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Thematic Matching as Remedial Teaching for Symbolic Matching for Individuals with Autism Spectrum Disorder

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Abstract

Matching-to-sample (MTS) is often used to teach symbolic relationships between spoken or printed words and their referents to children with intellectual and developmental disabilities. However, many children have difficulty learning symbolic matching, even though they may demonstrate generalized identity matching. The current study investigated whether training on symbolic MTS tasks in which the stimuli are physically dissimilar but members of familiar categories (i.e., thematic matching) can remediate an individual's difficulty learning symbolic MTS tasks involving non-representative stimuli. Three adolescent males diagnosed with autism spectrum disorder were first trained on symbolic MTS tasks with unfamiliar, non-representative form stimuli. Thematic matching was introduced after the participants failed to learn 0, 2 or 4 symbolic MTS tasks and before additional symbolic MTS tasks were introduced. After exposure to thematic matching, accuracy on symbolic MTS tasks with novel stimuli increased to above chance for all participants. For two participants, high accuracy (> 90%) was achieved on a majority of these sessions. Thus, thematic matching may be an effective intervention for students with limited verbal repertoires and who have difficulty learning symbolic MTS tasks. Possible explanations for the facilitative effect of thematic matching are considered and warrant further investigation.

Keywords

matching-to-sample; symbolic behavior; thematic matching; children with ASD

1. Introduction

Many children diagnosed with an intellectual and/or developmental disability have limited language and communication skills. Although the severity of these deficits varies across individuals diagnosed with autism spectrum disorder (ASD), it has been estimated that 25–50% never develop functional speech (Klinger, Dawson, & Renner, 2003). To promote

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functional communication, children with ASD or other developmental or intellectual disabilities are often taught to use a selection-based communication system (e.g., the Picture Exchange Communication System [PECS], Bondy & Frost, 1994, communication boards/devices, speech-generating devices, etc.). Selection-based systems consist of one or more arrays of potentially meaningful symbols (e.g., photographs, drawings, clip art, line drawings, etc.). After learning the meanings of the symbols, the child may communicate by responding to them with a simple motor response (such as exchanging pictures in PECS or touching with a finger in other systems). These systems offer several advantages, such as (1) giving the child a way to express needs and wants (and often reducing disruptive behavior); (2) establishing a context for social interactions; and (3) providing a structured teaching situation. These systems have been largely successful in increasing children's functional communication skills, particularly when the targeted behavior was requesting (Boesch, Wendt, Subramanian, & Hsu, 2013; Lancioni et al., 2007). However, some children with developmental or intellectual disabilities have difficulty with discrimination among multiple symbols, and these difficulties have been noted in training with various communication systems (e.g., Boesch et al., 2013; Cummings, Carr, & LeBlanc, 2012).

The aim of teaching someone to use selection-based communication systems is to establish symbolic relations between various icons, pictures or photos and the related real-world objects, activities, or people they represent. While there are a variety of teaching procedures to establish such relations, the matching-to-sample (MTS) task is among the most common for teaching children with intellectual and developmental disabilities. In one variation of the MTS task, each teaching trial begins with the presentation of a sample stimulus, which is followed by the simultaneous presentation of two or more comparison stimuli. Reinforcing consequences follow touching the comparison that is defined as correct (i.e., that "goes with" the sample), but do not follow touching any of the other comparisons. For experimental control in research settings, the stimuli used in MTS tasks are often non-representative (i.e., have no real-world counterparts) and the relations among them are arbitrarily assigned by the experimenter. In identity MTS tasks, the sample and the correct comparison are identical; in symbolic MTS tasks, the two stimuli are physically dissimilar and related according only to social conventions (e.g., the sample may be the written word "pizza," the correct comparison may be a drawing of a pizza and the incorrect comparisons may be drawings of a glass of milk and a cookie).

