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

Jacy Durdel
jacy.durdel@siu.edu

Maggie Ratcliff
Southern Illinois University Carbondale, Maggie.ratcliff@siu.edu

Matrix Training for Expanding the Communication of Toddlers and Preschoolers with Autism Spectrum Disorder. A Replication Study

Jacy Durdel

School of Psychological and Behavioral Sciences

Southern Illinois University, Carbondale

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Dr. Alan Franklin

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Abstract

Children diagnosed with autism spectrum disorder (ASD) commonly display a range of deficits from communication skills to play skills. When the ability to generalize is improved, a greater number of stimuli can be learned without having to be directly taught, which can be done through matrix training. Matrix training provides a framework for actively teaching a singular exemplar of a target, and, through recombination, many more stimuli can be learned. Participant is a 4-year-old boy diagnosed with ASD who was taught noun-verb combinations through tactile movement of figurines. All targets are tested before and after the single stimulus of each is trained, and with the improvement in correct responses on untrained targets, a degree of recombinative generalization was shown. This suggests matrix training stimulus arrangements can facilitate the acquisition of novel targets by teaching young children with ASD to recombine language components appropriately.

Keywords: Manding, Listener responding, Verbal behavior, Matrix training, Recombinative generalization, Language, Autism Spectrum Disorder

The Diagnostic and Statistical Manual of Mental Disorders (DSM-5) include a wide-range on childhood originating neurodevelopmental disorders, one of which being autism spectrum disorder. Autism Spectrum Disorder covers a wide range of conditions related to behavior differences that create unique challenges for children. Autism spectrum disorder is also commonly associated with repetitive disorders and decreased social skills, but these behavior discrepancies are far from untreatable. With 1 in every 36 children in the United States diagnosed with autism, many behavior therapy approaches have been used to improve their ability to learn and thrive (Autism Speaks 2023). Through alternative learning techniques, people diagnosed with autism spectrum disorder can accelerate their learning to promote a higher quality of functioning. Many different tactics have been used to try to reduce learning disabilities and other obstacles that autism spectrum disorder may present. While learning persists through life, early stages of development are imperative for children to hit targets set for their age. Falling behind in these targets may obstruct abilities in many contexts, impacting academic, occupational, or social growth and well-being.

Generalization and communication impairments are common in children diagnosed with autism spectrum disorder (ASD), causing persistent difficulties in social interaction (Gonzalez-Sala et al., 2021). Communication impairments can delay children in social aspects and is a core characteristic of autism spectrum disorder. These communication deficits can impair understanding between adults and the child which could inhibit their ability to express their needs. Behavioral interventions have shown to be beneficial in improving these communication barriers. When used with children, the approach is considered early intensive behavioral intervention (EIBI) which has demonstrated effectiveness in children with ASD (autism spectrum disorder) (Lovaas, 1987). Language intervention is used to improve a child's language development and assist in enhancing everyday communication. Language interventions have also been related to academic and social success for children with ASD (Gillam, et al. 2023). A practice done in language intervention to enhance generalization among children is referred to as matrix training. Matrix training is the direct teaching of a subset of 2-component combinations that represent multiple configurations of them. Following trained combinations, untrained combinations are then tested to demonstrate the generalization of single variables of the combinations across other materials (Pauwels, et al. 2015). For example, the name of a specific shape may be trained showing the shape to be red, then the same shape in blue will be tested to see if the participant can generalize over the two colors. With successful matrix training interventions, a child's ability to generalize may increase their understanding of the world and enhance their communication levels socially.

Using a subset of trained targets, matrix training introduces a larger realm of new skills without direct teaching of them (Rehfeldt & Barnes-Holmes, 2009; Sidman, 1994). Many objects in everyday life are not taught to us but learned through interaction with their everyday world through communication skills. If communication skills are impaired, such as through ASD< these skills are not as easily grasped. Play skills are imperative for children to develop social skills, and the development of play skills increased positive social interactions and decreased inappropriate behavior (Sainato, 2013). With successful recombinative generalization through matrix training, skills can be taught at an accelerated rate and increase a child's understanding of their world.

