A COMPARATIVE EVALUATION OF MATRIX TRAINING ARRANGEMENTS

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A common goal of instructional techniques is to teach skills effectively and efficiently. Matrix training techniques are both effective and efficient as they allow for the emergence of untrained responding to novel stimulus arrangements, a phenomenon known as recombinative generalization. However, it is unclear which type of matrix arrangement best promotes recombinative generalization. The current study compared two common matrix training approaches, an overlapping (OV) design and a non-overlapping (NOV) design, with respect to arranging relations targeted for training. We conducted a replication evaluation of a Wilshire and Toussaint study, and taught two typically-developing preschoolers compound object-action labels in Spanish and used either an OV or NOV matrix training design. Results from both studies demonstrated the participant trained with an OV design produced recombinative generalization and participants trained with a NOV design produced significantly low levels of emergence or none at all. These results suggest that an OV matrix design facilitates recombinative generalization more effectively than a NOV design. Implications for instructional arrangements are discussed.
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A COMPARATIVE EVALUATION OF MATRIX TRAINING ARRANGEMENTS

Recombinative generalization is a stimulus control process that produces emergent responding to novel stimulus configurations. Emergent responding is predictable given: (a) discriminated responding to constituent stimuli that are components of a compound stimulus and (b) discriminated responding to a frame that orders the constituent stimuli. For example, a learner may label an object as, “blue shoe,” without a direct history of the combination, “blue shoe,” given a history of discriminated responding to each term (i.e. blue, shoe) as well as the adjective-object syntactic rule.

Matrix training is an instructional design that may arrange for recombinative generalization depending upon judicious selection of instructional targets and their arrangement within the matrix. Foss (1968a, 1968b) evaluated two matrix arrangements to teach undergraduate students to label a set of colored shapes with nonsense syllables (e.g. zin-fub). The systematic group received instruction on a set of 10 compound stimuli. Eight of the 10 targets shared a constituent, color or shape, with another target, while two targets retained a unique color-shape combination. The control group received instruction on six targets that did not share any feature with another target; each target was a unique color-shape combination. Foss (1968b) referred to these different arrangements as overlap (OV) and nonoverlap (NOV), respectively.

Following training, OV participants demonstrated recombinative generalization of trained items, including emergent combinations of constituents from two novel targets that did not share a constituent during training. However, the NOV participants who received instruction on a set of stimuli with zero shared constituents, did not respond correctly to any novel stimulus combinations. According to Foss, a learner may “discover systematicity, not necessarily
consciously, and utilize it in further behavior.” (p. 458) Foss concluded that “what needs to be clarified is the nature of the mechanism that discovers such systematicity.” (p. 458) Additional research has clarified the mechanism as a stimulus control process.

Striefel and Wetherby (1973) demonstrated that multiple presentations of a constituent is insufficient to produce recombinative generalization (e.g. push car, push glass, push scissor). A later study conducted by Striefel, Wetherby, and Karlan (1976) demonstrated that instructional presentations that require discrimination between constituents (e.g. push car, blow on car, push glass) is sufficient to produce recombinative generalization. In an OV configuration, the learner observes and responds to each constituent of the compound stimulus. In contrast, responding may come under the control of any single constituent or the compound as a single unit with NOV training.

Overlap matrix training (OV) systematically arranges for recombinative generalization by training a subset of compound stimuli that share or overlap constituents with other training stimuli. Within OV matrix arrangements: (a) there are at least two shared constituents (e.g. red, truck) per three-item set of two-constituent, compound stimuli (e.g. red shoe, red truck, blue truck), and (b) all compound stimuli within the set share a frame that maintains the order of constituent stimuli. Given this arrangement, a learner may accurately respond to: (a) the constituents, red, blue, shoe, and truck, (b) the syntactic rule, adjective-object; (c) the novel compound, blue shoe. OV matrix training may be considered an efficient instructional technique as relational responding to constituents and the constituent frame is not required prior to instruction as these elements are derived as an outcome of instruction.

Goldstein, Angelo, and Moustesis (1987) further clarified that the stimulus control process was not only afforded by constituents, but the constituent frame also exerted control.
Goldstein et al. taught three children with communication deficits to receptively identify and label object-preposition-location combinations using a NOV matrix design. After identifying known constituent stimuli, object and location words, for each participant, Goldstein et al. taught a compound response that consisted of two known constituents within a novel frame (e.g. balloon on bed). Following this minimal instruction, participants correctly responded to all novel combinations amongst the known constituents demonstrating robust recombinative generalization. These results suggest that when constituents are established or “known,” an OV design may not be necessary since only discrimination of the frame is required before recombinative generalization can occur.

