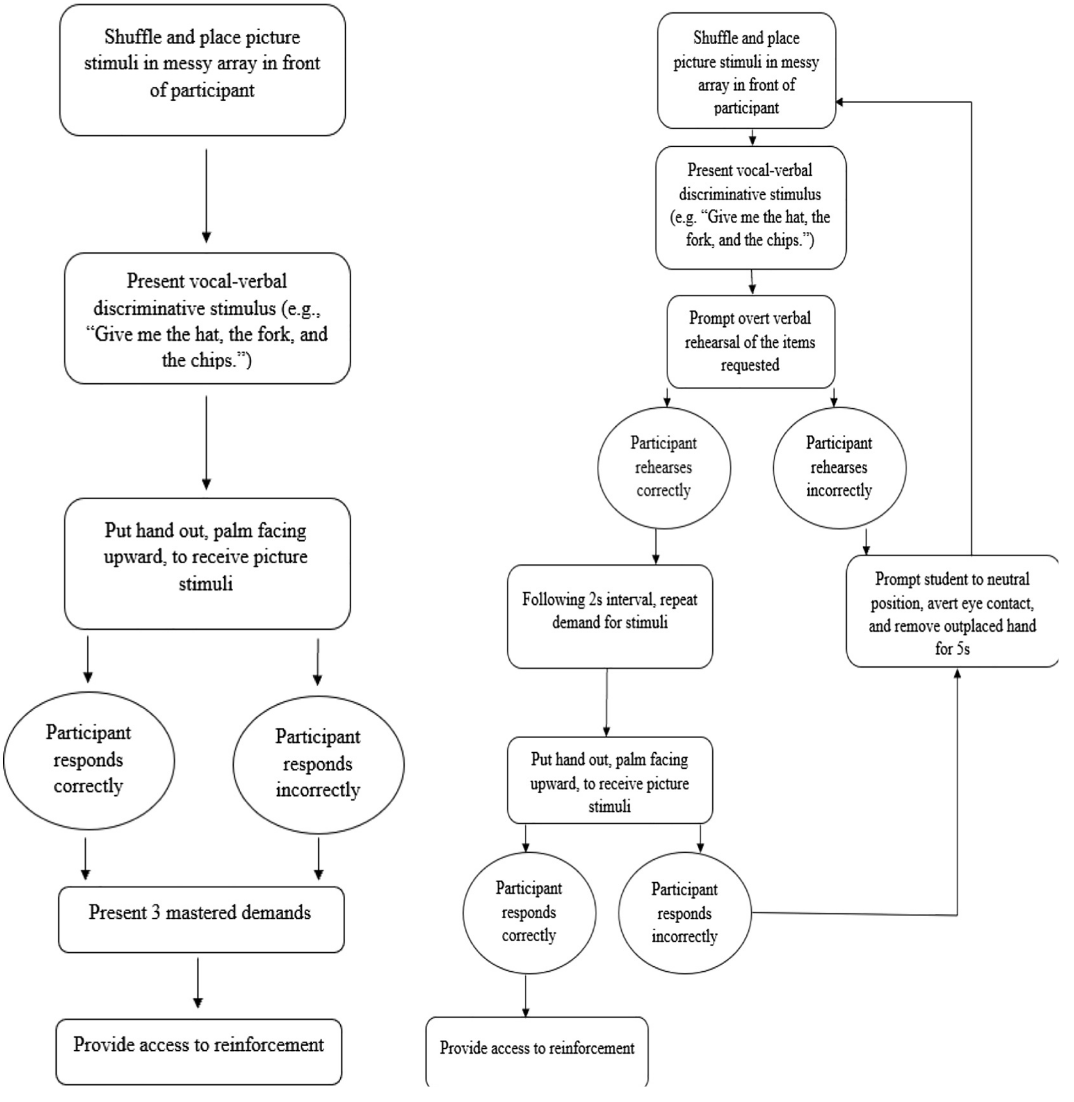

FIGURE 1 Flow charts for joint control cold probe procedure (left panel) and teaching procedure (right panel). Adapted from Causin et al. (2013)

Nonexamples included selecting any unspecified stimuli, selecting stimuli in any order other than that requested, or no response within the 20-s interval.

