Behavior Analysis in Practice

Matrix Training for Expanding the Communication of Toddlers and Preschoolers with Autism Spectrum Disorder

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RUNNING HEAD: Matrix training with toddlers

Matrix Training for Expanding the Communication of Toddlers and Preschoolers with Autism Spectrum Disorder

Abstract

Children diagnosed with Autism Spectrum Disorder (ASD) typically exhibit a range of social communication deficits. Pre-sequenced stimulus arrangements, such as matrix training, can be used to facilitate generative responding. Accordingly, training procedures can lead to acquisition of a greater number of targets that are not taught explicitly, with fewer learning trials. Matrix training provides a useful framework for selecting teaching targets to promote the emergence of untaught skills. Participants were three young boys diagnosed with ASD, who were taught noun-verb combinations of play actions as tact and listener responses. All participants learned the taught noun-verb targets and showed varying degrees of recombinative generalization to untaught targets. Across subsequent matrices, the rate of acquisition of new targets and the number acquired without direct teaching increased (i.e., recombinative generalization). This suggests matrix training stimulus arrangement can facilitate acquisition of novel targets by teaching young children with ASD to recombine language components appropriately.

Keywords: tacting, listener responding, verbal behavior, matrix training, recombinative generalization, language, autism

- Matrix training, a form of generative instruction, refers to the arrangement and selection of teaching targets so that few targets are directly taught and novel combinations can be assessed for generalization.
- The use of matrix training promotes recombinative generalization in individuals with ASD and intellectual disabilities.
- Matrix training can be useful in generating flexible use of language (e.g., novel noun-verb combinations) in young children with ASD.
- Future work evaluating whether recombinative generalization across operants occurs under matrix training arrangements is warranted.

Matrix Training for Expanding the Communication of Toddlers and Preschoolers with Autism Spectrum Disorder

Communication deficits are common in children diagnosed with Autism Spectrum Disorder (ASD) and can often take the form of limited spoken language, including vocabulary or short utterances (i.e., single words; APA, 2013). Behavioral interventions aimed at improving communication deficits often emphasize on the use of discrete trial teaching (DTT) in which a discriminative stimulus (e.g., presentation of toy plane) precedes the correct response (e.g., spoken word "plane") and is promptly followed by the delivery of a reinforcer (e.g., social praise, preferred tangible or edible). Such an approach is widely used in intensive early behavioral intervention (EIBI) and has been shown to be effective in teaching children with ASD (Lovaas, 1987). This approach, however, has been criticized for producing "rote learning." That is, individuals tend to emit the same communicative response (e.g., tacting "plane") in the presence of the discriminative stimulus (e.g., toy plane), despite the presence of other relevant antecedent stimuli such as the therapist making flying actions with the plane and providing the instruction to say what the item is *doing* (i.e., asked to tact noun-verb combinations).

Rote responding can be particularly problematic when teaching functional language to children with ASD, who are inclined to engage in repetitive patterns of behavior and may have difficulty generalizing learned skills to novel situations (APA, 2013; Stokes & Baer, 1977). The functional use of language requires individuals to employ learned words and sentence structures in novel and flexible ways. The use of generative instruction has been touted as an alternative teaching strategy, aimed at generating maximum novel repertoire after teaching minimum number of skills (Alessi, 1987; Goldstein, 1983).

Using generative instruction for communication skills, such as matrix training, instructors teach a subset of skills and new skills emerge without direct teaching (Rehfeldt & Barnes-Holmes, 2009; Sidman, 1994), resulting in efficient acquisition of functional language in children with communication delays. Matrix training refers to a recombinative generalization framework for selecting teaching targets in which components are arranged along horizontal and vertical axes such that their intersection creates novel combinations within the matrix. For instance, nouns and verbs can be arranged along the vertical and horizontal axes, respectively. The cells within the matrix result in noun-verb combinations. Within this framework, a subset of targets is explicitly taught. Recombinative generalization occurs when learners are able to emit untaught targets by combining elements of taught targets (Goldstein & Mousetis, 1989). For instance, if the learner were explicitly taught “dog walking” and “cat sitting,” recombinative generalization would be demonstrated with the learner independently emitting “dog sitting.”

Matrix training has been used to teach a range of skills to children with ASD, such as spelling (Kinney, Vedora, & Stromer, 2003), writing and receptive identification of letters and numbers (Axe & Sainato, 2010), play skills (Dauphin, Kinney, & Stromer, 2004; Jung & Sainato, 2013; Wilson, Wine, & Fitterer, 2017), and tacting emotions (Conallen & Reed, 2016). This approach also has been effective in teaching tacting and listener skills to children with intellectual disabilities (e.g., Goldstein, Angelo, & Mousetis, 1987); however, few studies have examined the usefulness of matrix training for expanding the communication repertoire of children with ASD (e.g., Axe & Sainato, 2010; Curiel, Sainato, & Goldstein, 2016; Frampton, Wymer, Hansen, & Shillingsburg, 2016).

Curiel et al. (2016) taught action-object listener responses using a matrix-training framework to a 31-month-old boy with ASD. After training, the participant was taught to emit response such as “give me dog” or “clean up cat,” and novel targets within the matrix were probed for generalization. Of the 16 untrained targets, this participant demonstrated recombinative generalization for 11 targets, suggesting matrix training can be beneficial to expand the listener repertoire of young children with ASD. This study, however, included one participant and thus far is the only study to our knowledge to employ matrix training with young children with ASD.