Improving communication, positive social interactions, and decreasing inappropriate behavior have all been key goals in children diagnosed with ASD. Teaching these in individual subsets can be time consuming and trying on clients and clinicians. The ability to generalize across items can speed up the learning process for almost all materials, which is especially useful with other learning deficits. If a child is taught how to zip up their jacket and they generalize that skill to zipping up their backpack, pencil case, and pants, then there are three other life skills that do not have to be individually taught. Using methods that promote efficiency in learning functional language while addressing other treatment goals may be hard to establish. By finding alternative forms to speed up learning efficiency, children with ASD will be less likely to fall behind in academics or social skills.

Behavioral interventions were conducted with three young boys diagnosed with Autism Spectrum Disorder in an article published by Jimenez-Gomes and colleagues (2019). A matrix of intermixed nouns and verbs was used to measure recombinative generalization. Responses to targets were trained for each participant and tested in each therapy training session-where each of the trained targets were tested five times. A full test of the matrix was taken before training started to gauge how much the participants already knew before they were taught. These are referred to as baseline sessions, and each of the participants scored 0% for each session in baseline. The four diagonal targets on the matrix were trained with immediate correction through training sessions. Training sessions were conducted like baseline with all targets presented, but only the 4 trained targets were corrected. Test sessions were conducted after to see if the participant could recombine the targets they were trained to the remainder of the untrained targets. For each participant, recombinative generalization revealed the majority of targets at mastery level. Four of six targets for one participant, and all targets for two participants required remedial training, but all participants reached mastery of 80% correct responses of the matrix.

The same study probed noun-verb targets with a 3-D material performing the labeled action. Researchers asked the participant to “Show me” the target behavior (ex. Baby walking), in which they would form the material to mimic the description (e.g., moving the baby's legs to show steps). The participants were also asked to label actions in which the researcher would mimic a noun-verb target and the participant would respond with the correct target (e.g., baby walking) (Jimenez-Gomez, Corina, et al. 2019). Based off this study, I plan to replicate their matrix with the manipulation of figurines as targets. While their study involved participants altering the figurines, I will alter my study to the researcher manipulating the figurines to decrease the grey area found when the participant struggles to manipulate the action-but has successfully learned the target. The purpose of this replication study validates the findings of this original study on 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.

Methods

Participant and Setting

The participant is a 3 year, 7-month-old male who began receiving BAT and Speech and Language services through the Center for Autism Spectrum Disorders (CASD) at Southern Illinois University Carbondale in September of 2022. Participant is verbal and has shown significant improvement on responding to clinicians. More work is needed on responding to complex questions with multiple parts.

All sessions will take place at the Center for Autism Spectrum Disorder at Southern Illinois University-Carbondale. Sessions will be conducted twice a week for 10-15 minutes following their regularly scheduled session. Matrix training will be conducted sitting in a chair in the client's individual therapy room and attending to materials. Materials include a clipboard, data sheets for data collection, a timer, a preferred toy/item as a reinforcer and figurines/plush animals.

Measurements

The primary dependent measure is the percentage of independent correct responses recorded across all matrices. Data will be collected using data sheets created at CASD. An independent correct untrained response was recorded when participant correctly identifies and emits response within 5s of it being presented. Correct responses will be recorded with a plus, while incorrect responses, will be recorded as a minus. A correct response is the full noun and verb, such as “Mickey waving”. An incorrect response, is only the noun, only the verb, or any other response such as “waving, bouncing, saying hi, etc.” If participant is not attending to researcher and task being modeled (is looking elsewhere), a vocal prompt will be given and the task will be modeled once more, this will be continued until correct or incorrect response is emitted. Each response will be marked as correct or incorrect. Responses will be averaged at the end of the session to determine the percentage or correct or incorrect responses per trial block. The total number of correct responses will be calculated by diving the number of correct trials in agreement by the total number or trail and multiplying the number by 100 to obtain the percentage of correct responses. If 80% of correct responses were recorded on untrained targets, mastery and recombinative generalization is considered achieved.

