Emergence of Equivalence Relations:
Comparing Sorting and Match-to-Sample Procedures

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Thesis Title: Emergence of Equivalence Relations: Comparing Sorting and Match-to-Sample Procedures

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Abstract

Match-to-sample procedures (MTS) are often implemented to train conditional relations and to test for emergent relations among arbitrary stimuli. In 1997, Eikeseth, Rosales-Ruiz, Duarte, and Baer evaluated the efficacy of using written instruction as an alternative to MTS to train conditional relations among arbitrary stimuli. Smeets, Dymond, and Barnes-Holmes (2000) extended Eikeseth et al. (1997) by introducing a sorting method, in which all comparison and sample stimuli were present simultaneously, to test for emergent relations among arbitrary stimuli after training conditional discriminations using MTS. The current study extended previous research further by using a paper-and-pencil format to compare MTS and sorting procedures for both training conditional relations among abstract stimuli and testing for the emergence of novel relations. Three typically developing adults, ages 24-25, learned AB and AC relations by first tracing and then independently drawing lines linking arbitrary stimuli. Once discriminations were established using one procedure, novel relations (BA, CA, BC, and CB) were tested using both sorting and MTS procedures. Participants then completed the protocol with a new set of stimuli, using the alternative procedure for training. Novel relations emerged for all three participants with both procedures. All participants required additional exposure to conditional discriminations when learning with the MTS procedure before demonstrating equivalence, suggesting that sorting may be a more effective method for both training conditional discriminations among arbitrary stimuli and promoting the emergence of equivalence classes among arbitrary stimuli.

_Keywords_: conditional discriminations, equivalence relations, match-to-sample, sorting
Stimulus equivalence is an important area of research in applied behavior analysis and has been for several decades. In *Equivalence Relations and Behavior: A Research Story* (1994), Sidman cites language as one of the most powerful and relevant examples of equivalence relations not only in applied behavior analysis but in everyday life. As he points out, words often symbolize other things or events; as human beings, individuals often react to words as if they were not merely collections of letters, but rather the thing or event which they symbolize (pp. 2-3). Most are familiar with the expression, “sticks and stones can break my bones, but words can never hurt me,” but anyone who was teased as a child for being too fat, too thin, too short, too tall, or otherwise different will likely disagree. Harsh words can be as painful as if the speaker were physically inflicting pain on the listener. That words are able to serve as substitutes for actual physical violence is due to their equivalence as stimuli. Another example Sidman provides (p. 3) is spoken, written, and thought language: because these linguistic forms are equivalent, humans are able to understand a story read aloud, make shopping lists, send e-mails, and have conversations. Equivalence relations are essential to verbal behavior.

**Stimulus Equivalence and its Properties**

Cooper, Heron, and Heward (2007) define stimulus equivalence as “the emergence of accurate responding to untrained and non-reinforced stimulus-stimulus relations following the reinforcement of responses to some stimulus-stimulus relations” (p. 398). The presence of equivalence is confirmed by positive tests for the three properties reflexivity, symmetry, and transitivity.

Reflexivity, also known as generalized identity matching, occurs when in the absence of training and reinforcement an individual is able to match a stimulus to itself: A=A, or A is
equivalent to A (Cooper et al., 2007). For example, when shown the sample of a picture of an apple and the comparison pictures of an apple, pear, and banana, a participant who demonstrates reflexivity will choose the picture of the apple.

Symmetry occurs when an individual demonstrates reversibility of the sample and comparison stimuli: if A=B, then B=A (Cooper et al., 2007). Symmetry is present when a participant who has learned to choose the word apple when presented with the picture of an apple chooses a picture of an apple when presented with the written word apple with no programmed consequences or direct training.

Transitivity is an untrained stimulus-stimulus relation that stems from two previously trained stimulus-stimulus relations: if A=B and B=C, then A=C (Cooper et al., 2007). Transitivity is present if, after training the first two relations described below, the third relation emerges with no programmed consequences or direct training:

If A (the picture of an apple) is equivalent to B (the written word apple), and

B (the written word apple) is equivalent to C (the written word mansana), then

A (the picture of an apple) is equivalent to C (the written word mansana).