Expanding vocabulary, lengthening sentence structure, and improving listener repertoires in children with ASD can be a time-consuming endeavor when conducted in the typical format of teaching each target in isolation. In addition to inefficiency, teaching each target in isolation does not address the skill of using functional language flexibly by recombining words to form novel sentence structures. Thus, finding efficient methods to teach and expand language in this population has important implications for treatment design and time required to achieve treatment goals. The purpose of this study was to determine whether matrix training would be an effective method for selecting targets to expand the tacting and listener repertoires in young children diagnosed with ASD.

Method

Setting and Participants

The present study took place at a university-based autism treatment center. All sessions took place during each participant's early intervention sessions, which were conducted five days per week in a classroom with several workstations. Therapists working with clients conducted matrix-training sessions within the regular instructional programming of each participant. For Hank and Bud, matrix-training sessions occurred on a floor mat, where naturalistic interventions were conducted. For Iggy, matrix-training sessions were conducted at a table. Materials present included clipboard and data sheet for data collection, clickers, timers, toys, edible items, human and animal figurines, and vehicles.

Participants were three boys diagnosed with ASD using the toddler module of the Autism Diagnostic Observation Schedule 2nd Edition, 25 (Hank), 28 (Iggy), and 34 (Bud) months old and had received at least four months of early intensive behavioral intervention at our center at the time of this study. All were considered early learners, with some level 2 skills of the Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP; Sundberg, 2008; see Table 1 for details), strong echoic repertoires, and previous experience with conditional discrimination training.

Procedure

All teaching sessions were conducted within the participant's early intensive behavioral intervention sessions. During this time, participants interacted one-on-one with their therapist either at a desk or on a carpet. Participants received praise and access to a preferred item for correct responses. Preferred items were either a small edible (e.g., goldfish cracker) or 30-sec access to a tangible item (e.g., iPad), and identified via a multiple-stimulus without replacement preference assessment procedure (MSWO; DeLeon & Iwata, 1996) conducted at the beginning of each daily session.

During teaching sessions, participants were exposed to a series of conditions in which they either performed an action with 3D research materials (e.g., when researcher said, "Show me 'baby walking,'" the participant moved the baby doll along table top) or labeled actions performed by the researcher (e.g., when researcher asked, "What is it doing?" the participant said "baby walking"). Hereafter, these behaviors will be referred to as listener responding and tacting, respectively.

A six-by-six matrix, with nouns along the rows and verbs along the columns, was created to identify teaching and generalization targets. Within each matrix, nouns and verbs can be combined into 36 noun-verb targets. Nouns selected for inclusion in the study were mastered as tacts, determined via review of clinical records or probes during which participants were asked, "Who [what] is it?" All verbs were novel targets, determined via probes during which researchers performed actions and asked, "What am I [is it] doing?" Figure 1 shows matrices 1 and 2 used for Hank, 3 and 4 used for Iggy, and 5 and 6 used for Bud. Noun-verb combinations along the diagonal of the matrix served as initial teaching targets (shaded cells), while other targets were used to assess whether participants generalized learning to novel noun-verb combinations (white cells). For all participants, the two matrices were evaluated sequentially. Matrices were divided into two submatrices (A and B), which allowed for evaluation of generative instruction within and across target sets (figurines and vehicles).

Baseline. All six targets along the diagonal of the matrix were probed as listener responding and tacting to establish baseline levels. Each of the noun-verb combinations along the diagonal was tested three to five times in randomized order. During this phase, there were no programmed consequences for correct or incorrect responses. Targets scoring above 60% correct during this phase were not included. In such cases, new targets were added to the teaching matrix.

For tacting responses, all stimuli were placed in front of the participant. The researcher would select an object (e.g., baby doll) and perform an action (e.g., walking), while asking, “What is it doing?” If the participant vocally emitted the correct noun-verb combination within 5 s, this was scored as correct. Incorrect responses consisted of only the correct noun, only the correct verb, incorrect noun and verb, or no vocal response. For listener responses, all stimuli were placed in front of the participant and the researcher would say, “Show me [noun-verb]” (e.g., baby walking). Correct responses consisted of the participant correctly selecting the correct object (e.g., baby) from an array of three to six items and performing the correct action (e.g., walking) within 5 s of instruction delivery.

Training. The three targets along the diagonal of submatrix A were trained initially (see Figure 1). No other targets were trained or probed during this condition. Trial blocks, referred to as sessions hereafter, consisted of five trials per target, which were interspersed with other skill acquisition programs in the participant's regular early intervention session. Training sessions were conducted similarly as in the baseline condition with the addition of prompts, error correction, and reinforcement. Throughout training, vocal prompts were used for tacting. The vocal prompt consisted of providing an echoic model of the correct tacting response, such as "baby walking." For listener response targets, gestural (Hank, Iggy) or model (Bud) prompts were used. The gestural prompt consisted of pointing towards the correct item in the array, whereas the model prompt consisted of the researcher demonstrating the action with the correct object. For some targets (e.g., bear waving), Bud required physical prompts in which the researcher physically guided his hands to perform the action with the appropriate object. Prompts were faded using a progressive time delay, starting with 0 sec and progressively increasing up to 5 s (MacDuff, Krantz, & McClannahan, 2001). Correct responses were immediately followed by praise and the delivery of a preferred edible or tangible item, as identified from the pre-session MSWO. Targets were considered to reach mastery after at least 80% independent correct responses per session for two consecutive sessions.