In a subsequent phase of the NOV training, Goldstein et al. (1987) serially introduced novel, compound stimuli comprised of unknown constituents. It should be noted that participants acquired the object-preposition location rule from the previous phase of the evaluation. Following introduction of the first unknown target (e.g. paddle on hutch), participants again demonstrated recombinative generalization. These results demonstrated that knowing the constituent frame may allow a learner to discriminate the individual constituents of an unknown compound stimulus. In other words, by knowing the frame, object-on-location, a learner may discriminate paddle and hutch after presentation of the stimulus, “paddle on hutch.” These results also explain the performance of the systematic group in Foss (1968a) in which participants demonstrated recombinative generalization for a subset of targets that did not share constituents during training. In Foss, if the frame came to exert control over responding via overlap training of the other eight constituents within the instructional set, then this provided the necessary conditions for recombinative generalization following the introduction of novel compounds.
Goldstein et al. 1987 continued to introduce additional unknown targets, but recombinative generalization decreased with each introduction. To improve discriminated responding, instruction with overlapping responses was necessary for all three participants. In summary, presenting unknown compound stimuli in a known frame may allow a learner to derive the constituent stimuli, but this instructional method may produce stimulus confusion and relatively poor performance.

Generative learning is a desirable outcome of instructional programs and is an important instructional design consideration for individuals with communication disorders and developmental disabilities who greatly benefit from efficient instruction. There is substantial research to support the use of matrix training for these populations. For example, applications of matrix training include teaching expressive modeling through observational learning to children with developmental disabilities (Goldstein and Mousetis, 1989), verb tenses to a patient with primary progressive aphasia (Schneider, Thompson, and Luring, 1996), prereading skills for adults with intellectual disability (Saunders, O’Donnell, Vaidya, and Williams, 2003), and sociodramatic play to children with autism spectrum disorder (ASD) (Dauphin, Kinney, Stromer, 2004). Across these applications, instructors have utilized either OV and/or NOV instructional matrices, and with mixed results.

Of interest are applications that utilize a NOV design with unknown words and demonstrate recombinative generalization. For example, Axe and Sainato (2010) provided instruction on unknown actions-pictures with a NOV instructional design to four preschoolers with ASD. Following instruction, two of the four participants demonstrated recombinative generalization with novel action-picture responding; the other two participants required additional instruction with overlapping constituents. Axe and Sainato recommended, “training on
only the diagonal of the matrix,” (p. 648) even when individual components are unknown for efficient learning. Similarly, Pauwels, Ahern & Cohen (2015) utilized a NOV design to teach object-preposition phrases to three individuals with ASD. Two of the three participants demonstrated recombinative generalization following NOV instruction with unknown components.

One factor that may account for recombinative generalization of unknown targets in NOV designs is contingent reinforcement during probe conditions. Providing reinforcement for a novel response during a probe condition may influence each subsequent response. For example, if an individual spuriously selects a response (e.g. red truck) and that response is followed by reinforcement, then consequent control may be spread to all other combinations that contain red or truck as a constituent. Although Axe and Sainato (2010) provided contingent reinforcement, Pauwels, Ahearn, & Cohen (2015) did not provide any form of feedback during probes. An additional factor that may influence responding is the identification of unknown targets during preassessments. Responses may be too weak to be detected during preassessment yet detected in a postassessment if they are indirectly strengthened as a result of training within the response class (Axe and Sainato; Hanna et al., 2011).

Wilshire and Toussaint (2015) compared the effectiveness of OV and NOV training on the acquisition of action-object labeling with two typically-developing toddlers. To minimize influence from the previously-described factors, Wilshire and Toussaint withheld reinforcement for responses during probes. In addition, participants were taught a sign response, similar to American Sign Language, to evaluate learning with responses with minimal extra-experimental history. Recombinative generalization was demonstrated for the participant who received the OV
instruction; recombinative generalization was absent for the participant who received NOV instruction.