When the participant has demonstrated reflexivity, symmetry, and transitivity, a test for equivalence is conducted: if the individual is able to match C to A, a novel relation, in the absence of additional training or reinforcement, the stimuli are then said to be members of an equivalence class (Sidman, 1994). The stimuli are then likely to also be functionally equivalent, such that behavior occasioned by one stimulus will also be occasioned by the other (Catania, 2007).

In 1971, Sidman conducted a landmark study with regard to stimulus equivalence. A developmentally disabled individual, able to match spoken words to pictures and name the
pictures but unable to read printed words aloud or with comprehension, served as the participant. Sidman demonstrated that by teaching the participant to match spoken to printed words, the participant then demonstrated reading comprehension (matching written words to pictures and matching pictures to printed words) and oral reading. This was a remarkable discovery in applied behavior analysis: by teaching only one stimulus-stimulus relation, three additional relations emerged without any further instruction or training.

In a systematic replication (Sidman & Cresson, 1973), two individuals with Down syndrome served as participants. Initially unable to match printed words to pictures (reading comprehension), the participants first learned to match printed words to printed words (visual discrimination) and to match dictated words to the corresponding picture (auditory comprehension). After being taught to match dictated words to printed words, the participants were then able to read the words orally and with comprehension.

After the publication of these first two studies, the field of applied behavior analysis saw an explosion of research on equivalence relations, including among non-humans such as monkeys and baboons (Sidman et al., 1982) as well as the expansion of the testing paradigm to include four-member stimulus classes (Sidman, 1982). Stimulus equivalence remains an important area of research today, as many unanswered questions continue to warrant further investigation.

**Match-to-Sample**

The most common method for training conditional discriminations is known as *match-to-sample* (Sidman, 2000) or MTS. In this procedure, one stimulus is presented as the sample and two or more stimuli are presented as comparisons. The selection of a particular comparison stimulus is reinforced and the selection of any other stimulus is not, strengthening the selection of that particular comparison stimulus in the presence of that particular sample stimulus (Cooper
MTS is also an effective procedure for testing equivalence. Once an individual demonstrates mastery of baseline relations (i.e., A=B and B=C) via MTS, the stimuli are presented in novel arrangements to test for the presence of transitivity and equivalence (i.e., A=C and C=A). Sidman’s initial study on stimulus equivalence (1971) and follow-up replication (as cited in Sidman, 1994, p. 44) used MTS both to train baseline discriminations and to test for equivalence relations, setting the foundation for MTS as the standard method for research in this area. Over the years, researchers have continued to use MTS to establish equivalence classes in basic and applied research, including teaching arbitrary relations to typically developing children (Sidman & Tailby, 1982) as well as teaching the spoken and written names of relevant therapists to adult men with brain injury (Cowley, Green, & Braunling-McMorrow, 1992).

**Sorting**

In recent years, a procedure known as sorting has emerged as an alternative technique to testing for equivalence. In a sorting procedure, the participant has access to all sample and comparison stimuli simultaneously, and the participant must sort the stimuli into stimulus classes. This can be done by physically moving the stimuli into separate locations, such as sorting colored and white laundry, or by drawing a line linking stimuli printed on paper. This procedure is commonly used in the educational system; for example, a student could be required to draw lines linking states to their corresponding capitos or to match a vocabulary word to its synonym.

Using written instructions presented in MTS format to establish four baseline discriminations in 23 undergraduate students, Smeets, Dymond, and Barnes-Holmes (2000) tested for equivalence in two ways. Participants were first required to respond to a series of MTS probe
trials, then asked to sort the stimuli into two groups. Of participants who responded correctly on the MTS probe trials, 88% also sorted the stimuli consistently with respect to class.

**Written Instruction/Paper-and-Pencil Format**

In addition to justifying a novel procedure for testing equivalence, this study extended previous research (Eikeseth, Rosales-Ruiz, Duarte, & Baer, 1997) on whether equivalence relations can be derived from instructionally induced conditional relations, or rules. Eikeseth et al. (1997) used written instructions to establish arbitrary conditional discriminations for 28 undergraduate students, 50% of whom demonstrated equivalence during testing. All 20 participants in a control group who did not learn the baseline discriminations were tested in the same way; none of these 20 demonstrated equivalence, indicating that instructions presented in a paper-and-pencil format were indeed sufficient for forming equivalence classes.