The experimenter recorded participant responses using paper and pencil. If the participant correctly selected the items in the requested order and within 20 s the experimenter manually recorded the probe as a "Yes." If the participant selected incorrect stimuli, selected the stimuli in the wrong order, did not respond, or began to respond before the experimenter finished giving the instruction, the experimenter recorded the probe as "No." Error responses that occurred during the rehearsal procedure were not recorded.

2.5 | Procedural fidelity and interobserver agreement

Procedural fidelity was scored for 30% of baseline, teaching, and natural environment sessions through a task analysis of the teaching and cold probe procedures used in this research. Each of the procedural fidelity checklists were comprised of yes/no criteria. Observation of the researcher's performance was conducted by a neutral third-party BCBA who observed the sessions via electronically recorded video. Procedural fidelity was calculated by dividing the number of experimenter responses that are scored as correct on the fidelity checklist by the number of responses listed on the fidelity checklist to produce a percentage correct score for treatment fidelity. Results showed that teaching the self-rehearsal at the table during joint control teaching sessions was conducted accurately in 93% of the observed sessions, natural environment teaching was conducted correctly in 89% of the recorded sessions, and baseline sessions were recorded as being conducted accurately in 93% of the observed sessions.

Interobserver agreement was measured by comparing the abovementioned treatment fidelity checklists filled out by a neutral third-party BCBA to fidelity checklists filled out by the experimenter following observation of the same sessions recorded with a portable digital camera. Agreement between the neutral third-party observer and the experimenter was defined as both observers scoring an instructor response as either correct, incorrect, or not applicable for the same session. A disagreement was defined as one observer recording an instructor response as correct, incorrect, or not applicable and the other observer recording the same response as any option other than that recorded by the first observer. IOA was calculated by dividing these agreements by agreements plus disagreements and converting the ratio to a percentage for each session in which IOA was conducted. IOA was conducted for of 30% of the sessions across participants and across conditions. The percentage of inter-observer agreement was 91% for the teaching procedure, 100% for the natural environment phase, and 97% for baseline.

IOA data for participant responses were recorded using the same process of having the third-party BCBA observer record if the participant correctly responded to the cold probe, joint control teaching procedures, and natural environment teaching sessions and then comparing their score to that of the experimenter to calculate agreement between the experimenter and the third-party BCBA. This IOA data were also collected for 30% of sessions across participants and conditions and consisted of a yes/no criteria whether the participant accurately engaged in the requested multiple-step direction. Inter-observer agreement on the participant's responding was 100% across the baseline and teaching phases. The natural environment phase IOA for the participant's responding was 93%.

2.6 | Procedures

2.6.1 | Baseline

Baseline consisted of cold probes of target stimulus selections and novel stimulus selections. The experimenter shuffled and placed a messy array of pictorial stimuli directly in front of the participant. The messy array field size was determined by reviewing each participant's initial assessments conducted by classroom staff or by the primary experimenter if no field size was previously established. The number of stimuli in the field were as follows for each participant: Eric scanned a field size of 15 stimuli, Nathan's field size was seven, June's field size was eight, Jessica's field size was seven, and Michel's field size was six. The experimenter then asked the participant to select at least three items from the field and held out their hand to receive the selected stimuli. Following the response opportunity, the experimenter removed the stimuli and either arranged a new field to run another cold probe or the participant would be asked to complete three tasks that were previously mastered (e.g., mimetic, listener response, tact, and echoic) and reinforcement would be provided for accurate responding to the previously mastered response prior to returning to their scheduled instruction.

2.6.2 | Joint control teaching

Following stable responding in the baseline condition, joint control teaching with the target sets of stimuli began in the classroom (contrived environment).