The purpose of the current evaluation was to replicate and extend the work of Wilshire and Toussaint (2015) by teaching object-action labeling with two typically-developing preschoolers utilizing an OV and a NOV design. Similar to Wilshire and Toussaint, there was no programmed reinforcement during probes, and participants were taught to label object-action phrases in Spanish, a response class absent from participants’ general repertoire. Finally, the current evaluation extended the work of Wilshire and Toussaint in two ways. Previous research has suggested that constituent in closer proximity to the consequence may exert greater stimulus control over emergent responding (Axe & Sainato, 2010). We taught object-action labels, in contrast to action-object labels, to evaluate if either the second term or a type of constituent (action vs. animal) was more likely to control emergent responses. We also extended the previous evaluation by conducting post-hoc analyses of emergent responses.

Method

Participants, Setting, and Materials

Two female preschoolers participated. One participant, Violet, continued her participation from Wilshire and Toussaint (2015) and therefore provided intra-subject replication. The second participant from Wilshire and Toussaint moved to a different state. Thus, for the current evaluation, we recruited participants via flyers distributed to parents whose children attended the private daycare that participated in Wilshire and Toussaint. We selected a participant based upon the order that parents returned the flyer and provided written consent; there was no participation selection criteria. Violet was 3 years and 5 months and Daisy was 3 years and 10 months at the beginning of the evaluation. Violet obtained an age equivalent score
of 3 years and 11 months on the Expressive vocabulary test, Second edition (EVT-2 [Williams, 2007]) and an age equivalent score of 4 years and 8 months on the Peabody Picture Vocabulary Test, Fourth Edition (PPVT-4 [Dunn, Dunn, & Pearson, 2007]), which we conducted prior to the start of this study. Daisy obtained an age equivalent score of 5 years and 7 months on the EVT-2 and 4 years and 9 months on the PPVT-4, which we conducted prior to the start of this study.

We conducted all experimental sessions for Violet in her home at a designated play area, and for Daisy we conducted sessions in a designated area of the hallway at the daycare. We conducted sessions three to four days per week, and one to three sessions per day. Each setting contained various age-appropriate toys and materials needed to conduct the session. Target stimuli included three miniature, animal figurines, a cow (6”x 3”), cat (2.5”x 2.5”), and dog (4.3”x 3”). Materials also included pencils and paper for data collection, a token board for participants, and a video camera to record sessions for interobserver reliability and treatment integrity data collection. The experimenter collected data and sat on the floor within 3 m of the participant; the experimenter and participant sat facing each other. A second observer was occasionally present for data collection.

Response Measurement, Interobserver Agreement, and Procedural Integrity

Response measurement. During instructional baseline and training sessions, the primary dependent variable was the number of correct responses, defined as providing the predetermined vocal response within the specified time delay. Prompted responses were defined as providing the correct response following a vocal-model prompt, incorrect responses were defined as providing any word other than the predetermined response within the specified time delay, and nonresponses were defined as failing to provide a response or providing a non-word vocalization (e.g. humming) within the time delay. The number of correct responses was expressed as a
percentage by dividing the number of correct responses by the total number of trials in the session and multiplying by 100. We set mastery criterion at 89% correct across two consecutive sessions. During matrix probes, the primary dependent variable was the number of correct responses to trained and untrained target stimulus presentations.

*Interobserver agreement.* A second, independent observer collected data for at least 30% of the sessions across all experimental phases for each participant. An agreement was scored if both independent observers scored a trial the same way. Interobserver agreement (IOA) was calculated by dividing the number of agreement by the total number of agreements and disagreements and multiplying by 100. The mean agreement for sessions in the single component conditions was 99.93% (range 99% to 100%) for Violet and 100% for Daisy. The mean agreement for sessions in the matrix conditions was 100% for Violet and 100% for Daisy. The mean agreement for posttests was 100% for Violet and 100% for Daisy.

*Treatment integrity.* A second, independent observer collected treatment fidelity measures on instructor responses for at least 30% of all experimental sessions for each participant. Data were recorded on implementation of instructional steps: (a) securing child’s attention, (b) when relevant, demonstrating the target action with the target animal, (c) presenting the correct prompt at the correct delay following an incorrect response, and (d) delivering praise and a token following correct responses as applicable to the experimental condition.

Percentage of treatment integrity was calculated by dividing the number of steps implemented correctly by the total number of steps per session and multiplying by 100. The mean treatment integrity for sessions in the single component condition was 99.66% (range 98% to 100%) for Violet and 99.76% (range 97% to 100%) for Daisy. The mean treatment integrity
for sessions in the matrix condition was 100% for Violet and 99.5% (range 97% to 100%) for Daisy. The mean treatment integrity for posttests was 100% for Violet and 100% for Daisy.