The current research on stimulus equivalence poses many questions for future experiments. Though MTS is a reliable method for training and testing equivalence relations, the notion persists that another procedure could be equally, if not more, effective. Given results from current research (Eikeseth et al., 1997; Smeets et al., 2000), sorting may be a valid method to test equivalence; however, the question remains whether it is an equally proficient tool for training conditional discriminations. Furthermore, the introduction of a paper-and-pencil format begs the question of whether conditional discriminations or equivalence relations can be established through the use of written instructions, or rules.

The present study explores these questions in a procedure designed to compare the efficacy of MTS and sorting procedures in establishing equivalence classes with typically functioning adults.
Method

Participants and Setting

Participants were three typically developing adults, two male, Patrick and Chris, and one female, Claire, ages 24-25 at the onset of the study. Participants were of varying occupations and levels of education, ranging from some undergraduate work to graduate degrees.

All sessions were conducted at a kitchen table, measuring approximately 1 m by 2 m, at the participant’s or experimenter’s residence.

Materials

Materials present during sessions included all necessary pre-training, training, and testing stimuli, a paper and pen for data recording, and a Flip® video camera for video recording. All pre-training and training stimuli were presented in paper-and-pencil format on standard white computer paper measuring approximately 22 cm by 28 cm. Pre-training stimuli included pictures of common shapes, animals, and colors, and the written words heart, red, blue, and green.

Eighteen arbitrary symbols comprised the training stimuli (see Tables 1 and 2). These stimuli were divided into two stimulus sets and further sub-divided into stimulus classes each containing three stimuli. Arbitrary stimuli were used to ensure a lack of pre-existing relationship between any of the stimuli.

Procedure

Introduction and Pre-Training. Before each of two training conditions, participants read aloud an introduction paper (see Appendix A) with a brief description of the experimental format and the instruction to draw or trace lines throughout both phases of the experiment linking images that go together. Participants were given the opportunity to ask questions before proceeding with each condition.
Pre-training consisted of practice trials using known stimuli to familiarize the participant with the expectations of the procedure. This lasted fewer than five minutes for each participant and included eight pages of familiar stimuli printed in MTS and sorting formats. On four MTS sheets, participants traced pre-existing lines on some sheets and drew their own lines on other sheets linking one sample stimulus with one of three comparison stimuli. On four sorting sheets, participants again traced pre-existing lines on some sheets and drew their own lines on other sheets linking all six comparison stimuli to one of three corresponding sample stimuli. After completing pre-training with 100% accuracy, participants continued to the training phase of the experiment.

**Baseline.** Before each experimental condition, participants completed 18 baseline trials to ensure lack of pre-existing relations among the arbitrary stimuli. Baseline trials were presented in the same format the training phase was to be presented, and participants drew their own lines linking the stimuli.

**Training.** All participants completed both MTS and sorting conditions, with at least one week between conditions. During each condition, participants learned six conditional discriminations (A1B1, A2B2, A3B3, A1C1, A2C2, A3C3, or a1b1, a2b2, a3b3, a1c1, a2c2, a3c3). Patrick completed the sorting condition first with Stimulus Set 2, then completed the MTS condition with Stimulus Set 1. Chris completed the MTS condition first with Stimulus Set 1, then completed the sorting condition with Stimulus Set 2. Claire completed the sorting condition first with Stimulus Set 1, then completed the MTS condition with Stimulus Set 2. This design was implemented to safeguard against sequencing effects and stimulus set bias.

Sessions for both experimental conditions were presented in blocks of six trials. No differential programmed consequences were provided for correct or incorrect responding within
each block of trials. During step 1 (see Appendices B and C), participants were required to trace pre-existing lines linking comparison and sample stimuli in the same stimulus class. After responding correctly in at least 5/6 trials for three consecutive blocks at step 1, participants advanced to step 2 (see Appendices D and E), during which they were required to draw their own lines linking comparison and sample stimuli in the same stimulus class. After responding correctly in at least 5/6 trials for three consecutive blocks at step 2, participants advanced to the emergence test. If a participant made more than one error in any block of trials, he or she first completed the block of trials, then returned to the previous step.