Procedural Fidelity

Baseline

1. Participant will transition from ABA therapy and have free time for 2 minutes.	
2. Participant will be prompted to transition to therapy room.	
3. If participant brings a reinforcing toy, allow him to play with it for 1-2 minutes and say, "let's put our toy HERE (anywhere out of his reach) and it can watch us do ACTIVITY". Give him 5-10 seconds to comply before helping him using least to most prompting.	
4. Researcher will present each target from the matrix in a randomized order through drawing cards with labeled noun-verb combinations on them and a verbal prompt, "What's going on?" or "What's happening?"	
5. Participant is given 5 seconds to respond to the questioned stimuli after it is presented.	
6. No feedback will be given on the response except recurring praise for working and sitting	
7. Repeat until full submatrix has been probed	
8. Once all targets are probed, reinforce with preferred item and free play time.	

Intervention

1. Participant will transition from ABA therapy and have free time for 2 minutes	
2. Participant will be prompted to transition to therapy room.	
3. If participant brings a reinforcing toy, allow him to play with it for 1-2 minutes and say, "let's put our toy HERE (anywhere out of his reach) and it can watch us do ACTIVITY". Give him 5-10 seconds to comply before helping him using least to most prompting.	
4. Researcher will present each target from the matrix in a randomized order through drawing cards with labeled noun-verb combinations on them and a verbal prompt, "What's going on?" or "What's happening?"	
5. Participant is prompted to respond to the questioned stimuli within 5 seconds of it being presented.	
6. If the target is correct verbal praise will occur. If the response is incorrect, immediate vocal correction will be given. If there is no response within 5 seconds of the SD, vocal prompt will be given, and question will be repeated.	
7. Repeat until each trained target is presented 3 times.	
8. Once all targets are presented, reinforce with preferred item and free play time.	

Procedural fidelity will be taken by an assistant researcher during sessions. Assistant researcher will have the full procedural fidelity checklist in front of them and score each step as it is done during the session. If the researcher completes the step as described on the procedural fidelity checklist, the assistant researcher will mark with a "+". If they do steps out of order or do not follow the steps as described the assistant research will mark a "- "for the designated step. Procedural fidelity will be taken for at least 33% of sessions. The total procedural fidelity will be calculated for each session by dividing the number of pluses by the full number of steps and multiplying by 100 to obtain a percentage. The percentage of all procedural integrity checklists will be taken and averaged to show the full experiments procedural fidelity.

Procedure

Sessions will be conducted after behavioral therapy sessions at the CASD (Center for Autism Spectrum Disorders) on campus. Participants will be working one-on-one with the researcher and assistant researcher present. Participants will receive positive verbal reinforcement for correct responses on targets, with no responses on untrained targets taken during baseline or test sessions. During sessions, participants will be shown the object modeling the behavior of four different animals (nouns) exemplifying four different actions (ex: waving, walking).

A four-by-four matrix with nouns along x axis (columns) and verbs along the y axis (rows). Within the full matrix, there will be 16 targets. A diagonal line from the top left to the bottom right of the matrix will show the targets marked as teaching targets, one teaching target will be presented for each noun and each verb, but not each noun-verb combination.