Experimental Procedures

Preference assessment. Prior to each instructional session, a brief preference assessment was conducted. Participants were presented with three to five items or activities from a set of previously established or parent-reported preferred items. The items in the array varied slightly across sessions by including new items in if the participant began to request an activity in exchange for activities the participants seemed disinterested in. The item selected first from the array was provided at the end of each session during reinforcement periods. However, participants could still select a different item or activity at that point simply by indicating disinterest in the item that was offered (e.g., not engaging in the activity or telling the experimenter “I changed my mind”) and/or interest in a different item (e.g. asking to play with a different activity).

Experimental design. Similar to Wilshire and Toussaint, we conducted constituent training of animals and actions, separately, before training compound stimuli. Wilshire and Toussaint intended to initiate instruction with matrix training of unknown, compound stimuli. However, both participants demonstrated pervasive bias responding with the onset of instruction. The experimenters identified new targets and began with the training of unknown constituents. We replicated this instructional sequence.

Following constituent training, we conducted a probe with compound targets to evaluate if participants would demonstrate recombinative generalization with known constituents but without direct training of the constituent frame. If no recombinative generalization occurred, we trained compound targets using either an OV or NOV instructional design. We evaluated the
effects of training compound targets using a multiple-baseline-across-participants experimental design (Horner et al., 2005). Following compound training, we conducted post-training probes to evaluate the effects of OV and NOV instructional arrangements on emergent responding using a pretest-train-posttest sequence (Groskreutz, 2010).

*General instructional procedures.* We taught all constituent and compound targets using a progressive-time delay procedure (Charlop, Schreibman, & Thibodeau, 1985). The experimenter secured participant attending and presented the target object with the relevant instruction. During instruction for actions and object-action, the experimenter also manipulated the object to engage in the action (e.g. jumping). The experimenter immediately provided a model of the correct response (i.e. 0s delay) for the first two sessions. Subsequently, the experimenter presented the instruction and waited up to 2 s for a response. The experimenter increased the delay by 3 s if 50% or greater of incorrect responses were nonresponses rather than an anticipatory response for two consecutive sessions. The experimenter modeled the correct response contingent upon an incorrect response. All correct responses, prompted and unprompted, produced praise and one token on a fixed-ratio (FR) 1 schedule.

The experimenter implemented an error-correction procedure if correct responding reached a plateau or if biased responding emerged (e.g. providing one response irrespective of stimulus presentation). The initial error correction procedure involved re-presenting the same trial until the participant engaged in a correct unprompted response (i.e. represent until independent). If performance did not improve, we implemented an alternative error correction strategy that required the participant to repeat the correct response five times (i.e. multiple response repetition) (Carroll, Joachim, St. Peter, & Robinson, 2015). Correct unprompted responses before or after error correction produced praise and one token on a fixed-ratio (FR) 1
schedule. After 3 tokens the participants exchanged them for approximately 45 seconds of access to the highly-preferred item that was chosen at the beginning of the session. Mastery criterion was two consecutive sessions with 89% unprompted, correct responses.

*Matrix pre-training probe.* Each 27-trial probe consisted of three presentations of the nine combinations from the instructional matrix. The experimenter provided the SD, “In Spanish, what’s happening?”, waited up to 5 s for the participant to respond, and provided a general statement such as “okay” after each response; no other programmed consequences delivered. We interspersed mastered targets on an FR3 and each correct response resulted in brief access, approximately 30 seconds, to a highly preferred item identified at the beginning of the session.

*Constituent baseline.* Each constituent was presented three times per session which resulted in nine-trial sessions. For objects, the experimenter presented the target animal and delivered the SD “In Spanish, what is it?” For actions, the experimenter presented a non-target animal (i.e. a horse) demonstrating the target action and delivered the SD “In Spanish, what’s it doing?” and then demonstrate the target action. Contingencies were identical to those in the matrix instruction baseline except mastered targets were presented on an FR2 schedule.

*Constituent training.* The experimenter presented stimuli and instructions within a nine-trial session as described in constituent baseline conditions. Instruction was provided as outlined in the general procedures. In addition, we continued to conduct training sessions for the first-trained constituent (i.e. objects) two to three times per week during ongoing instruction for the second constituent (i.e. actions) to ensure performance was at mastery criterion levels for both constituents prior to matrix training.