Generalization probes. Once participants reached mastery of the trained targets, the rest of the targets within the submatrix were probed for generalization (i.e., white cells in matrices displayed in Figure 1). For submatrix A, six novel targets were probed during this condition. For submatrix B, 24 novel targets were probed.

If the correct noun-verb recombinative response was below 60% independent correct responding for novel targets, those targets were trained as described above.

After the initial three diagonal targets were mastered and generalization probes were conducted for submatrix A, the same process of training the three targets on the diagonal of submatrix B and probing for generalization was conducted. Thus, training was conducted using a multiple probe design across target sets or submatrices.

Inter-observer agreement

An independent observer either attended sessions and collected data simultaneously with the researcher or scored trials from a video recording of sessions. Trial-by-trial inter-observer agreement (IOA) was calculated by dividing the number of trials of agreement by the total number of trials and multiplying this number by 100 to obtain a percentage score. Inter-observer agreement data are not available for Hank, but the protocol was implemented in the same manner as for Iggy and Bud. For Iggy, IOA data for matrix 3 are unavailable due to experimenter error, but for matrix 4 these data were collected for 93% of trials, with trial-by-trial IOA resulting in 96.25%. For Bud, IOA data were collected for 14% of trials in matrix 5, and 58% of trials in matrix 6. Mean IOA for matrix 5 was 100%, and mean IOA for matrix 6 was 99.8%.

Results

Table 2 shows the average sessions to mastery of initial training targets (i.e., diagonal of matrix), average sessions to mastery of generalization targets that required training, and percent of generalization targets that met mastery criteria without direct training for all participants. Overall, the average trials to mastery of diagonal targets decreased and the percent number of targets that showed recombinative generalization without explicit teaching increased from submatrices A to B.

Percent correct responding across sessions for tacting (top panels) and listener responding (bottom panels) for Hank, Iggy, and Bud is shown in Figures 2, 3, and 4, respectively. For all figures, separate panels show data for each submatrix. During baseline, Hank had low levels (0%) of correct responding for tacting targets and moderate levels (40-60%) of correct responding for listener responding targets for all submatrices (see Figure 2). The first three training targets were mastered within 7-12 sessions for submatrices 1A and 2A as both tacting and listener response. After reaching the mastery criteria for the initial training targets, generalization probes were conducted and any untaught target with independent correct responses below 60% were taught. For submatrix 1A, only two of six tacting targets and one of six listener response targets required additional training. These targets reached mastery in fewer trials than the initial training targets. The same was true for submatrix 2A, with only one of six tacting targets requiring additional training to reach mastery. Listener response data for matrix 2 are not displayed because Hank demonstrated performance of 80-100% during initial training trials and selected targets could no longer be used as listener response targets.

Upon completion of submatrices 1A and 2A, training of submatrices 1B and 2B began. For submatrix 1B, tacting targets along the diagonal did not require teaching, as they all scored at 60% correct or above when probed. Similarly, four of

24 generalization tacting targets required teaching to reach mastery. The same was not true for tacting targets in submatrix 2B, with diagonal targets scoring 50% correct and requiring teaching, followed by four generalization targets requiring teaching to reach mastery criteria. For submatrix 1B listener response, Hank did not require teaching of targets along the diagonal, as he scored above 60% upon re-probing. Responding for the majority of generalization targets showed recombinative generalization, with only three targets requiring teaching to reach mastery level.

For Iggy, correct responding for tacting and listener responding targets was low (0%) during baseline for all submatrices, except for listener responding targets in submatrices 3A and 3B (20-35%; see Figure 3). The initial training targets of submatrices 3A and 4A were mastered within 4-11 sessions. When testing for recombinative generalization in submatrices 3A and 4A, three of six tacting targets and four (in 3A) or five (in 4A) of six listener response targets required additional training. When diagonal targets in submatrix 3B were retested, all tacting targets required teaching to meet mastery criteria, whereas the listener responding targets were at mastery level. Next, probes for recombinative generalization revealed a majority of novel targets scored at mastery levels, with only two tacting and three listener responding targets requiring additional training. In submatrix 4B, diagonal targets met mastery criteria within 5-7 sessions for both tacting and listener responding. Of the untaught targets, only 2 tacting and 4 listener response targets required explicit training to reach mastery, which was accomplished within 4-7 sessions.

During baseline, Bud demonstrated low levels (0%) of correct responding for tacting and listener responding targets during baseline for all submatrices, except for listener responding targets in submatrices 6A and 6B (55%; see Figure 4). The initial training targets of submatrix 5A for tacting and listener responding were mastered within 6-10 sessions. When testing for recombinative generalization in submatrix 5A, all targets required additional training. Upon re-testing diagonal targets in submatrix 5B, all tacting targets required teaching to meet mastery criteria. Subsequently, probes for recombinative generalization revealed a majority of novel targets scored at mastery levels, with only two requiring additional training. For listener response, all diagonal targets in submatrix 5B met mastery criteria upon re-testing and only one generalization target required explicit teaching to reach mastery levels. In submatrix 6A, diagonal targets met mastery criteria within 3-5 sessions for both tacting and listener responding, and all untaught targets met mastery criteria without explicit training. Further, all tacting or listener responding targets in submatrix 6B met mastery criteria upon re-testing after completing teaching diagonal targets in submatrix 6A.