	Submatrix A		**Submatrix B**	
	MICKEY	MINNIE	DAISY	GOOFY
WALKING	**Mickey Walking**	Minnie Walking	Daisy Walking	Goofy Walking
WAVING	Mickey Waving	**Minnie Waving**	Daisy Waving	Goofy Waving
JUMPING	Mickey Jumping	Minnie Jumping	**Daisy Jumping**	Goofy Jumping
CLAPPING	Mickey Clapping	Minnie Clapping	Daisy Clapping	**Goofy Clapping**

Baseline

All 16 targets will be tested twice each during the first three sessions to establish baseline levels. Each noun-verb combination will be tested two times in a randomized order, which will represent one 32 trial block. One trial block will be tested each session. Noun-verb combination will be printed onto cards which will be mixed up and chosen in a random order. There will be no programmed responses for correct or incorrect responses. Continuous verbal reinforcement will be given for attending, sitting, and working. Targets scoring above 66% (2/3) answered correctly during baseline will be removed and replaced with a different target in the teaching matrix.

All stimuli will be modeled in front of the participant. Participant must be attending by not playing with another item and maintaining eye contact with the object being modeled. If he is not attending, a verbal prompt will be given to redirect attention back to SD being modeled (ex.

"Look here"). Each target with one noun-verb combination will be selected at random by card with SD being chosen. If the participant correctly identifies the noun and the verb being modeled, the stimuli will be marked as correct on the data collection sheet. If only the noun or verb is used the probe will be marked as incorrect. If their vocal response to the noun or verb or both are incorrect, the stimuli will be considered incorrect. Open-ended questions will be prompted to the client such as "What is happening?" and "What's going on?" The client may respond verbally or physically to the question in which the target will be marked accordingly.

Training

The two trained targets in Matrix A along the matrix diagonal will be trained intermixed with submatrix B's baseline. Submatrix B will remain in baseline during Submatrix A training sessions. Diagonal targets will be trained 4 times each for increased learning exposure, intermixed with baseline targets (diagonal and non-diagonal) being tested twice. This will create a 32-trial block for intervention of Submatrix A and baseline of Submatrix B. Once submatrix A is mastered during a test session, the two diagonal targets in submatrix B will be trained. The researcher will provide the SD: ("what's happening?"), wait 5 seconds for a response, then provide consequence or prompt based on response. Training sessions will include prompt, error correction, and reinforcement of the trained targets (diagonal on the matrix). Once the action is modeled, and the SD is provided, if the participant answers incorrectly, immediate error correction will occur where the correct answer is given and participant echo's the corrected response. A simple distractor will be given (ex. Touch your nose, clap your hands) then the SD will be presented again. If the response is correct, verbal praise will be given and the next target will be presented. If response is incorrect, the incorrect protocol would occur again until response is correct. If the participant has no response, vocal prompt will be given and target will be prompted again, if no response continues then the response will be marked as no response, and the next target will be presented. If the participant answers correctly, verbal praise will be given immediately following the correct response (e.g., Yes good job that is mickey walking).

Training blocks will occur twice a week until mastery to measure improvements on recombinative generalization of the matrix. The clinician's vocal response following the participants incorrect response will provide an echoic model of the correct trained target response, such as "It's Mickey waving." Full completion of the trained targets (each submatrix=2 trained targets four times each) will be followed by preferred item and a break. When participants meet 75% (6/8) correct responses to trained targets for two consecutive training sessions, then a generalization probe will be conducted on untrained targets, as a test session. When test session of matrix A responds with 80% or above correct responses, the submatrix will be considered mastered, and intervention of submatrix B will begin.

Once two training sessions meet mastery, a testing session will occur where there will be no feedback for correct or incorrect responses of non-diagonal targets (as completed in baseline sessions). As submatrix B remains in baseline through submatrix A training, no feedback will be given for submatrix B responses until it is in intervention/training sessions. Full completion of a baseline and test trial block will be followed by preferred item and a break.

Trial blocks refer to each time all trained targets in the matrix are trained four times creating a 32-trail block with the 2 trained targets in Submatrix A trained 4 times each (8), and 12 targets that remained in baseline on submatrix B prompted twice each (24). Each correctly answered trained probe will initiate positive verbal reinforcement and the completion of a full 32-trial block will earn the preferred item and a break for free-play time.