**MTS Condition.** One sample stimulus was printed at the top of the sheet with three comparison stimuli printed underneath. For example, stimulus A1 was presented with stimuli B1, B2 and B3 underneath, with B1 as the correct comparison stimulus. The positions of the comparison stimuli were alternated each trial to ensure attending and to avoid selections based on location. AB and AC conditional discriminations were distributed semi-randomly throughout blocks of training trials. Each sheet of paper in this phase consisted of one trial; therefore, one block of trials contained six sheets of paper.

**Sorting Condition.** Three sample stimuli were printed at the top of the sheet with six comparison stimuli printed underneath. For example, stimuli A1, A2, and A3 appeared at the top of the sheet with stimuli B1, B2, B3, C1, C2, and C3 printed underneath. In this phase, correct responses linked B1 and C1 to A1, B2 and C2 to A2, and B3 and C3 to A3. Again, positions of the sample and comparison stimuli varied each trial. Because each line between two stimuli is considered one trial, each sheet during this phase represented six trials, or one block of trials.

**Emergence Tests.** Participants proceeded to the next phase of the study after meeting criteria for mastery of conditional discriminations AB and AC at step 2. This phase included 36 trials
testing for the emergence of the untrained symmetry (BA and CA), transitivity (BC), and equivalence (CB) relations.

Patrick and Chris first completed emergence tests presented in the same format in which they originally learned the conditional discriminations. For example, after demonstrating mastery of the conditional discriminations learned via MTS, Patrick and Chris were first tested for the emergence of untrained relations using the MTS procedure. Following the first emergence test presented with the same procedure, Patrick and Chris completed a second emergence test with the alternative procedure. For example, after completing an MTS emergence test for conditional discriminations learned via MTS, these participants then completed an emergence test presented using sorting procedure.

Claire completed emergence tests in the reverse order. For example, after demonstrating mastery of conditional discriminations learned via MTS, she first completed an emergence test presented using sorting procedure, then completed an emergence test presented using MTS procedure. Emergence tests consisted of 36 trials distributed semi-randomly. The criterion for demonstrating equivalence was 30/36 for each emergence test.

Results

All participants completed pre-training with 100% accuracy, demonstrating comprehension of the required response for both sorting and MTS procedures.

Figure 1 depicts the percent of responses correct for Patrick for training during the sorting condition. During baseline, Patrick drew lines consistent with the experimentally defined stimulus classes in 6/18 trials. During training, Patrick traced lines consistent with stimulus classes in 18/18 trials at step 1 and drew lines consistent with stimulus classes in 18/18 trials at
Patrick drew lines consistent with stimulus classes in 36/36 of the test trials in both the sorting and MTS emergence tests.

Figure 2 depicts the percent of responses correct for Patrick during the MTS condition. During baseline, Patrick drew lines consistent with stimulus classes in 5/18 trials. During training, Patrick traced lines consistent with stimulus classes in 18/18 trials at step 1, and during step 2 drew lines consistent with stimulus classes in 4/6 trials. Patrick was returned to step 1, during which he again traced lines consistent with stimulus classes in 18/18 trials, and during step 2 he drew lines consistent with stimulus classes in 17/18 trials. Patrick drew lines consistent with stimulus classes in 17/18 trials of the MTS emergence test and in 18/18 trials of the sorting emergence test.

Figure 3 depicts the percent of responses correct for Chris during the MTS condition. During baseline, Chris drew lines consistent with stimulus classes in 4/18 trials. During training, Chris traced lines consistent with stimulus classes in 18/18 trials at step 1, and drew lines consistent with stimulus classes in 16/18 trials at step 2. Chris drew lines consistent with stimulus classes in 15/36 trials of the MTS emergence test, and in 12/36 trials of the sorting emergence test. Because his responding on the tests did not indicate equivalence, Chris returned to step 1 with this set of stimuli. During the second round of training, Chris traced lines consistent with stimulus classes in 18/18 trials at step 1 and drew lines consistent with stimulus classes in 18/18 trials at step 2. During the second round of testing, Chris drew lines consistent with stimulus classes in 35/36 trials of the MTS emergence test and in 36/36 trials of the sorting emergence test.