The teaching procedure was conducted as follows: the experimenter shuffled and placed a messy array of picture stimuli directly in front of the participant, gained eye contact, and requested selection of three stimuli from the field (e.g., "Give me cup, phone, hat"). The experimenter then prompted overt verbal rehearsal of the requested stimuli. The experimenter first presented a verbal prompt (e.g., "Say, 'cup, phone, hat'") to set the occasion for an echoic response and then presented a hand signal to prompt the participant to continue repeating the response without the vocal verbal prompt until the participant had emitted one echoic and four self-echoic responses (a total of five repetitions). The hand signal consisted of the experimenter first raising and then dropping their hand to signal each repetition. Participants were not required to imitate the hand signal and no participant was observed to imitate the hand signals consistently. Attempts to select the stimuli during rehearsal were blocked. Following the rehearsal, the experimenter repeated the request for multiple stimuli and placed their hand out to receive the selected stimuli. If an error response occurred, the instructor signaled that no reinforcement was available by removing their hand and removing attention for 5-s. After the 5-s interval, the instructor reintroduced the vocal verbal prompt. If the participant's echoic response was incorrect on three consecutive attempts the trial was ended and a different set of stimuli was introduced. Correct multiple-step selection responses were reinforced with access to preferred stimuli and/or activities based on a free operant preference assessment conducted before the experimental session. Reinforcers were withheld following any error responses. This teaching procedure was used across all participants for whom vocal-verbal responses were their primary response form. The right panel of Figure 1 provides a flow chart for the joint control teaching procedure. In this figure, the experimenter's behavior is in the squares and the participant's response is in the circles.

For Michel, whose primary response form was sign language, intraverbal prompts were used to evoke the rehearsal preceding the selection of stimuli. In this procedure, the experimenter used a vocal verbal prompt for the participant to engage in the hand sign (e.g., "Sign ball, cup, hat") with the same hand drop signal to continue each signed rehearsal. When these prompts proved ineffective, as shown by errors during the rehearsal, an imitative prompt was added during which the experimenter signed each item while delivering the vocal prompt. Again, at least five rehearsals of the selected stimuli set were prompted prior to the final request to select the items.

Upon correct selection of the stimuli in the order in which they were requested, the experimenter delivered a preferred item (edible, games, toys, etc.) for 30 s or until the edible item was consumed. When requesting the multiple-step selection, the order of the items requested was randomized for each trial. After the reinforcer was delivered, the experimenter recorded the trial data, removed the array of pictures, and shuffled and laid out a new messy array. Cold probes of novel multiple-selections were introduced following mastery of a multiple-stimulus selections. Training moved to the natural environment baseline phase after the participant accurately selected three sets of novel stimuli, cumulatively, during cold probe assessment.

A total of 54 joint control teaching sessions were conducted in the contrived environment across all participants with a range from eight joint control teaching sessions for Nathan to 16 joint control teaching sessions for Michel. A total of 18 sessions were conducted for novel sets of stimuli and 36 sessions for target stimuli.

2.6.3 | Probes of novel sets in contrived environment

Cold probes for novel sets of stimuli were conducted twice a day with at least two separate sets of stimuli probed at the participant's desk. The participant then moved to the natural environment probe phase. Sets of novel stimuli were selected from the list of mastered tact responses. These sets were kept separate from the target sets of stimuli used in the teaching phase. If the participant did not accurately select the correct stimuli for the novel set selected for cold probe, the set was not taught using the errorless teaching procedure. The novel set would be returned to the participant's teaching materials and probed again later.

2.6.4 | Natural environment baseline

Generalization probes assessed each participant's ability to follow multiple-step directions in the natural environment. Probes were conducted in the natural environment baseline phase following mastery of at least three novel multiple-step selections in the joint control teaching phase. These probes followed identical procedures described in the initial baseline phase except that they occurred in the natural environment using 3D objects. The probes for generalization in the natural environment was conceptualized as a test of whether the participant had learned to respond to their own verbal behavior to mediate their overt behavior in novel situations. Two of the participants, Eric and Nathan, were tested on three multiple-step selections of three stimuli in the natural environment probe phase. Jessica, Michel, and June were tested on four multiple-step selections of three sets of stimuli.