Generalized Probes

Once the participant completes mastery of the trained targets (diagonal cells), the full matrix will be probed for recombinative generalization. Mastering the full matrix indicates learning nouns and verbs in one specific configuration, noun and verbs can be generalized to other novel configurations. For Submatrix A (2x2), two novel targets (untrained targets) will be probed, with two trained targets. In Submatrix B (4x4), ten novel targets will be probed, and four trained targets-with inclusion of targets from submatrix A. Following the mastery of diagonal trained targets and untrained targets are probed, the same training process will be conducted for the following submatrix. If the untrained targets responses are 80% or above, recombinative generalization will be considered successful.

Submatrix B will include some stimuli from submatrix A, as submatrix B is extended to 4 nouns and 4 verbs and overlaps with the 2 nouns and 2 verbs already taught. Once three trial blocks of baseline on Matrix A are complete, submatrix A will start intervention while Submatrix B will continue in baseline, creating a multiple baseline design. Once Matrix A training is mastered, intervention on submatrix B will begin. Submatrix A will be mastered before starting the intervention of Submatrix B. When in baseline for submatrix A, all 16 targets will be probed 3 times creating a 48-trial block. When submatrix A moved into intervention, two targets on matrix A will be trained and all of submatrix B will be probed as it remains in baseline, creating a 46-trial block. Once submatrix A is mastered and submatrix B moves into intervention, only the 4 trained target will be prompted creating a 2-trial block. During test sessions, all targets will be probed on the matrix to measure recombinative generalization progress.

Experimental Design

Replicated study is hypothesized to show similar results of the original study by seeing an improvement before and after training of nondiagonal targets showing achieved recombinative generalization. Control will be obtained through baseline data to see the level of knowledge already known to accurately measure growth of generalization. Selection of participant was based off convenience sampling from children already enrolled in behavior therapy at CASD. Data will be collected by ear, then marked accordingly on data sheets created at CASD. Researcher and volunteer will be sitting at the table with the participant to ensure responses are heard clearly. Statistics will be taken through adding up correct responses and graphs will be formed through an excel spreadsheet and updated after each session.

Interobserver Agreement

An independent observer will either attend sessions with the researcher and simultaneously collect data or collect data from video recording after sessions. Inter observer agreement will be calculated for every session. For observers to be in agreement, the individual target must have the same recorded response for both observers. Disagreement would result in observers having opposing results for a single stimulus, recording one as correct and one as incorrect. Trial-by-trial interobserver agreement (IOA) will be calculated by diving the number of trials in agreement by the total number or trail and multiplying the number by 100 to obtain the percentage on agreement.

Matrix A **Matrix B**

Nouns

Verbs

Mickey Walking	Minnie Walking	Daisy Walking	Goofy Walking
Mickey Waving	**Minnie Waving**	Daisy Waving	Goofy Waving
Mickey Jumping	Minnie Jumping	**Daisy Jumping**	Goofy Jumping
Mickey Clapping	Minnie Clapping	Daisy Clapping	**Goofy Clapping**

Nouns: Mickey, Minnie, Daisy, Goofy

Verbs: Walking, Waving, Jumping, Clapping

Matrix A

Mickey Walking	Minnie Walking
Mickey Waving	**Minnie Waving**

Matrix B

Mickey Walking	Minnie Walking	Daisy Walking	Goofy Walking
Mickey Waving	Minnie Waving	Daisy Waving	Goofy Waving
Mickey Jumping	Minnie Jumping	Daisy Jumping	Goofy Jumping
Mickey Clapping	Minnie Clapping	Daisy Clapping	Goofy Clapping