Many individuals, including typically-developing children and those with developmental or intellectual disabilities, fail to achieve high accuracies on symbolic MTS when training involves only the differential reinforcement procedures (aka *trial-and-error training*) just described (e.g., Eikeseth & Smith, 1992; Pilgrim, Jackson, & Galizio, 2000). A variety of effective supplementary teaching procedures has emerged, and they usually fall into either of two categories: stimulus manipulations and contingency manipulations (see McIlvane, Kledaras, Callahan, & Dube, 2002 for a similar taxonomy). Stimulus manipulations involve systematic modifications to the samples, comparisons, and/or stimulus displays. At least four different stimulus manipulations have been described: (1) stimulus fading (e.g., Dube, McIlvane, Maguire, Mackay, & Stoddard, 1989; Rosenberger, Stoddard & Sidman, 1972); (2) stimulus shaping (e.g., Zygmunt, Lazar, Dube, & McIlvane, 1992); (3) positional prompting (e.g., Smith, Mruzek, Wheat, & Hughes, 2006); and (4) delayed prompting (e.g., Clark & Green, 2004). For all of these procedures, the initial discriminations are either easily mastered or have been mastered prior to current training, and there is gradual progression toward the final discrimination: The degree of prompting decreases after correct responses but increases (i.e., backs up) after incorrect ones. The success of the procedure requires a transfer of stimulus control from the stimulus dimension used as the prompt to the dimension of the target discrimination.

Contingency manipulations involve modifying either the structure of trial-and-error sessions or the structure of individual trials while training with unaltered stimuli and stimulus displays. Such procedures include blocked trials (e.g., Perez-Gonzalez & Williams, 2002; Saunders & Spradlin, 1989, 1990, 1993), revised and combined blocked trials (e.g., Perez-Gonzalez & Williams; Smeets & Striefel, 1994), and error-correction (e.g., Rodgers & Iwata, 1991; Sidman & Cresson, 1973).

Another procedure, but one that does not constitute either a stimulus or contingency manipulation and that has received considerably less attention, involves training with so-called *thematic matching* (Pilgrim et al., 2000). Pilgrim et al. noted that the switch from identity to symbolic MTS requires a shift in stimulus control from physical identity in the former task to relational (i.e., between the sample and comparison) in the latter task. They suggested that a matching task in which the sample and comparison pairs are members of various categories (e.g., types of fruit or animals) that the participants had likely learned prior to the experiment might be an effective intermediate step between identity MTS and symbolic MTS with non-representative and/or unfamiliar stimuli. Pilgrim et al. recruited nine typically-developing children between 43 and 79 months of age, three of whom had previously achieved high accuracies on identity but not on symbolic MTS tasks involving trial and error training, blocked trials, and/or verbal instructions within their experimental context. The children were first taught identity matching with both familiar picture and non-representative stimuli, and then thematic matching with familiar picture stimuli related by category. Finally, the children were taught two symbolic MTS tasks with non-representative stimuli. On thematic MTS tasks, some children immediately matched samples and comparisons from the same category while others did so after several sessions, and only two required supplementary teaching in the form of verbal instructions. More importantly, after exposure to thematic matching, eight of the nine children were able to learn symbolic MTS tasks involving non-representative stimuli with trial and error training alone. To date, Pilgrim et al. is the only report using thematic matching as a remedial teaching step for symbolic matching.

The purpose of the current study was to replicate critical aspects of Pilgrim et al.'s (2000) procedure but with individuals diagnosed with ASD and presenting with significant language deficits. The data reported here are from three participants who were part of a larger investigation into the efficacy of various error-correction procedures on teaching symbolic matching to children with ASD and intellectual disability. All the participants achieved accuracy scores of 90% correct or higher on pre-tests of generalized identity matching with non-representative form stimuli. A non-concurrent multiple-baseline design (Harvey, May, & Kennedy, 2004) was used to assess whether thematic matching facilitated the acquisition of symbolic matching that involved non-representative stimuli. Specifically thematic matching was introduced after unsuccessful training on zero, two, or four symbolic MTS tasks involving different stimulus sets and before one or more additional symbolic MTS tasks were presented. Evidence for thematic matching having facilitated acquisition of the final symbolic MTS tasks would be of practical importance – clinicians and special educators would have an additional remedial teaching technique for individuals with developmental or intellectual disabilities and limited language.

2. Method

2.1 Participants

Three students enrolled at a school for children with neurodevelopmental disabilities participated. The gender, chronological age, clinical diagnosis, and mental-age equivalent scores from the Peabody Picture Vocabulary Test (4th Ed.; Dunn & Dunn, 2007) for each participant are listed in Table 1. The PPVT-4 was administered by research assistants and

clinical diagnoses were obtained from student records. All three participants presented with significant deficits in language but could communicate using simple sentences. All were experimentally naïve at the start of the study.