During probes, the experimenter asked participants to engage in a particular behavior chain that involved more than one step. For example, if caregivers identified setting a table for breakfast as something they would like for their child to be able to do, the selection of stimuli necessary for this task would be occasioned by the instruction, "Get the bowl, spoon, and coffee cup." The experimenter arranged for each set of stimuli necessary (e.g., a bowl, a spoon, and a coffee cup) to be available in the environment prior to directing the participant to complete the task. In the natural environment setting, other stimuli were also available to create natural conditions (e.g., other items related to setting the table that would not be requested as part of the multiple-step selection). A total of 16 probes were conducted in the natural environment with all participants receiving three probe sessions in the natural environment except June who received four sessions. During baseline in the natural environment, the consequences for participant's responding were identical to those in initial baseline. The experimenter would either present another request for multiple-step selection of stimuli or request the participant engage in three mastered skills and provide reinforcement for accurate responding before returning to scheduled instruction.

2.6.5 | Natural environment teaching

Tasks that the participants did not complete with 100% accuracy during the natural environment baseline were taught using the joint control self-rehearsal procedures described above. Training continued until three untrained multiple-step directions were followed with 100% accuracy. A minimum of three natural environment tasks were taught for each participant. In the natural environment teaching and probe conditions, the array used was whatever natural context under which the task would be completed outside of experimental conditions. A modification was made for two participants in the natural environment phase. Michel and Jessica failed to acquire the skill of correctly rehearsing the three items and then selecting the items after three trials for Michel and four trials for Jessica, so the number of items was reduced from three to two on trial 30 for Jessica and trial 34 for Michel. A total of 55 sessions of natural environment teaching were conducted with a range of 10 sessions for Eric and 14 sessions for Michel and Jessica. Of the cumulative 55 sessions, 18 sessions were for novel sets of stimuli and 37 sessions were for sets of target stimuli.

2.6.6 | Probes for novel sets in natural environment

Probes for multiple-step selection of novel sets of stimuli in the natural environment were conducted in the same manner described in the natural environment baseline, except novel sets of items (not included in teaching) were used. During cold probes in the natural environment, the same consequences for correct or incorrect responses described previously were used. Following the opportunity to respond, the experimenter would request the participant to engage in three previously mastered skills and provide reinforcement for accurate responding. The participant would then return to their scheduled instruction. All probes in the natural environment were for multiple-step selection of items (e.g., get the paintbrush, paints, and a cup).

3 | RESULTS

Figure 2 displays concurrent multiple probe data across the five participants. The cumulative number of mastered joint control responses, as determined by cold probe procedures, are plotted across sessions. The data presented are only of the mastered joint control responses and not responses during teaching sessions. During baseline, none of the participants followed multiple-step selection of picture cards from an array on a table and none followed multiple-step selection of novel stimuli in natural environment conditions. Following the introduction of the joint control teaching procedure, all participants learned to select multiple stimuli from an array of picture cards in the order in which they were requested.

All participants learned to self-rehearse during the teaching phase, with the fewest number of trials to mastery being three for Eric and the most being 18 for Michel. Nathan mastered his first set of stimuli after 10 teaching trials, June mastered her first set after seven teaching trials, and Jessica mastered her first set after 12 teaching trials (see Table 1). Displayed in panels four and five, Michel and Jessica had slower rates of acquisition. During the natural environment phase, Michel and Jessica made errors on both the cold-probe trials and during the selection of items that they had been prompted to rehearse. The lack of acquisition and errors during direct teaching prompted a procedural modification. The number of items to be retrieved in natural environment settings was reduced from three to two for both trained and novel stimuli sets.

As reflected in Figure 2, none of the participants generalized the use of the overt verbal rehearsal strategy taught in the joint control intervention phase to the natural environment probes. This skill was acquired for all participants after using the same teaching procedure within the natural environment setting as was used during the joint control teaching phase. Eric and June both mastered multiple-step selection of stimuli in the natural environment with zero errors once the prompted self-rehearsal was introduced in the natural environment. Nathan made errors on the first two teaching trials of natural environment training; on both trials he selected the correct stimuli but in the wrong order. Subsequently, Nathan correctly selected the three stimuli in correct order without any errors.