*Matrix baseline.* Sessions were identical to matrix probes. Baseline sessions were conducted to evaluate if participants could correctly label the compound targets following
constituent training.

**Matrix training – Set A.** The experimenter presented stimuli and instructions as in matrix probe/baseline conditions. Instruction was provided as described in general procedures. Targets were arranged in either an overlap (OV) or nonoverlap (NOV) design. Instructional matrices are depicted in Figure 1. In the OV training, targets were arranged so that they shared either an animal or action. In the NOV training, targets were arranged so that no targets shared either an animal or action.

**Matrix training - Set B.** Training for Set B was similar to that described for Set A except we included an additional target which changed the number of presentations of each target within an instructional trial. We presented the fourth target three timers per session and presented each Set A target twice. Thus, sessions remained at nine trials. In addition, we presented the fourth target at a 0s time delay for the first two instructional sessions while all other previously trained targets remained at the time delay that was in place at the conclusion of Set A training.

**Matrix training – Set B – II (Daisy only).** The experimenter inserted distractor trials after each presentation of an instructional target to provide a training condition that more closely approximate the conditions during probe sessions. That is, we included the presentation of untrained stimuli. Distractor trials consisted of non-target animals (i.e. goat, seal, and duck) and engaging in a non-target action (i.e., tapping, spinning, and flying). The experimenter provided a general statement such as “okay” after each distractor trial. Otherwise, training was identical to Matrix Training – Set B conditions.

**Matrix post-training probe.** We conducted post-training probes after each training set to evaluate emergent responding following matrix instruction. Sessions were similar to matrix probes/baseline conditions except posttests were arranged for a trained relation to follow an
untrained relation to match reinforcement schedules as in pre-training probes. Correct responses to trained relations resulted in the participant gaining access to a highly preferred for approximately 30 s. Sessions consisted of 36 trials in Posttest 1 and 31 trials in Posttest 2 and 3 after the addition of the fourth training target.

*Post-hoc analysis - constituents.* At the conclusion of instruction, we reassessed responding to single constituents. We presented each target animal three times to test for responding to the object constituent. We presented each action three times by including an animal that was not included in the matrix (e.g. horse) engaging in the action. During these sessions the experimenter provided general statement such as “okay” after each trial. There were no programmed contingencies for correct responses.

*Post-hoc analysis – stimulus control.* We analyzed which stimulus control processes may have facilitated recombinative generalization for participants. Across instructional designs and stimulus sets, an emergent response may have occurred given several different processes that are explicitly arranged via matrix instruction. An emergent response may occur if: (a) both constituents of the emergent response were part of a compound with shared constituents during matrix instruction, (b) the action constituent of the emergent response was shared during instruction, (c) the object constituent of the emergent response was shared during instruction, or (d) neither constituent of the emergent response was shared during instruction, resulting in control by the constituent frame only. Stimulus control by the constituent frame was an additional process common across all four possibilities. An illustration is depicted in Figures 2. We calculated the percentage of correct responding by dividing the total number of correct responses per stimulus control process by the total number of possible emergent responses per stimulus control process and multiplying by 100%.
Results

*Matrix Training*

Prior to matrix training, we trained each participant on single constituents. Violet met mastery for objects after 28 sessions and actions after 27 sessions. Daisy met mastery for objects after 28 sessions and actions after 37 sessions.

Figure 3 depicts the results for independent correct responding of trained and untrained relations during overlap matrix training for Violet (top panel) and NOV training for Daisy. Correct responding did not occur for either participant during the initial probe of all relations or during baseline of trained targets. Violet mastered Set A targets in 12 instructional sessions. We conducted a probe of all relations following mastery performance, and she responded correctly to 72% of trained targets and 39% of untrained targets. The matrix on the left in Figure 4 displays the distribution of correct responses to trained and untrained relations during the first probe for Violet. We added a new training target to form Set B, and Violet mastered this instructional set in 26 sessions. We made two instructional modifications during training of Set B. We implanted error-correction at session 21 because of a decrease in correct responding to previously-mastered targets (noted as “a”). After a plateau in correct responding, we increased the number of trials in each session to 12 trials in order to provide additional practice opportunities with each instructional target (noted as “b”) at session 43. After Violet’s performance reached mastery criterion, we conducted a terminal probe and Violet responded correctly to 88% of trained targets and 73% of untrained targets. The matrix on the right in Figure 4 displays the distribution of correct responses to trained and untrained during the final probe.