Discussion

Matrix training has been proposed as a teaching method to promote recombinative generalization in children with ASD. Recently, the use of matrix training for the selections and arrangement of target stimuli has been shown to be effective for expanding the communication repertoire of children with ASD (e.g., Axe & Sainato, 2010; Curiel et al., 2016; Frampton et al., 2016). The present study sought to expand this literature by evaluating whether matrix training was an effective method for selecting targets to expand the noun-verb tacting and listener repertoires in children diagnosed with ASD. Particularly, the aim was to evaluate whether matrix training would promote recombinative generalization in children with ASD under the age of three. In all three participants, recombinative generalization of tacting and listener responding skills was observed when participants performed novel untaught noun-verb targets. Thus, gains in both tacting and listener responding skills were broader than the targets selected for direct teaching. The findings of the present study extend the literature on recombinative generalization and suggest directions for future research.

For all participants, the percent number of targets that showed recombinative generalization without explicit teaching increased from submatrix A to B, suggesting matrix training can be a useful instructional strategy for expanding communication repertoires of very young children with ASD. This finding is particularly relevant for two reasons. Firstly, when programming language acquisition targets for young children with ASD, it may be beneficial to provide a history of contacting reinforcement for spontaneously recombining words. For children with ASD, rigid and scripted language is a common problem (APA, 2013) that could be inadvertently reinforced by providing highly structured language programming in which each target is taught separately. Instead, clinicians can promote flexible language structures (e.g., variable noun-verb combinations, variable use of manding frames) by arranging teaching targets in a matrix format. Secondly, it is likely that not all young children with ASD will demonstrate recombinative generalization to the same extent as participants of the present study. Thus, the extent to which individuals can recombine language components in novel, untaught configurations may be indicative of the degree of behavioral rigidity and restrictive stimulus control of each individual and can be used to guide treatment (e.g., need to teach behavioral variability).

For Hank and Bud, acquisition of targets was faster for the matrix taught second (2 and 6, respectively). Although we argue this was due to the previous history with matrix training, it is possible some targets were acquired more readily than others due to preference for the toys used for teaching in addition to the previous history of matrix training. For instance, acquisition of diagonal targets and recombinative generalization for matrices 2 (Hank) and 6 (Bud) may have been impacted by the nature of the toys (i.e., vehicles). Both Hank and Bud spontaneously interacted with vehicles during play; as a result, it is possible they received additional exposure to tacts of actions associated with these items (e.g., rolling, crashing) relative to actions associated with figurines (e.g., waving, dancing). Thus, the targets selected for the second matrices may have contributed to the faster acquisition and greater recombinative generalization observed. Despite this possibility, the recombinative generalization to untaught targets for all participants across matrices suggests this arrangement of teaching targets promoted the emergence of novel responses.

Data were collected for Hank and Bud on spontaneous noun-verb tacting occurring outside the experimental session (i.e., during early intervention session). Figure 5 shows cumulative spontaneous noun-verb tacting of novel and recombinative targets. Novel targets refer to noun-verb combinations that did not contain components included in the study (e.g., Mickey climbing), whereas recombinative targets refer to noun-verb combinations that contain one element (noun or verb) included in the study (e.g., Mickey sitting). Hank and Bud spontaneously emitted between 30-60 noun-verb tacts outside the experimental sessions over the course of the observation period. The gradual increase in spontaneous noun-verb tacts in the natural environment suggests teaching tacts in a manner that promotes recombinative generalization (i.e., matrix training) functioned to teach a complex language skill. Some have suggested this form of recombination may be a type of higher order operant or behavioral cusp (Frampton et al., 2016).

According to Rosales-Ruiz and Baer (1997), a behavioral cusp exposes individuals to novel responses or forms of stimulus control for existing responses, thereby allowing the individual to contact new contingencies in their environment. For instance, a child may be taught to imitate motor actions such as clapping hands and stomping feet upon hearing "do this." Once this child can spontaneously imitate novel motor actions without explicit verbal instructions to imitate, it is said she has a generalized imitative repertoire, which is considered a behavioral cusp. Similarly, the spontaneous recombination of language components may be considered a behavioral cusp because it allows individuals to expand their expressive and receptive language without explicit teaching of all language components, consistent with how children without language delays acquire language.

In the present study, all participants demonstrated recombinative generalization within the nouns and verbs included in the matrices. Further, clinical data for Hank and Bud spontaneously emitting novel noun-verb combinations support the notion of matrix training promoting spontaneous recombination of language components as tact and listener response. Results from the present study suggest matrix training led to the achievement of a behavioral cusp for all participants. It is unclear, however, the extent to which this higher order operant impacts performance on other tasks. Anecdotal observations during the conduct of this study suggested participants might generalize skills acquired as verbal operants to other operant classes. Future studies should further evaluate whether the recombination generalizes across operant classes (e.g., tacting to listener response, tacting to play actions). The use of matrix training in clinical practice can lead to the rapid expansion of language through recombinative generalization. In turn, this can produce flexible language structures that do not require explicit training. In order to maximize clients' time in early intensive behavioral intervention, emphasis should be placed on interventions that develop behavioral cusps and lead to large-scale change in behavior.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Table 1. Verbal behavior milestones assessment and placement program (VB-MAPP) results and participant's time receiving early intervention services.