2.2 Setting and Apparatus

Experimental sessions took place in a research room located within the participant's school building. The participant sat alone at a table on which was placed a touchscreen monitor (Elo Touchmonitor, model #1515L). The monitor was connected to a laptop computer located on the other side of the wall. Mounted in the wall to the right of the touchscreen was a reward delivery chute that could be illuminated with a red LED light when either food items or tokens were delivered. The experimenter remained outside the room, manually delivered food items or tokens through the chute, and monitored the participant via closed-circuit television. In this way, procedural integrity was enhanced because the possibility of inadvertent prompting and variation in reinforcement delivery was eliminated. Software written in MATLAB (2010b) controlled images presented on the touchscreen, signaled when the experimenter should deliver a food item or token, and recorded the position and time of touchscreen responses. Two participants (CUB and OLY) earned food items for correct responses and one (JBK) initially earned tokens that were later exchanged for access to a leisure activity; after 14 training sessions, JBK requested to earn food items during the research sessions and token use was discontinued. The specific food item used for a participant was selected from a set of four foods (recommended by the participants' classroom teachers) using the results of a 36-trial, paired-stimulus preference assessment (Fisher, Piazza, Bowman, Hagopian, Owens, & Slevin, 1992). These foods included chips, candy, and fresh fruit.

Examples of the stimuli used in the symbolic and thematic MTS tasks are depicted in Figure 1. For symbolic MTS tasks, the stimuli were black non-representative line drawings. For thematic MTS tasks, the stimuli were color clip-art drawings of objects that were very likely to be familiar to the participants. The clip-art was obtained from a software package (Mayer-Johnson, 2008) or from clipart websites freely available on the internet. All of the stimuli were presented on a white background inside a 3 cm × 3 cm square.

2.3 Procedure

2.3.1 General matching-to-sample procedures—Three different stimulus sets (i.e., three sample-comparison pairs) were used in each MTS task. Each trial of each MTS task began with the presentation of a sample stimulus at the top center of the touchscreen. Effective responses to the sample were defined as touching the screen anywhere within the bounds of the sample stimulus and were accompanied by a 0.05 s offset of the sample. Three responses to the sample produced two comparison stimuli at the bottom of the screen, 10 cm apart (and the sample remained on the screen). A response to the correct comparison extinguished the sample and comparisons, and produced a 2-s animated display of stars accompanied by a short computer-generated melody, 2-s illumination of the light reward chute, and the delivery of a food item or token. A response to the incorrect comparison extinguished the sample and comparisons, and produced a black screen for 2 s. Trials were separated by a 3-s inter-trial interval (ITI) with a black screen; touches to the screen during the ITI delayed the onset of the next trial by 3 s. In all conditions, each of the three samples appeared equally often in a session, and each of the three comparisons appeared an equal number of times in each location (i.e., left or right) and with each incorrect comparison stimulus. The order of sample presentation, and the order of correct-comparison location, were both determined by a random number generator at the beginning of each session, and so varied unsystematically across sessions. Sessions were conducted 3–5 times per week and lasted no longer than 30 min.

2.3.2 Pretraining—The first session consisted of a stimulus tracking task. On 24 trials, a target stimulus (9.3 cm × 9.3 cm) was presented in a random location on the touchscreen. One to three touches resulted in its removal and the delivery of a food item or token simultaneously with the audio-visual display described above. Touches to the background had no programmed consequences. The second session was an identity MTS task with non-representative black forms presented on a white background. There were 24 trials in this session, and the accuracy criterion was one session at 92% correct or better.

2.3.3 Symbolic and thematic matching—Immediately after pretraining, the participants received training on a series of symbolic and thematic MTS tasks. In these, participants were required to match non-identical stimuli, and the stimulus sets used in each condition were different from the ones used in pretraining. Introduction of thematic matching occurred in a non-concurrent multiple-baseline design (Harvey et al., 2004) and, thus, after a varying number of symbolic MTS tasks. One participant, CUB, received the thematic-matching condition without any prior training on symbolic matching, while the other two participants, JBK and OLY, received training on thematic matching after two and four symbolic MTS tasks, respectively. All participants received a series of three to six symbolic MTS tasks following training on thematic matching. Within each condition (thematic or symbolic), each MTS task was taught with a different stimulus set, and each stimulus set included three sample-comparison relations (i.e., six stimuli per set).