While none of the participants generalized the skill taught in the joint control intervention phase without additional teaching trials in the natural environment, all participants learned to follow novel multiple-step selection responses in the natural environment following natural environment teaching procedures using the self-rehearsal procedure that had been used during the joint control teaching phase. Eric, Nathan, and June learned to follow three- and four-step selection of stimuli within the natural environment following this natural environment teaching. Jessica and Michel learned to follow novel two-step selection of stimuli following natural environment teaching. A planned check for maintenance of the joint control skill across time was not possible due to the time constraints of this research and the closure of schools due to COVID-19.

4 | DISCUSSION

The purpose of this study was to replicate and extend previous research (Causin et al., 2013) evaluating the effects of self-rehearsal strategies on the selection of multiple stimuli in a contrived teaching condition and in a natural environment setting. The replication included using the same teaching procedures, similar experimental design, and similar conceptual analyses in developing the teaching methodologies. The extension included a check for generalization of the joint control responses in natural environment conditions and conducting the research in public school autism

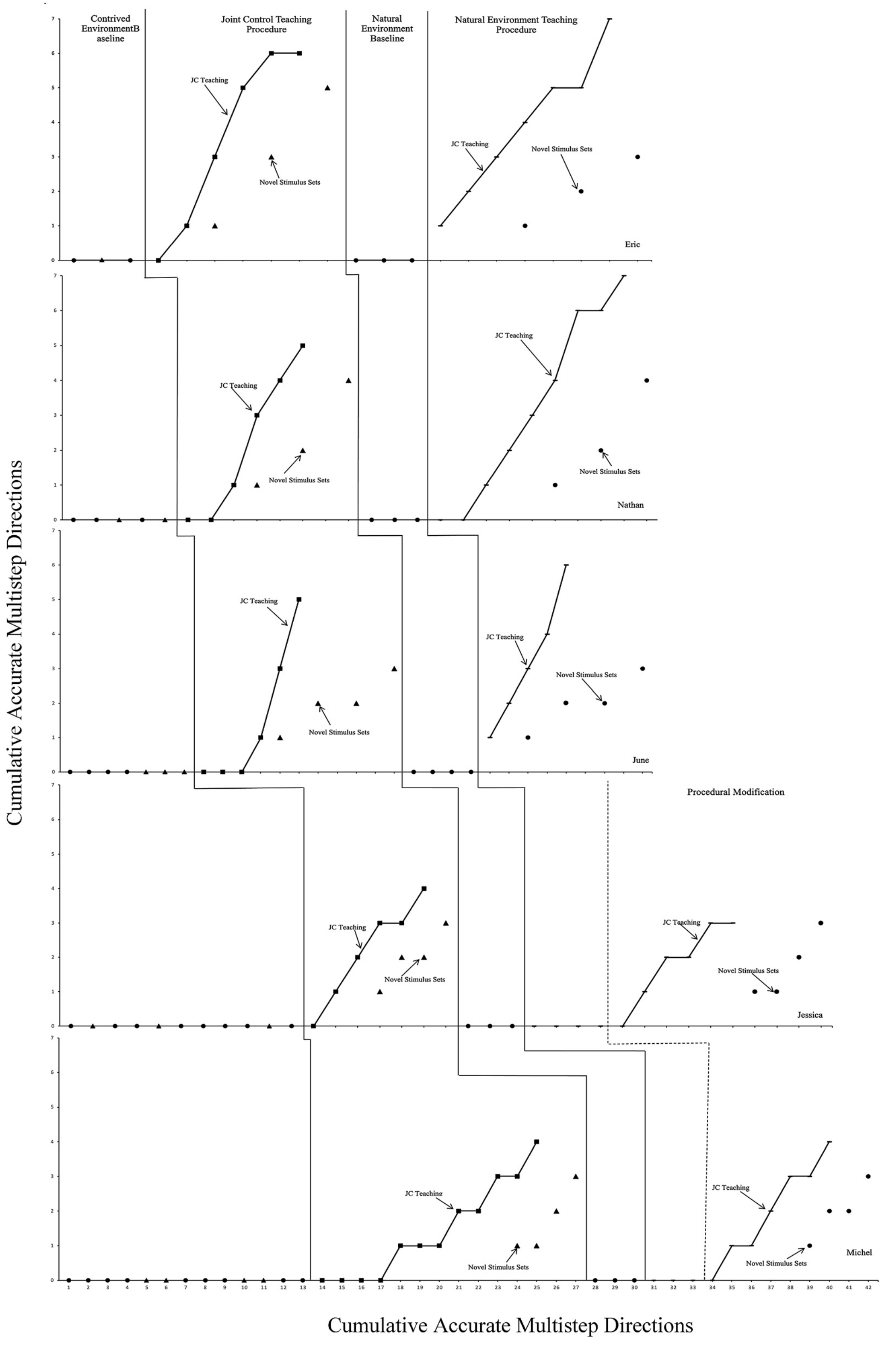
Contrived EnvironmentB aseline
Joint Control Teaching Procedure
Natural Environment Baseline
Natural Environment Teaching Procedure
Procedural Modification
JC Teaching
Novel Stimulus Sets
Eric
Nathan
June
Jessica
Michel
Cumulative Accurate Multistep Directions
Cumulative Accurate Multistep Directions