		VB-MAPP Results		
Participant	Time in EI (in months)	Milestones score	Tact domain score	Listener domain score
Hank	5	78.5	7	8
Iggy	4	57.5	6	7
Bud	7	74.5	6.5	8

Table 2. Individual participants' average sessions to mastery for taught targets (diagonal) and targets taught after failing to generalize for each submatrix.

Participant		Submatrix	Average trial blocks to mastery *diagonal* ●	Average trial blocks to mastery *generalization* △	Percent novel targets generalized
Hank	Tacting	1A	11.7	4.5	66%
		1B	0.0	6.0	83%
		2A	9.0	5.0	83%
		2B	7.0	8.0	83%
	Listener	1A	8.3	4.0	83%
		1B	0.0	6.0	88%
		2A	-	-	-
		2B	-	-	-
Iggy	Tacting	3A	10.0	9.0	50%
		3B	11.0	11.0	92%
		4A	4.7	6.3	50%
		4B	6.0	5.5	92%
	Listener	3A	9.0	8.0	83%
		3B	0.0	8.7	88%
		4A	4.0	6.5	66%
		4B	6.0	5.7	83%
Bud	Tacting	5A	4.7	8.5	0%
		5B	4.0	0.0	83%
		6A	3.0	0.0	100%
		6B	0.0	0.0	100%
	Listener	5A	4.3	5.0	0%
		5B	0.0	0.0	88%
		6A	3.0	0.0	100%
		6B	0.0	0.0	100%

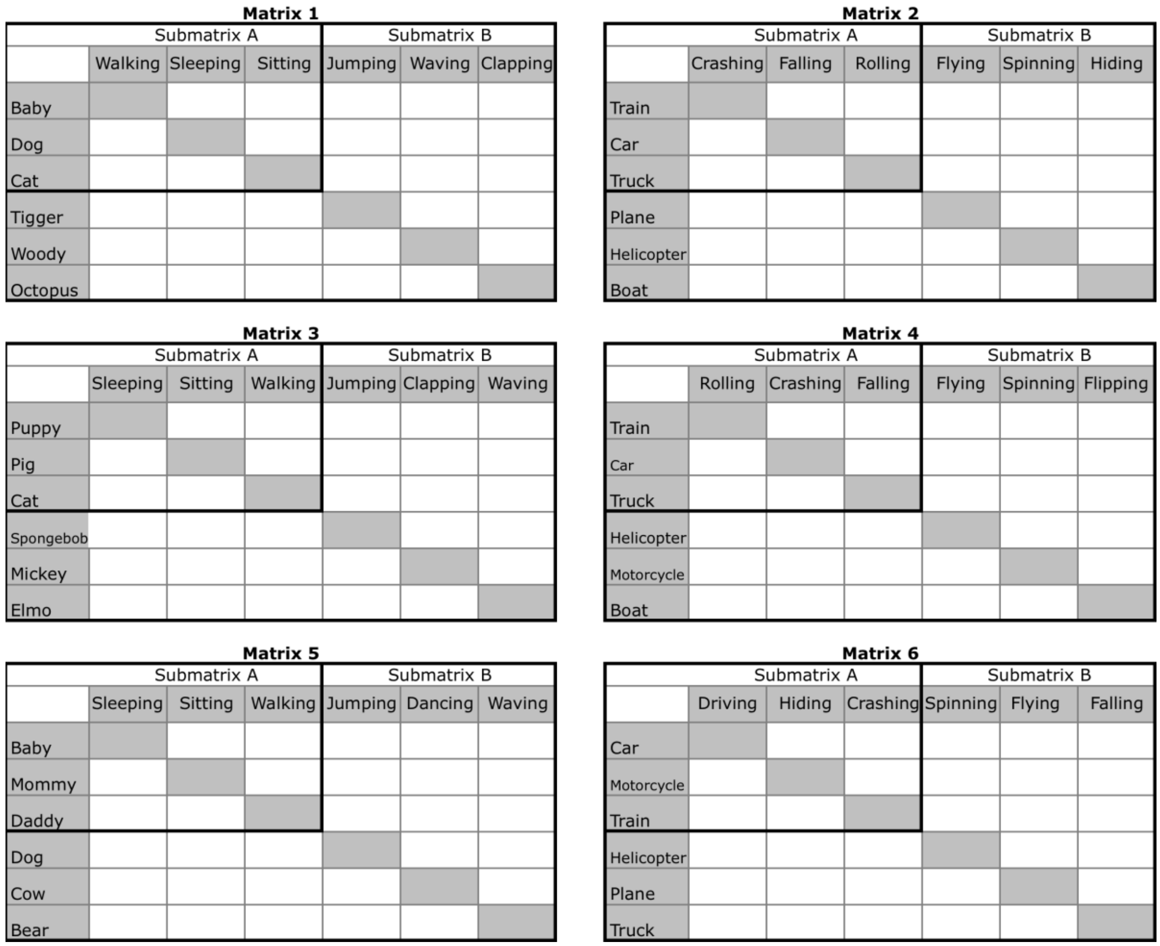

Figure 1. Noun-verb matrices for Hank (1 and 2), Iggy (3 and 4), and Bud (5 and 6). Nouns are located along vertical and verbs along horizontal lines. All cells inside matrices form unique noun-verb combinations. Shaded diagonal cells and white cells comprised instructional and generalization targets, respectively.