Daisy mastered training Set A in 29 sessions, but required several instructional modifications. We implemented a represent-until-independent error-correction at session 17 as
there was a response bias toward “perro besando” when presented with the target “perro saltando”, noted as “a” in the bottom panel of Figure 3. Biased responding persisted so we increased the number of trials with “perro saltando” from three to seven presentations at session 28 (noted as “b”). Daisy continued to provide incorrect responses to “perro saltando” so we implemented a 0s time delay for trials of “perro saltando” while keeping all other targets at a 2 s time delay at session 30 (noted as “c”), and we returned all targets to a 2 s delay at session 31 (noted as “d”). The same response pattern continued so we implemented a multiple-response error-correction technique at session 33 (noted as “e”). After performance improved, we decreased the number of presentations of perro saltando to five trials at session 35 (noted as “f”) and finally returned to the original configuration of three presentations of each target at session 34 (noted as “g”). Once performance reached mastery criterion, we conducted a probe and Daisy responded correctly to 100% of trained targets and 11% of untrained targets. The matrix on the top left in Figure 5 displays the distribution of correct responses to trained and untrained relations during the first probe for Daisy.

We selected a new target (see Figure 3) that shared constituents with the original training set, thus forming Set B. Daisy’s performance met mastery criterion after six instructional sessions. In the subsequent probe, Daisy responded correctly to 94% of trained targets and 7% of untrained targets. The matrix on the top right in Figure 5 displays the distribution of correct responses to trained and untrained relations during the second probe for Daisy.

We provided instruction with distractors as outlined for Set B-II. Correct responding maintained at mastery levels (89%), and we conducted the final probe. Daisy responded correctly to 94% of trained targets and 0% of untrained targets. The matrix on the bottom in Figure 5
displays the distribution of correct responses to trained and untrained relations during the final probe for Daisy.

Post-hoc Analysis of Constituents

We evaluated Daisy’s performance to single constituents following matrix instruction. Daisy did not respond correctly to any objects as she labeled them all in English. Daisy did partially respond correctly to 78% of action trials as she provided a response that contained the correct action with an incorrect object (e.g. if the action was “caminando” the participant responded with “gato caminando”).

Post-hoc Analysis of Stimulus Control Processes

We depict the results of this analysis for the current evaluation (referred to as Experiment 2) as well as the results from Wilshire and Toussaint (referred to as Experiment 1) in Figure 6 for Violet and Figure 7 for Lily and Daisy. Across both experiments, Violet demonstrated an average of 50% of correct emergent responses when both constituents of the emergent responses were part of a compound with shared constituents during training, 80% of correct responses when the action was shared during training, 8% of correct responses when the object was shared during training, and 0% of correct responses when neither constituent was shared during training. For both participants who experienced NOV training, Lily and Daisy, emergent responses were minimal. Participants averaged 11% of correct emergent responses when both constituents of the emergent responses were part of a compound with shared constituents during training, 0% of correct responses when the action was shared during training, 0% of correct responses when the object was shared during training, and 2% of correct responses when neither constituent was shared during training.
Discussion

The current study replicated and extended the work of Wilshire and Toussaint (2015) by teaching object-action labeling with two typically-developing preschoolers utilizing an OV and a NOV design. Results from both evaluations demonstrated recombinative generalization following an OV instructional design and minimal recombinative generalization following NOV instruction. Our results support previous empirical evaluations that demonstrate the teaching conditions provided during NOV lap training may be insufficient to produce emergent responding (Foss, 1968a, 1968b; Striefel, Wetherby, and Karlan, 1976).

We identified targets that participants had minimal experience with outside of the experimental context. We subsequently taught the constituents to create “known” targets from a specific learning history. Yet, our results differ from previous applications with known targets in that our participants did not demonstrate recombinative generalization following NOV instruction. The constituent post-hoc analysis for Daisy may explain these results. Daisy was unable to correctly label the single constituents following matrix training, although constituents were taught prior to matrix training. Simply put, it seems that Daisy forgot the names of the constituents over the course of instruction. In previous applications that have identified known targets, the participants entered the evaluation with correct identification of the constituents (Goldstein, 1983; Goldstein, Angelo, and Mousetis, 1987; Goldstein and Mousetis, 1989). This suggests a relatively longer learning history as the relations were first established and then maintained over some unknown period of time until the onset of these evaluations. This may also explain why the serial introduction of novel targets into the NOV matrix of known targets resulted in decreasing levels of recombinative generalization in Goldstein (1987). If correct
responding is not well-established for constituents, it is unlikely for constituents to exert sufficient stimulus control to facilitate recombinative generalization.