Figure 4 depicts the percentage of correct responses for Chris during the sorting condition. During baseline, Chris drew lines consistent with stimulus classes in 1/18 trials. During training, Chris traced lines consistent with stimulus classes in 18/18 trials at Step 1 and drew lines
consistent with stimulus classes in 18/18 trials at Step 2. Chris drew lines consistent with stimulus classes in 36/36 trials in both the sorting and MTS emergence tests.

Figure 5 depicts the percentage of correct responses for Claire during the MTS condition. During baseline, Claire drew lines consistent with stimulus classes in 5/18 trials. During training, Claire traced lines consistent with stimulus classes in 18/18 trials at step 1, and during step 2 drew lines consistent with stimulus classes in 1/6 trials. Claire was returned to step 1 and traced lines consistent with stimulus classes in 18/18 trials. At step 2, she drew lines consistent with stimulus classes in 4/6 trials and again was returned to step 1. At step 1, she traced lines consistent with stimulus classes in 18/18 trials. She was advanced to step 2 again, and drew lines consistent with stimulus classes in 2/6 trials. Claire was returned to step 1 again and traced lines consistent with stimulus classes in 18/18 trials. At step 2, she drew lines consistent with stimulus classes in 3/6 trials. She was returned to step 1 and again traced lines consistent with stimulus classes in 18/18 trials. At step 2, she drew lines consistent with stimulus classes in 10/12 trials. She was again returned to step 1 and traced lines consistent with stimulus classes in 18/18 trials. At step 2, she drew lines consistent with stimulus classes in 18/18 trials and continued to the emergence tests. Claire drew lines consistent with stimulus classes in 32/36 trials during the sorting emergence test and in 35/36 trials during the MTS emergence test.

Figure 6 depicts the percentage of correct responses for Claire during the sorting condition. During baseline, Claire drew lines consistent with stimulus classes in 6/18 trials. During training, Claire traced lines consistent with stimulus classes in 18/18 trials at step 1, and drew lines consistent with stimulus classes in only 10/12 trials at step 2. Claire was returned to step 1, during which she traced lines consistent with stimulus classes in 18/18 trials. At step 2, she drew lines consistent with stimulus classes in 8/12 trials. She was returned to step 1 again, during
which she again traced lines consistent with stimulus classes in 18/18 trials, and drew lines consistent with stimulus classes in 18/18 trials at step 2. Claire drew lines consistent with stimulus classes in 36/36 trials in both the MTS and sorting emergence tests.

**Discussion**

For three typically functioning adults, equivalence classes emerged as a result of teaching conditional discriminations with both MTS and sorting procedures. However, all three participants required more exposure to conditional discriminations during the MTS condition than during the sorting condition before demonstrating mastery of untrained relations. MTS has proven a reliable method for teaching conditional discriminations for decades, but the success of a novel procedure such as sorting provides important insight to clinicians and educators teaching non-arbitrary relations to individuals with and without developmental delays.

One advantage of learning conditional discriminations with the sorting procedure is the simultaneous presence of all sample and comparison stimuli, which may facilitate discrimination and expedite learning. In an MTS trial, there is one S+ stimulus (the correct comparison stimulus) and two S- stimuli (the incorrect comparison stimuli). In a block of sorting trials, however, each comparison stimulus serves as both an S+, for the other stimuli in the same class, and as an S-, for the stimuli that belong in another class. Therefore, once a participant makes one correct response on a block of sorting trials, the probability that he or she will continue to respond correctly increases. On the contrary, one incorrect response will increase the likelihood that the participant will make another error. Because blocks of trials during the sorting condition included six trials on one sheet of paper, participants had access to all sample and comparison stimuli simultaneously and could make educated guesses based on previous responses within the same blocks. For example, if a participant remembered only four conditional discriminations
(A1B1, A1C1, A2B2, and A2C2), by process of elimination the participant could respond correctly to A3B3 and A3C3 without having learned those relations.