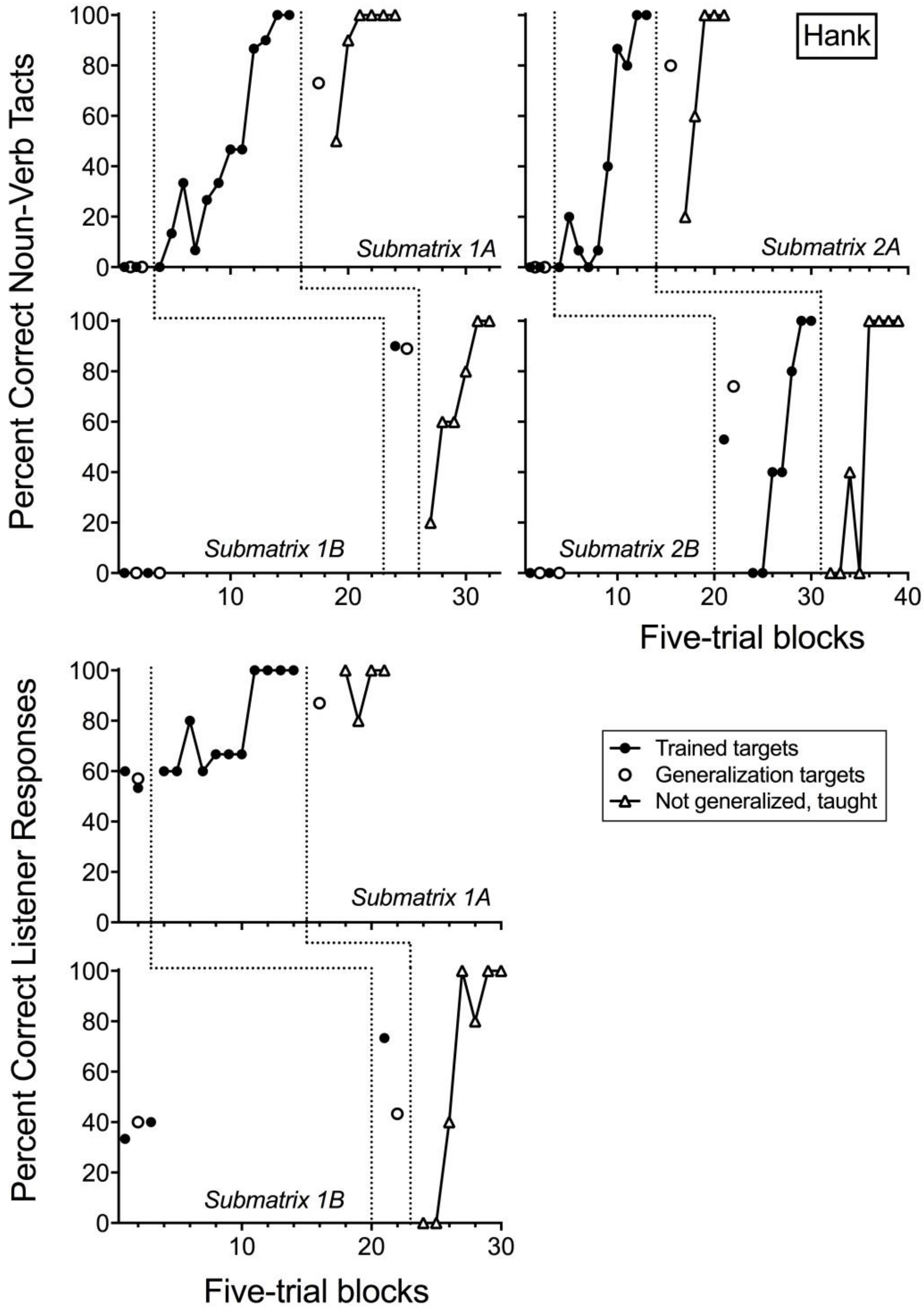

Figure 2. Percent correct noun-verb tacts (top) and noun-verb listener responses (bottom) across experimental sessions for Hank. Each data point depicts average percent correct for all noun-verb combinations across five-trial blocks. Black data points reflect the three trained targets, whereas white data points reflect generalization targets. White triangle data points depict acquisition of

generalization targets that did not meet mastery criteria in recombinative generalization probe.