TABLE 1 Trials to mastery for initial target stimulus sets across tabletop and natural environment conditions

Participant	Trials to mastery of first stimulus set (tabletop)	Trials to mastery for first stimulus set (natural environment)
Eric	3	5
Nathan	10	13
Jun	7	14
Jessica	12	7*
Michel	18	10*

Note: These data are reflective of the trials to mastery following the procedural modification where mastery criteria was adjusted to two-step selection of stimuli in the natural environment.

support classrooms. Participants learned to rehearse the instructions and correctly select multiple stimuli with novel exemplars but did not generalize the multiple-stimulus selection to the natural environment until teaching was conducted in that setting.

All participants required training in the natural environment, so it is unclear whether the joint control teaching procedure in the contrived environment was necessary. The prior exposure to the joint control procedure in a more orderly setting might have enhanced training in the natural setting, but future research should investigate whether the skill is better taught in the natural context straight away. The most recent review of the literature on joint control (Ampuero & Miklos, 2019) shows measures of generalization of joint control related to match-to-sample skills (Lowenkron, 1984, 1988, 1989; Sidener & Michael, 2006), but no research was identified that measured generalization across environments and stimuli in natural environment conditions. The lack of generalization in the present research may be conceptualized as the result of stimulus control being overly restrictive to the setting in which the skill was taught and not being transferred to new environments until the rehearsal was taught in these novel environments.

Generalization is of fundamental importance in behavior analytic research on effective teaching strategies (Stokes & Baer, 1977) so it is critical to understand how independent variables like teaching a rehearsal strategy affects emergent repertoires. All of the participants were able to follow multiple-step selection of stimuli following direct teaching of the self-rehearsal procedure in the natural environment and generalized this multiple-step selection to novel stimuli that included ADLs (e.g., retrieving the necessary items to set the table for a meal). However, the generalized responding only occurred following teaching trials in the natural environment that replicated the teaching trials within the joint control teaching sessions. Future research should determine whether practicing the self-rehearsal strategy under less constrained conditions more readily leads to the skill being learned in natural environment settings, or if training within the natural environment is adequate. Further, it is possible that the original joint control teaching phase in the contrived environment could be altered to increase the likelihood of generalization.

One issue relevant to generalization in the current study was the use of 2D stimuli in the teaching phase and 3D stimuli in the generalization phase. Pictures of common items were used during the contrived environment teaching phase because they were stimuli that had been previously taught to evoke tact responses. In the natural environment, where checks for generalization occurred, the items targeted for multiple-step selections were 3D items that were often dissimilar to the mastered 2D stimuli in a variety of ways (e.g., color, size, orientation to the observer, etc.). There was no record of direct teaching of tact responses conducted in the natural environment for the items selected as targets for multiple-step selection and no such instruction occurred during the research. The implications of differences in the stimulus properties of 2D versus 3D stimuli is a topic for future research. The participants in this study did not need to be taught the tact of the items in the natural environment, but rather had to be taught the skill of rehearsal in

FIGURE 2 The cumulative number of trained and novel stimulus sets mastered by Eric, Nathan, June, Jessica, and Michel across baseline, joint control teaching, and natural environment probes and teaching the natural environment. While no data were collected regarding the abilities of the participants to tact the items in the natural environment, once the participants were taught the self-rehearsal in the natural environment, they were able to retrieve those items without additional tact training. This would imply that the skill that did not generalize was the skill of talking to oneself to mediate other responses and not the tact of items that had been previously taught using 2D picture cards.