Furthermore, this study replicated the findings of Eikeseth et al. (1997) and Smeets et al. (2000). Paper-and-pencil format was effective in teaching conditional discriminations among arbitrary stimuli and as a test for the emergence of untrained relations. The benefits of paper-and-pencil over tabletop stimulus presentation are substantial. Because the stimuli are already arranged on the paper, the risk of experimenter error during stimulus presentation is reduced, increasing procedural integrity within and across experimenters. The data collection on paper is a permanent product, eliminating the potential for error in experimenter data collection as well as the need for a second experimenter to collect data. Paper-and-pencil is both time- and cost-efficient, and its success as a method sets the occasion for the development of similarly designed computer software, which could further cut costs and preserve resources.

One evident limitation of this research is the age and capability of the participants. That three typically functioning adults learned conditional discriminations and demonstrate equivalence classes more efficiently with a sorting procedure does not necessarily imply that children, particularly those with developmental delays and behavioral disorders, will learn in the same way. Replication of this research among the special education population will be necessary to determine what method may work best for these individuals.

In this study, no differential programmed consequences were provided for correct or incorrect responding, other than advancing to the next step or repeating the previous step. Participants received monetary reinforcement for completion of the experiment regardless of performance, but immediate reinforcement or punishment for each response during training could have facilitated the acquisition of conditional discriminations and emergence of equivalence relations
in either or both procedures. Preference and reinforcer assessments as described by Pace, Ivancic, Edwards, Iwata, and Page (1985) are useful tools for determining potent reinforcers.

Careful consideration of these results is necessary to apply the findings to the field of applied behavior analysis and particularly for use with individuals with developmental delays such as Autism Spectrum Disorder (ASD). During a brief post-experiment interview, all three participants revealed the use of verbal mnemonic devices (specifically, naming the arbitrary stimuli) in learning AB and BC relations. Though naming as a pre-requisite for equivalence relations has been disputed (Lowe, Horne, Harris, & Randle, 2002; Sidman, 1994, p. 279), these participants found naming useful in establishing stimulus classes. However, previous research (Schusterman & Kastak, 1993; Kastak, Schusterman, & Kastak, 2001) has established equivalence relations in non-human and non-vocal human participants, so the underlying question remains as to the role of language on the formation of equivalence classes.

Future research should explore the questions raised by this study; namely, the use of paper-and-pencil format to teach conditional discriminations and establish equivalence classes, the benefits of a sorting procedure in comparison with the MTS procedure, and the establishment of equivalence in young children with developmental delays such as ASD. As evidenced by such phenomena as language, equivalence relations are an important component of human behavior. A better understanding of stimulus equivalence can assist educators in providing the best possible services to individuals with and without developmental delays.
References


Appendix A

Participant Instructions

Please read aloud:

Thank you for your participation in this research. You will receive a debriefing when you are finished to explain the purpose of this research and to answer any questions you might have about the nature of the study.

This study consists of two phases. Today you will complete one phase, and later you will complete the second phase. After completing both phases you will receive a debriefing and a small token of compensation for your participation.

Throughout both phases you will draw lines linking one or more images to another image. Sometimes you will trace pre-existing lines linking images that go together. Other times you will draw your own lines linking images that go together. On the following pages are sample tasks similar to what you will do throughout the sessions. Please complete these sample tasks now.

Once you begin, I will not be able to answer any questions or talk to you at all. This is not a test of your intelligence and there is no time limit, so please take your time and answer as you see fit. Please make sure you mark your answer on each page before continuing on to the next page.

If you have any questions, please ask them now.

When you are ready to begin, hand these pages back to the experimenter.
Appendix B

Sorting Step 1
Appendix D

Sorting Step 2
Appendix E

MTS Step 2
Table 1

*Stimulus Set 1*

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<td><img src="image5.png" alt="Image" /></td>
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Table 2

*Stimulus Set 2*

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1. 
2. 
3. 
Figure 1. Percent correct for Patrick during the sorting condition.
Figure 2. Percent correct for Patrick during the MTS condition.
Figure 3. Percent correct for Chris during the MTS condition.
Figure 4. Percent correct for Chris during the sorting condition.
Figure 5. Percent correct for Claire during the MTS condition.
Figure 6. Percent correct for Claire during the sorting condition.