Stimulus control within recombinative generalization is provided by both the constituents and the constituent frame. We conducted a post-hoc analysis of recombinative generalization to identify the relative contribution of these stimulus control components. For Daisy and Lily, recombinative generalization was too minimal to identify any stimulus control patterns. For Violet who experienced OV instruction, recombinative generalization was most likely to occur when either both constituents of the emergent compound response were part of a compound with shared constituents during instruction or if the action constituent was shared. Surprisingly, emergent responses did not occur more often when both constituents were shared in comparison to the action alone. This pattern was demonstrated when the constituent order was either action-object (Experiment 1) or object-action (Experiment 2). Together, these results suggests that the action constituents exerted the greatest degree of stimulus control. Future research is needed to explore which type of stimuli are more likely to exert control over emergent responding during instructional tasks.

For Lilly and Daisy who first experienced NOV instruction, we included a fourth target that provided overlap instruction with two of the previously acquired targets. We provided this instruction to facilitate discrimination of the constituents and frame as is provided with OV instruction. However, recombinative generalization was not demonstrated during posttests of Set B. It is possible that participants learned the targets from Set A as one unit, rather than a unit comprised of two subunits. Unless initial responding is under control of individual constituents and the frame, adding in an additional target that shares constituents and frame would be irrelevant because the new target would, in essence, not functionally share a constituent or frame.
but only topographically. Therefore, adding in the additional target (i.e. cow walking) that shared features with previously trained targets (i.e. cat walking and cow kissing) likely did not result in discrimination of constituents. Again, Daisy’s incorrect responding to single constituents following matrix instruction further suggests that NOV training does not facilitate discriminated responding to constituents. However, our results are limited in that the constituent post-instruction evaluation was only conducted for one participant. Future research may consider conducting a similar analysis after matrix instruction for participants who experience both OV and NOV instruction.

Axe and Sainato (2010) state, “The largest benefit of matrix training is its efficiency, which comes primarily from training on only the diagonal of the matrix.” (p. 648) However, this definition of efficiency only considers the output, recombinative generalization, and it overlooks the input or the initial requirements. For NOV training to produce recombinative generalization, an individual has to enter the instruction with either the constituent elements or the rule. Our results further refine the requirements of “known” constituents; the response must be well-established to a degree that correct responding to constituents will maintain throughout NOV instruction. There is a greater number of possible emergent responses given a greater number of constituents that an individual already has in their repertoire. Thus, there must be some consideration as to the “costs” of this efficiency. On the other hand, OV matrix training is possible with unknown constituents as it not only produces emergent compound responses, but it also allows the learner to derive both constituent and the constituent frame. In other words, the components that an individual must have to benefit from NOV training, are also provided as an outcome in OV training.
The results from this study, combined with previous literature, suggest that when a learner has one of the two requirements for recombinative generalization (i.e., knows constituents or the rule) then NOV may be effective. If the learner has both requirements, matrix instruction is not even necessary, as teaching a single compound target is sufficient to produce recombinative generalization (Goldstein et al. 1987). However, if both requirements are missing, then we recommend training with an OV design.
**Figure 1.** An illustration of the instructional matrix. OV matrix set A is represented by cells marked with “a”; OV matrix set B is represented by both ‘a’ and ‘b’ cells; NOV matrix set A is represented by cells marked with “c”; NOV matrix set B is represented by both “c” and “d” cells. Blank cells represent untrained targets.

<table>
<thead>
<tr>
<th></th>
<th>Cat</th>
<th>Dog</th>
<th>Cow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>a, c</td>
<td>a</td>
<td>d</td>
</tr>
<tr>
<td>Jumping</td>
<td>a</td>
<td>c</td>
<td></td>
</tr>
<tr>
<td>Kissing</td>
<td></td>
<td>b</td>
<td>c</td>
</tr>
</tbody>
</table>

**Figure 2.** An illustration of different stimulus control processes given in OV matrix set A (left) and in NOV matrix set A (right). The shaded cells depict OV and NOV instruction. Each cell denotes a potential stimulus control process by constituents. Cells marked “a” depict when both constituents of the emergent response were shared constituents during matrix instruction, “b” is when the action constituent of the emergent response was shared during instruction, “c” is when the object constituent of the emergent response was shared during instruction, and “d” is when neither constituent of the emergent response was shared during instruction.