As noted in the introduction, symbolic training was conducted in the context of a larger research study investigating the efficacy of different error-correction procedures. Training in the symbolic condition occurred with one of two error-correction procedures. Procedure 1 involved immediate re-presentation(s) of an incorrectly performed trial until the correct comparison was selected, while Procedure 2 involved re-presentation(s) of an incorrectly performed trial at a later time in the session and until the correct comparison was selected. The background color of the touchscreen signaled which error-correction procedure was operating (yellow for Procedure 1 and green for Procedure 2) and the two procedures alternated unsystematically across symbolic MTS tasks (i.e., each correction procedure was in effect for multiple consecutive sessions and until the criterion for each MTS task was reached). JBK began symbolic training with Procedure 1, and CUB and OLY began with Procedure 2. There was a minimum of 24 trials (two blocks of 12 unique trial types) and a maximum of 45 trials per session. For each session, the total number of trials presented depended on the number of incorrect responses that resulted in correction trials. Training on each task continued until either an accuracy score of 92% correct or higher was achieved for three consecutive sessions, or until a maximum of 10 sessions were completed with no upward trend.

Training in the thematic condition involved a series of three MTS tasks, each with a unique set of stimuli. There were 24 trials per session, no error-correction procedure was used, and the accuracy criterion was 92% correct or higher in a single session. Participant JBK received additional training on thematic matching (i.e., three further thematic MTS tasks) after decreasing matching accuracies were seen in two symbolic MTS tasks following the first exposure to thematic matching. JBK's second exposure to thematic matching was followed by training on a fifth symbolic MTS task.

3. Results

Figure 2 shows accuracy for each session in the symbolic and thematic conditions for individual participants. In the figure, the thematic condition is depicted by squares, the symbolic condition is depicted by circles, and each task is indicated by a separate label (e.g.,

“S2” refers to the second symbolic MTS task and “T4” refers the fourth thematic MTS task). There were no systematic differences in results for error correction Procedures 1 and 2.

The dashed lines in Figure 2 indicate the initial introduction of thematic matching. For all participants, accuracy on the three thematic MTS tasks in a series (i.e., T1, T2 & T3, or T4, T5 & T6) was relatively high from the first session on each task. Accuracy for CUB was 100% correct and accuracy for JBK and OLY did not fall below 87.5% correct in any of these sessions. Consequently, all participants met the accuracy criterion in one or two sessions for each task in the series.

Participant CUB (top panel of Figure 2) did not receive symbolic matching before thematic matching. Accuracy on his first session of symbolic matching following thematic matching (S1) was 70.8% correct. Accuracy scores steadily increased over subsequent sessions, and averaged 98.6% for the last three sessions. This can be contrasted with matching accuracy on the first session of symbolic matching for JBK and OLY (center and bottom panels, respectively), who were both exposed to symbolic matching prior to thematic matching. For both of these participants, accuracy on the first symbolic session was approximately at chance levels (50%) and did not increase over subsequent training sessions.

With repeated training on new symbolic matching tasks, accuracy remained above chance for CUB. On the first session of the second condition (S2), accuracy was 87.5% correct and the accuracy criterion was reached in the same number of sessions as in the first task. On the following tasks (S3–S6), the accuracy criterion was achieved in a fewer number of sessions, providing some evidence of learning set (i.e., learning to learn; Harlow, 1949). By contrast, neither JBK nor OLY showed an increase in accuracy or decrease in the number of sessions to criterion over exposures to the first two (JBK) or four (OLY) symbolic matching tasks prior to thematic matching.

For both JBK and OLY, accuracy on symbolic matching showed a marked increase only after training on thematic matching had been conducted (S3 and S5, respectively). On the first session of symbolic matching after the thematic condition, JBK matched at 62.5% correct and OLY matched at 79%. In addition, accuracy averaged over all sessions on this task was higher than that on the previous symbolic MTS task (82.6% vs. 47.3% for JBK, and 93.7% vs. 45.8% for OLY).

Each participant was then given two or three additional symbolic MTS tasks. For OLY, accuracy was high on the first session with each new task and criterion was reached in three sessions (the minimum). By contrast, JBK’s accuracy scores on the second symbolic MTS task following thematic matching were low, averaging 38.7% over all 10 sessions. For this reason, JBK was again given remedial thematic matching with an additional three tasks. Although accuracy was high during this second exposure to thematic matching, it did not assist acquisition on a subsequent symbolic MTS task, and the experiment was terminated after five sessions of chance-level matching accuracy.