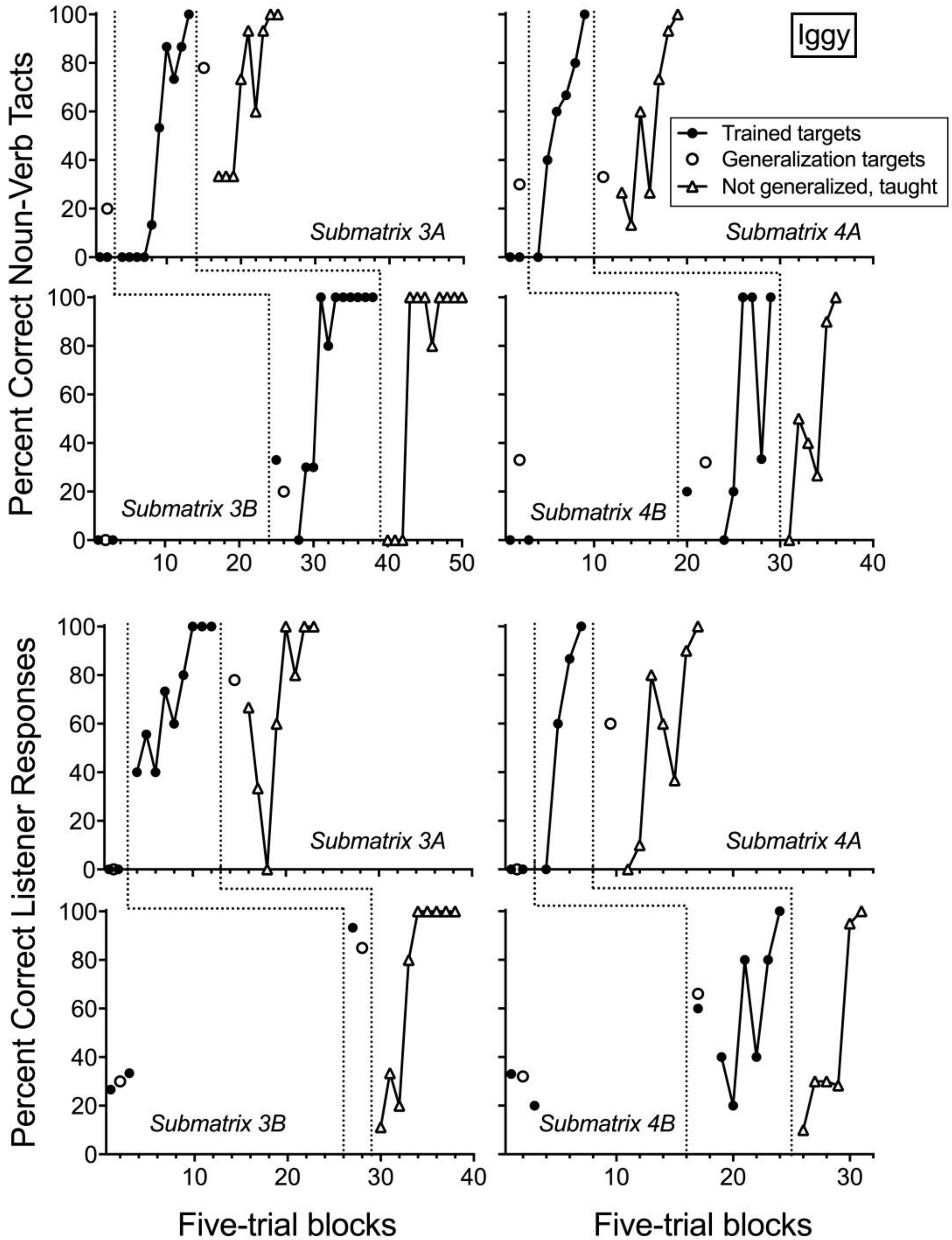

Figure 3. Percent correct noun-verb tacts (top) and noun-verb listener responses (bottom) across experimental sessions for Iggy. Each data point depicts average percent correct for all noun-verb combinations across five-trial blocks. Black data points reflect the three trained targets, whereas white data points reflect

generalization targets. White triangle data points depict acquisition of generalization targets that did not meet mastery criteria in recombinative generalization probe.