<table>
<thead>
<tr>
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<th>Cat</th>
<th>Dog</th>
<th>Cow</th>
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</thead>
<tbody>
<tr>
<td>Walking</td>
<td></td>
<td>b</td>
<td></td>
</tr>
<tr>
<td>Jumping</td>
<td>a</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td>Kissing</td>
<td>c</td>
<td>c</td>
<td>d</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Cat</th>
<th>Dog</th>
<th>Cow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td></td>
<td>d</td>
<td>d</td>
</tr>
<tr>
<td>Jumping</td>
<td>d</td>
<td></td>
<td>d</td>
</tr>
<tr>
<td>Kissing</td>
<td>d</td>
<td>d</td>
<td></td>
</tr>
</tbody>
</table>
Figure 3. Percentage of correct responses during probes and instruction for Violet (top panel) and Daisy (bottom panel). Letters beside data points are references to instructional modifications.
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
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<td>5/6</td>
<td>2/3</td>
</tr>
<tr>
<td></td>
<td><strong>Set A</strong></td>
<td><strong>Set A</strong></td>
<td></td>
</tr>
<tr>
<td>Jumping</td>
<td>4/6</td>
<td>2/3</td>
<td>3/3</td>
</tr>
<tr>
<td></td>
<td><strong>Set A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kissing</td>
<td>0/3</td>
<td>0/3</td>
<td>0/3</td>
</tr>
</tbody>
</table>

**Walking**

**Set A/B**

**Jumping**

**Set A/B**

**Kissing**

**Set B**

*Figure 4.* The top number represents correct responding to trained (bold) and untrained targets and the bottom number represents total presentations in Posttest 1 (left) and Posttest 2 (right) for Violet.

<table>
<thead>
<tr>
<th></th>
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<th>Cow</th>
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</thead>
<tbody>
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<td>0/3</td>
<td>0/3</td>
</tr>
<tr>
<td></td>
<td><strong>Set A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jumping</td>
<td>0/3</td>
<td><strong>6/6</strong></td>
<td>0/3</td>
</tr>
<tr>
<td></td>
<td><strong>Set A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kissing</td>
<td>0/3</td>
<td>2/3</td>
<td><strong>6/6</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Set A</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Cat</th>
<th>Dog</th>
<th>Cow</th>
</tr>
</thead>
<tbody>
<tr>
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<td><strong>4/4</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Set A/B</strong></td>
<td></td>
<td><strong>Set B</strong></td>
</tr>
<tr>
<td>Jumping</td>
<td>0/3</td>
<td><strong>4/4</strong></td>
<td>0/3</td>
</tr>
<tr>
<td></td>
<td><strong>Set A/B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kissing</td>
<td>1/3</td>
<td>0/3</td>
<td><strong>3/4</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Set A/B</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 5.* The top number represents correct responding to trained (bold) and the untrained targets and the bottom number represents total presentations in Posttest 1 (top left), Posttest 2 (top right) and Posttest 3 (bottom).
Figure 6. Percentage of correct responses to different stimulus control processes during probes for Violet in Experiment 1 (left) and Experiment 2 (right). Bars denote a potential stimulus control process of emergent responding by constituents arranged. Bars filled in black depict when both constituents of the emergent response were part of a compound with shared constituents during matrix instruction, bars filled with diagonal lines is when the action constituent of the emergent response was shared during instruction, bars filled in with waves is when the object constituent of the emergent response was shared during instruction, and bars filled in gray depict when neither constituent of the emergent response was shared during instruction.
Figure 7. Percentage of correct responses to different stimulus control processes during probes for Lily in Experiment 1 (left) and Daisy in Experiment 2 (right). Bars denote a potential stimulus control process of emergent responding by constituents arranged. Bars filled in black depict when both constituents of the emergent response were part of a compound with shared constituents during matrix instruction, bars filled with diagonal lines is when the action constituent of the emergent response was shared during instruction, bars filled in with waves is when the object constituent of the emergent response was shared during instruction, and bars filled in gray depict when neither constituent of the emergent response was shared during instruction.
REFERENCES