4. Discussion

The results of this experiment replicate those reported by Pilgrim et al. (2000): A history of conditional discrimination established by thematic matching may contribute to improved accuracy on subsequent symbolic MTS tasks with non-representative stimuli. For all three participants, accuracy on the first symbolic MTS task after initial exposure to the thematic condition was above chance and increased over sessions. In contrast, accuracy on symbolic MTS tasks prior to the initial thematic condition was at chance levels for those participants who received them (JBK and OLY). These results suggest that thematic matching can be used as a remedial teaching strategy for clients with developmental or intellectual

disabilities who have difficulty acquiring symbolic-MTS tasks. These sorts of tasks are frequently used in settings serving individuals with intellectual and developmental disabilities to teach a variety of academic skills and use of selection-based communication systems. Thematic matching may be particularly useful in situations in which repeated attempts to teach symbolic matching have failed and when other remedial strategies (e.g., verbal instructions, stimulus shaping, stimulus prompting, etc.) are impractical or unsuccessful.

Although our data suggest that thematic-MTS training has a facilitative effect on subsequent symbolic matching, two limitations of this study should be noted. First, only two participants (JBK and OLY) received a baseline symbolic-matching condition. Thus, it is unclear whether CUB would have learned symbolic matching without prior exposure to thematic matching. Even so, CUB's accuracy on the first session of symbolic matching was substantially higher (approximately 70%) than those of the other two participants (approximately 50%). Second, only two participants (CUB and OLY) continued to match at high accuracy levels on new symbolic matching tasks following thematic matching, whereas one (JBK) did not, despite repeated exposure to thematic matching. Thus, while the results of this study suggest that thematic matching may be an effective remedial strategy for some individuals with developmental and/or intellectual disabilities, the effects may be idiosyncratic.

One difference between JBK and the other participants is that his accuracy on the first symbolic MTS task after the thematic condition reached asymptote at only 85% in the final three sessions, in contrast to 98% for CUB and OLY. This intermediate accuracy score indicates that the sample stimuli exerted stimulus control over a majority JBK's comparison selections, but other factors (e.g., stimulus location, etc.) also still exerted some control, resulting in a varying number of errors across sessions. This was not the case, however, in the thematic condition: On those tasks, JBK consistently matched at very high accuracy levels. One possibility is some unsuspected problem with JBK's stimulus sets S4 and S5 (e.g., physical similarities between samples and incorrect comparisons), although this seems unlikely because those same stimulus sets were CUB's S2 and S3 (see Figure 2). Another interpretation of JBK's data is contextual control by stimulus type – when the stimuli were members of previously existing categories, comparison selections were controlled by those existing stimulus relations, but when the stimuli were non-representative forms, comparison selections were jointly controlled by the sample stimulus and some other factors. A third interpretation is that similarity, rather than pre-existing category membership, may have controlled comparison selections during the thematic MTS tasks for JBK. The picture stimuli used as sample-comparison pairs in thematic matching had varying degrees of physical similarity that did not exist between the sample and incorrect comparisons. Figure 1 shows three of the 18 thematic relations used in this experiment; both the flower and the slide samples share a stimulus feature with their corresponding correct comparison (e.g., the color green and a slightly angled line, respectively) that is not shared between those samples and their corresponding incorrect comparisons. To the extent that shared features were the basis for JBK's comparison selection during the thematic condition, then the task was a de facto identity MTS task and not a matching task involving symbolic relations between dissimilar stimuli.

One reason that JBK and OLY failed to learn symbolic MTS in the baseline phase might be because those tasks immediately followed preliminary training on an identity MTS task. This pretraining verified that the participants had various prerequisite skills (e.g., effective scanning of the comparison array). Moreover, the reversal of the discriminative function of comparisons across trials that occurs in MTS tasks often poses difficulty for people with intellectual disabilities (Saunders & Spradlin, 1989; 1990; 1993), and identity MTS

pretraining verified that these participants did not have such difficulty. However, as pointed out by Pilgrim et al. (2000), accurate performance on identity MTS tasks requires that comparison selection is controlled by physical similarity between samples and matching comparisons, whereas accurate performance on symbolic MTS tasks does not. Thus, it is possible that JBK and OLY failed to learn symbolic matching because the abrupt change from identity to symbolic MTS rendered responding in accordance with physical similarity ineffective, and allowed undesirable stimulus control topographies (McIlvane & Dube, 2003) to occur and inadvertently be reinforced. If this hypothesis is correct, then the common practice of shifting students with developmental disabilities from identity MTS tasks to symbolic MTS tasks (e.g., Hammond, Hirt, & Hall, 2012; Mansfield, Dudley, DeGregory, & Foster, 2011; Saunders & Spradlin, 1989; 1993) may hinder learning of the latter tasks in some cases. The current results indicate that an intermediate step involving thematic matching could be beneficial.