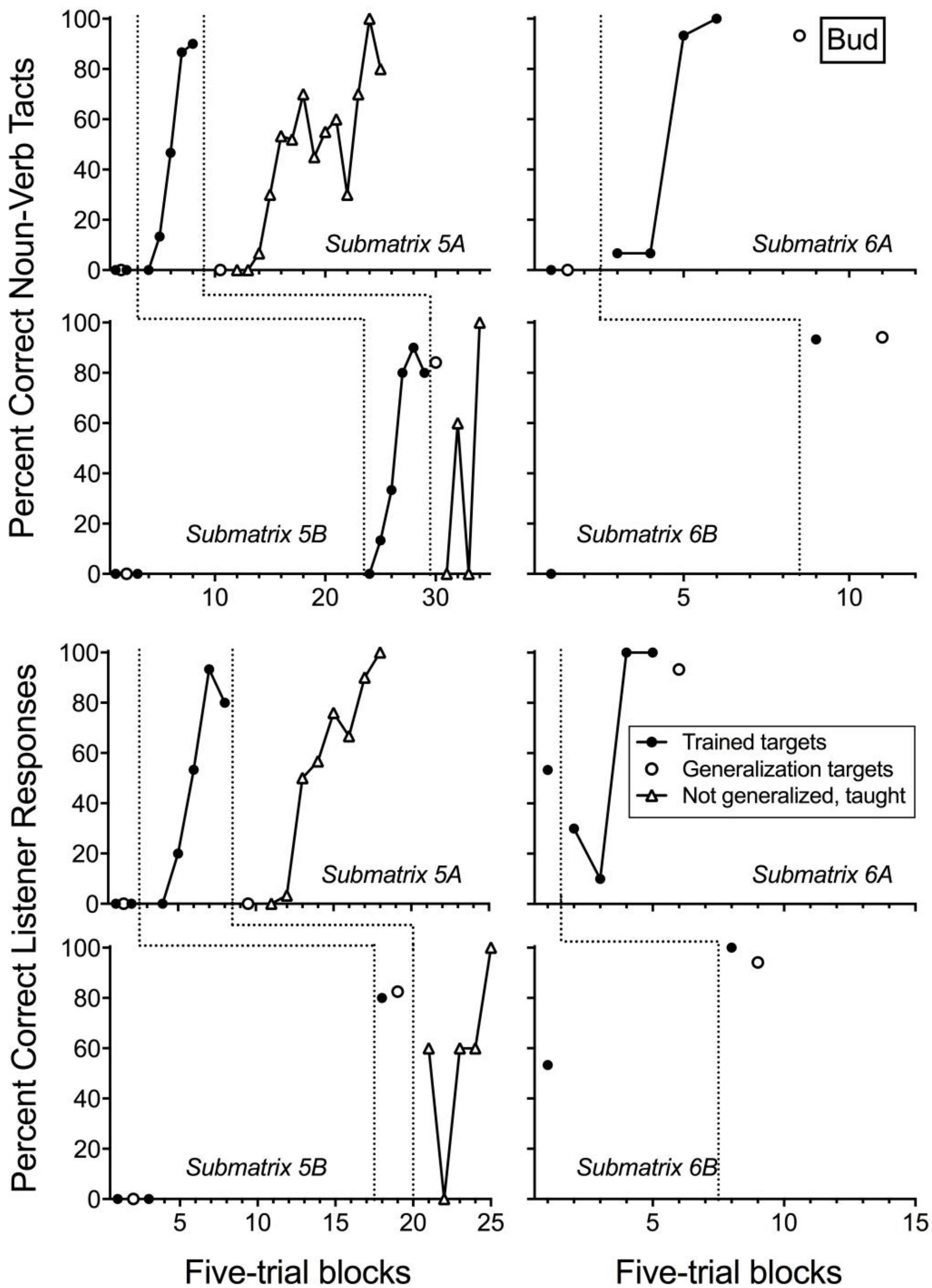

Figure 4. Percent correct noun-verb tacts (top) and noun-verb listener responses (bottom) across experimental sessions for Bud. Each data point depicts average percent correct for all noun-verb combinations across five-trial blocks. Black data

points reflect the three trained targets, whereas white data points reflect generalization targets. White triangle data points depict acquisition of generalization targets that did not meet mastery criteria in recombinative generalization probe.

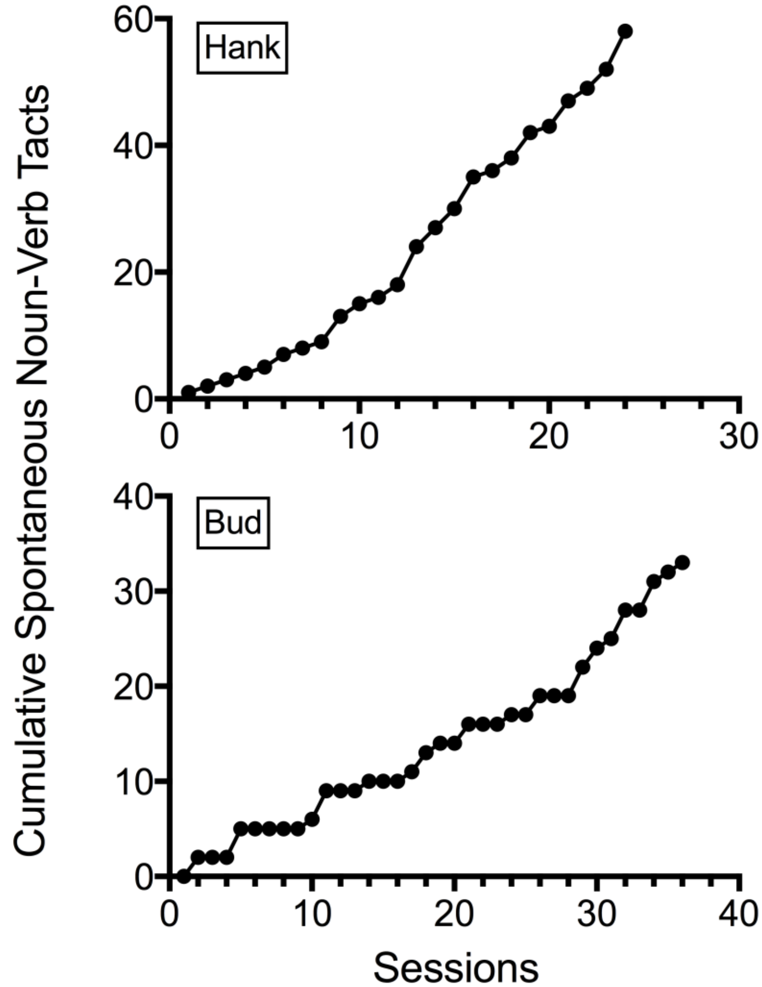

Figure 5. Cumulative recombinative noun-verb tacts occurring spontaneously in the natural environment across sessions for Hank (top) and Bud (bottom).

Matrix Training for Expanding the Communication of Toddlers and Preschoolers with Autism Spectrum Disorder

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Authors declare they have no conflict of interest.