The current study did not parse out rehearsal errors from stimulus selection errors. It also made no attempt to program for generalization by intervening on rehearsal errors and selection errors via separate protocols. Future research might evaluate the influence of potential modifications on error correction methods for inaccurate rehearsal versus inaccurate selection after accurate rehearsal. It is also important to note that probes in the natural environment occurred after mastery of three stimuli sets. Future research might evaluate the effects of introducing probes earlier during acquisition on generalization.

The covert nature of the behavior that is inferred to bring about selection of multiple stimuli makes it difficult to investigate transfer to the natural environment. The teaching procedure used in this research was of pragmatic value because it required an overt verbal response that could be measured for the purpose of research. However, responses brought to strength through rehearsal need not be overt (Lowenkron, 1998) and covert verbal behavior is unique only in the sense that it can be observed by a single individual, the speaker. As Skinner (1957) points out, "The stimuli generated by covert behavior are relatively subtle and easily overlooked" (p.141). However, the stimuli generated through covert verbal mediation are nonetheless evocative of other responses. The difficulty of observation of covert verbal behavior is an important consideration when analyzing why self-rehearsal did not generalize to the natural environment. In the teaching phases, overt responding was required. However, during cold probes the overt rehearsal was not required. This creates a circumstance in which an overt verbal response inferred to mediate the multiple-step selection may or may not occur. The same can be said for the covert verbal behavior that is inferred to bring the overt selection response to strength. During cold probe phases of this research, both in the contrived teaching and natural environment setting, three of the participants were observed engaging in other overt behavior that may be indicative of covert verbal rehearsal. During teaching sessions where overt rehearsal was required, Eric would frequently look up and nod along while rehearsing. This same behavior was observed to occur when Eric was being given instructions to retrieve items during cold probes when no overt rehearsal was required. June was observed to occasionally whisper the names of the items she was requested to retrieve to herself during natural environment teaching and cold probe procedures as she searched for the items. Nathan was observed to occasionally engage in overt rehearsal of items during cold probes even though the overt rehearsal was neither prompted nor required during these trials. The question of why overt rehearsal might become covert is difficult to answer. Skinner (1957) discussed to the difficulty in identifying what might cause overt verbal behavior to become covert:

> Covert speech is not, however, wholly or perhaps even primarily a labor-saving practice. As we have seen, verbal behavior is frequently punished. Audible behavior in the child is reinforced and tolerated up to a point; then it becomes annoying, and the child is punished for speaking. Comparable aversive consequences continue into the adult years. Punishment is not always in the nature of reproof, for speech which is overheard may have other kinds of undesirable effects, such as giving away a secret. The privacy of covert behavior has a practical value (p. 436).

For Jessica and Michel, generalization of multiple-step selection did not occur until the number of items was reduced to two items during the natural environment phase. It may be that Jessica and Michel would have been successful in natural environment training if they had more sessions of direct teaching of the self-rehearsal strategy in the natural environment or during the joint control teaching phase. It is also possible Jessica and Michel lacked precursor skills necessary for engaging in joint control responses, which are generative in nature (e.g., Palmer, 2012). Both Jessica and Michel had mastered fewer verbal operants (e.g., tact, mand, echoic, and intraverbal responses) and fewer nonverbal operants (e.g., imitation, listener responding, and match-to-sample responses) than the other participants.

One consideration is how durable the self-echoic responses are over time. Esch, Mahoney, Kestner, LaLonde, and Esch (2013) showed that self-echoic responses degraded over time and proposed that "a 5-s (vs. 2-s) delay weakens stimulus control for a self-echoic response to what was recently heard" (p. 120). Sidener (2006) offered a similar analysis, describing individuals who do not engage in joint control responding: "Independently the child may be taught to go to various locations in the classroom such as the door, the window and the chalkboard. However, efforts to combine these activities ("Go to the window and get the book.") have failed, possibly because by the time the child gets to the window, the rest of the stimulus (". . . and get the book.") is no longer available" (p. 121). Michel, who uses sign language, relied on observation of an instructor to engage in the sign responses. This stimulus is necessarily absent once the final verbal discriminative stimulus to retrieve the items is presented. Future research might explore responses and response products that might mediate novel multiple-step selection for individuals who use sign language as their primary response form. Future research might also evaluate a skills sequence that leads to successful rehearsal in natural environments.