The main difference between our experiment and Pilgrim et al. (2000) is that Pilgrim et al. studied the learning of children without intellectual and developmental disabilities and we studied that of adolescents with ASD and significant language deficits. Our replication suggests that thematic matching may also be an effective intervention for people with intellectual and developmental disabilities and limited verbal repertoires. This conclusion, however, warrants caveats. First, all our participants presented with significant language deficits, but none was strictly non-verbal and their receptive language levels as measured by the PPVT-4 were comparable to those of the children in Pilgrim et al. Second, the participant who showed the least improvement in symbolic matching following thematic matching (JBK) also scored lowest on the PPVT-4 (see Table 1), indicating that he likely had a more limited vocabulary than the other participants. Thus, although our results suggest that thematic matching can be an effective remedial procedure for people presenting with language deficits, we cannot rule out the possibility that linguistic ability moderates the intervention's effectiveness.

Neither our results nor those of Pilgrim et al. (2000) speak to the underlying mechanism(s) of this effect. Nevertheless, various possibilities are worth entertaining and should be investigated in future research. First, the stimuli used in the symbolic and thematic conditions may have differed in terms of stimulus discriminability; that is, both form and multiple color differences were available to support discrimination among the color clip-art drawings, but only form and black vs. white differences were available with the non-representative forms (cf. Carter & Eckerman, 1975). The color differences may have encouraged broader attending to stimulus features during the thematic condition that carried over to the symbolic condition. To more convincingly demonstrate that the thematic relation between the sample and correct comparison is responsible for the improvement in symbolic-matching accuracy, a control condition in which the sample-comparison pairs are color clip-art drawings that are unrelated in terms of pre-experimental category membership or physical similarity is needed.

Assuming the facilitative effect observed here is related to the thematic relations among the stimuli, it might be that experience with thematic matching caused participants to generate rules (in the form of sub-vocal speech) regarding the general nature of symbolic MTS (e.g., "select the comparison that, while different, goes with the sample"), and to apply these rules when performing symbolic MTS tasks with non-representative stimuli. This mechanism clearly involves verbal behavior such that the intervention's effectiveness should increase with the verbal competency of participants. Alternatively, the presentation of familiar and thematically related stimuli in thematic matching, and the accurate matching that ensued, may have disrupted inappropriate stimulus-control topographies (McIlvane & Dube, 2003) and/or response biases that dominated in the prior symbolic tasks. This disruption may have

facilitated the acquisition of subsequent symbolic MTS tasks by allowing new and desirable topographies to occur and be differentially reinforced. Finally, the facilitative effect of thematic matching on later acquisition of symbolic MTS tasks might be understood in terms of Relational Frame Theory (Barnes, 1994; Hayes, 1994); namely, thematic matching might have established relational responding as a generalized operant class that persisted and was reinforced when symbolic MTS tasks were introduced (see Healey, Barnes-Holmes, & Smeets, [2000] for a description of this account). Further research aimed at identifying the mechanism that underlies this effect is likely to advance our understanding of MTS performance and inform more effective procedures for teaching symbolic matching.

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Highlights

- Exposure to thematic MTS improved accuracy on a subsequent symbolic MTS task.
- Two participants maintained high accuracies on additional symbolic MTS tasks.
- Accuracy on additional symbolic MTS tasks decreased to chance for one participant.
- Thematic MTS may be an effective intervention for improving acquisition of symbolic MTS.

SYMBOLIC MATCHING		THEMATIC MATCHING	
<u>Samples</u>	<u>Comparisons</u>	<u>Samples</u>	<u>Comparisons</u>

Figure 1.
Examples of the form stimuli used in symbolic matching (stimulus set 1) and the clip-art stimuli used in thematic matching (stimulus set 3).

Figure 2.

Accuracy for each training session for individual participants. The dashed horizontal line at 50% correct indicates chance matching accuracy and the dashed vertical line indicates the introduction of thematic matching. Separate matching tasks within each condition are indicated by “T” for thematic matching and “S” for symbolic matching. The specific stimulus sets used for each thematic task (e.g., T1) were the same across participants; the stimulus sets used for each symbolic task differed across participants.

Table 1

Participants' chronological ages, clinical diagnoses, and PPVT-4 Mental Age Equivalent scores.

Participant	Gender	Age	Diagnosis	PPVT
CUB	Male	15.2	Autism	5.8
JBK	Male	12.6	Autism	3.8
OLY	Male	13.8	Autism	7.5

Note: Participants' ages in years at the start of experimental testing.