Results

Overall, the average sessions to achieve mastery decreased with indirect training of untrained targets. Percentages of correct responses grew consistently throughout the 11 sessions. During Matrix A baseline, nondiagonal target correct responses were low (0%) and diagonal targets correct responses started with little recognition (25%). These both fell back to 0% in the last two sessions of baseline, before they rose again following training. After one session of training diagonal targets, the following score immediately increased (75%). After the first four sessions on submatrix A training, the criteria of 3 consecutive sessions of 75% or higher was met, probing a test session. The test session implemented the nondiagonal targets after not probing them throughout training. Non diagonal targets were tested in session 8, which met criteria of over 80%, indicating successful recombinative generalization (87.5%). Following the test session for submatrix A, non-diagonal targets raised to 100% and stabilized there for all proceeding sessions.

Discussion

Matrix Training effectiveness in expanding the communication and play skills of toddlers with ASD has been previously supported (Gonzalez-Sala et al., 2021). The present study sought to provide additional support for the use of matrix training to support children's communication, play, and social skills and its effectiveness in expanding their vocabulary without direct teaching. This present study was a replication of Gonzalez-Sala et al., 2021 study. The idea of the replication study proposed that children with ASD can recombine novel tacts to create new familiar stimuli and expand their language repertoire. The participants in this study showed successful recombinative generalization with a steady increase in correct responses from baseline. Based on the findings of this study, recommendations for future research and expansion of literature on recombinative generalization were identified. Future research should be done to expand research on matrix training. With the average matrix training study including 1-3 participants, research must be expanded to promote the methods ability to generalize across all children with autism.

During Matrix A baseline collection, diagonal targets started with one correct response (25%), then fell to 0% for the remaining baseline sessions. After the remaining 2 sessions stabilized to 0%, it was concluded the single correct response target in the first baseline session of Matrix A was likely a coincidence. Following the first training session (4) there was a spike in correct responses which then stabilized. Given the single training sessions increased correct diagonal responses from 0% to 75%, it was inferred there could have been a miscommunication regarding the correct answer. While the first matrix only presented two nouns and two verbs, these may have not been novel tacts, but created incorrect responses due to lack of understanding.

As Matrix A started training, Matrix B continued in baseline and stabilized at 0%. In session 4, nondiagonal targets raised to 5%, indicating a single correct response. Following this session, correct responses in submatrix B unsteadily increased, with a drop during session 7 then a consistent increase in diagonal targets when training started in session 8. Like submatrix A, after one training session in submatrix B, correct responses increased consistently and probed a test session by session 11. Session 11 reported 100% correct responses, which indicated recombinative generalization for both submatrices. With the full matrix accomplishing correct responses in the last session, this indicated that 12 novel targets were indirectly taught through recombining of the four initial trained targets.

While the replicated study was conducted on a different time schedule, a large limitation was lack of time and breaks of the school year. As sessions were being conducted at Southern Illinois University Carbondale, time was limited by the days that the university was open and needed to be confined to a single school year. If future studies were to include three separate matrices or multiple participants, the study could increase in credibility. With potential participants being those already enrolled in the Center for Autism Spectrum Disorders, the participant chosen did not have generalization as a target goal, which meant sessions had to be conducted outside of their already scheduled behavior interventions. With these taking place on Monday and Wednesdays, there was a slight decrease in correct responses following the weekend. Wednesday session responses consistently increased with less time passing since the previous training session.

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Appendix

Clinician: Date:

Co-Clinician: IOA:

Baseline: Correct: +

Intervention: Incorrect: -

Test:

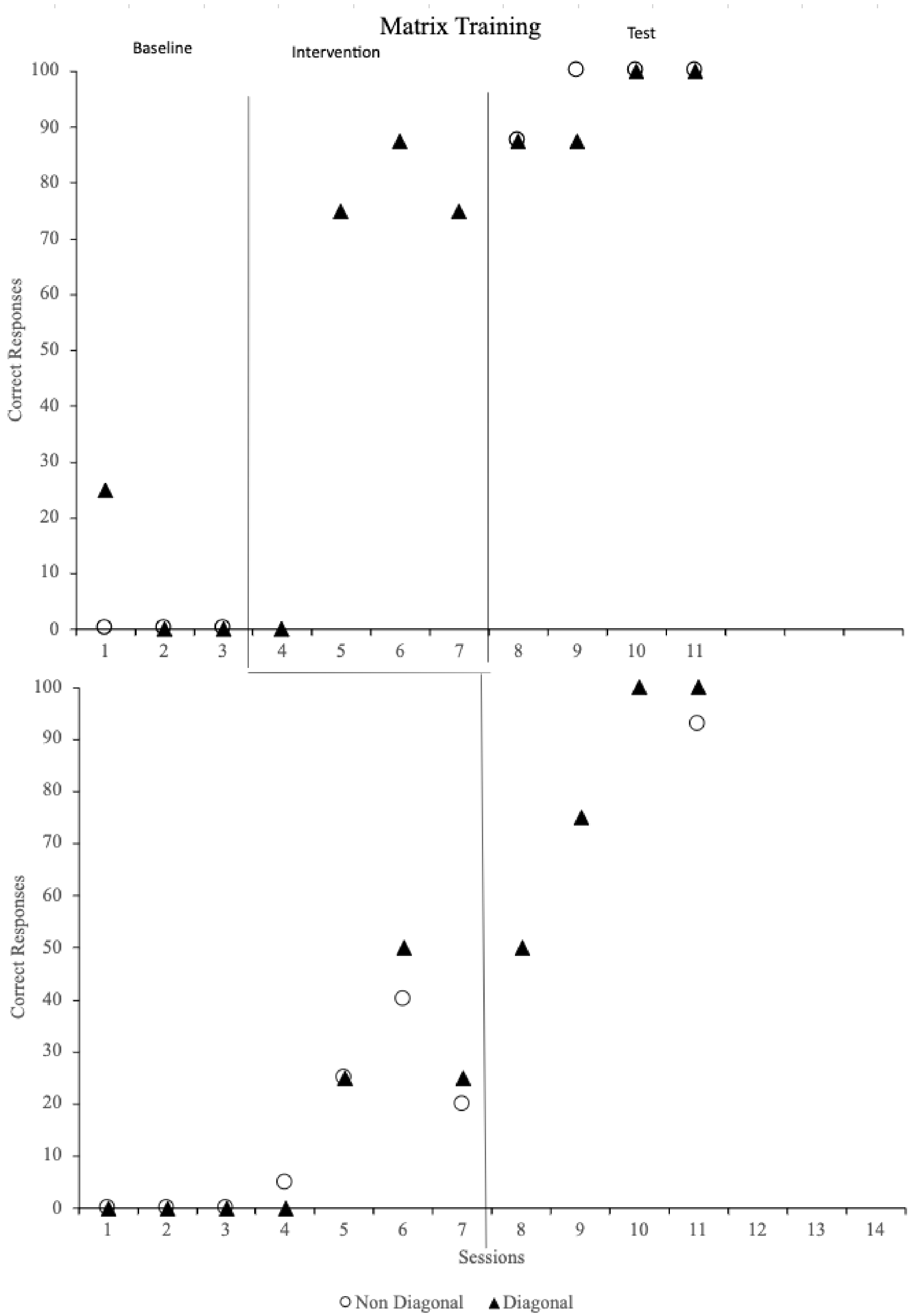
	Mickey	Minnie	Daisy	Goofy
Walking				
Waving				
Jumping				
Clapping				
	Mickey	Minnie	Daisy	Goofy
Walking				
Waving				
Jumping				
Clapping				

Correct: +

Incorrect: -

Vocal Prompt: VP

Both noun and verb must be correct, singular correct is marked as incorrect.


Matrix Training
Baseline
Intervention
Test
Correct Responses
Correct Responses
Sessions
Non Diagonal
Diagonal