A significant consideration for teaching any skill is the role of potential prerequisite skills. As an example, a person who cannot respond to tasks that involve prepositions will struggle with mathematic computation because much of mathematics involves prepositions (e.g., "Put the 5 *over* the tens place," "one comes *before* two," "write your answer *under* the line," etc.). Because no data were available for any of the participants that indicated mastery of responding to task demands that included prepositions, adjectives, or adverbs, multiple-step responses that involved actions with items (e.g., put the spoon in the cup) or topographies other than selection (e.g., zip up your jacket, put on your hat and gloves, get the small cup and big spoon, etc.) were not probed. The reason for excluding these types of multiple-step demands was that not all of the participants had mastered necessary prerequisite or component skills, such as tacts of prepositions, to bring these types of responses to strength through joint control. In choosing which skills to target for teaching, Palmer's (2012) analysis of atomic repertoires was utilized. In Palmer's analysis, the behavioral repertoires necessary to engage in novel responses involve previously mastered skills that are brought to strength under novel circumstances. As an example of an atomic repertoire, read the following nonsense words: whag nuz shriv dun. While it is extremely unlikely that anyone has a learning history with reading this specific series of nonsense words, anyone with a fluent repertoire of phonemic decoding of the English language will read the passage effortlessly. Some of the atomic repertoires necessary to read the nonsense passage include phonemic blending, the rules that guide English reading conventions (e.g., in English text is read left to right, stop at the period, etc.), as well as knowing the sounds each of the individual letters make in the English language. However, another passage, fad saol agat, gob fliuch, agus bás in Éireann, will prove difficult for someone who has only learned English reading conventions and not Gaelic. This difficulty is the result of a lack of discrete skills necessary that allow fluent reading in Gaelic. In selecting which chains of behavior to teach and assess, it was determined that without having mastered requisite tacts of prepositions, actions, and features the participants would not have learned the necessary skills to follow instructions that depended on these skills. Much as a reader who has no learning history with Gaelic reading conventions will struggle to engage in accurate textual behavior when presented with written Gaelic, people who have not learned to engage in verbal behavior related to prepositions, actions, or parts and features, are unlikely to respond accurately to demands involving those relations.

No studies have addressed the prerequisite skills necessary for teaching joint control (Ampuero & Miklos, 2019). In the most current literature review on joint control Ampuero and Miklos (2019) state the following:

> An unexplored aspect of the current literature is the specification of precursor skills that facilitate competency related to the occurrence of joint control. Considering the current evidence suggesting that skills related to tact and echoic training are necessary for joint control, it is likely that, for some learners in which the repertoires do not develop without specific training, instruction that initially focuses on building the basic tact and echoic repertoire will be necessary. Although three studies that used the analysis of joint control and procedures that derive from this account have been conducted

with individuals with disabilities, to date, an analysis of the skill profiles that facilitate the multiple control necessary for joint control have not been specifically studied (p. 165).

Further, none of studies included in Ampuero and Miklos (2019) tested for maintenance of the taught skills over time, which is a limitation of the current study as well. Finally, the results of the current study suggest that the procedure was ineffective in establishing generative responding under conditions of greater complexity without additional teaching. Future research should, therefore, conduct an analysis of prerequisite skills that facilitate teaching joint control, evaluate maintenance of joint control responding as a function of the teaching procedures, and continue to explore methods to remediate this socially significant skill deficit commonly observed in individuals with learning delays.

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CONFLICT OF INTEREST

The authors report no conflicts of interest involved with the research conducted or the submitted work.

ETHICS STATEMENT

The research was conducted with approval from the Chicago School of Professional Psychology's IRB and all of the research abides by ethical guidelines.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the first author. The data are not publicly available due to privacy or ethical restrictions.

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