COMPARING RETENTION OF EQUIVALENCE CLASSES FOLLOWING EQUIVALENCE-BASED INSTRUCTION AND COMPREHENSIVE INSTRUCTION

by

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ABSTRACT

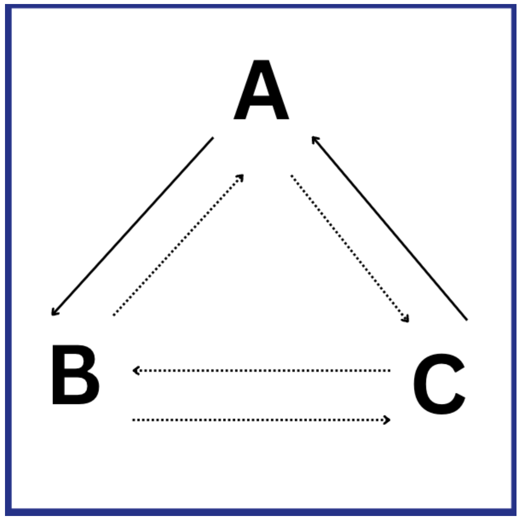
A retention test that followed equivalence-based instruction (EBI) was analyzed with the goal of understanding how variations of this teaching methodology impacted memory for taught and untaught associations between stimuli. In EBI, a small number of relations between pieces of information are taught directly, which leaves other relations to emerge. This study was conducted online during COVID-19 with 61 participants who learned three-4 member stimuli classes. The participants were randomly assigned to three experimental groups. The two EBI groups included many-to-one (EBI- MTO) and linear series (EBI-LS) training designs. The control group received complete instruction (CI), in which they were taught all stimulus relations. The retention test occurred two weeks after the original study. The test had two identical 36-trial blocks and demonstrated that overall performance increased from Block 1 to Block 2. However, there were no significant differences in performance between groups. Therefore, this suggests that both EBI structures did not improve retention for taught information in comparison to the control group. Additional research is needed to further evaluate retention in EBI teaching designs.

Comparing Retention of Equivalence Classes Following Equivalence-Based Instruction and Comprehensive Instruction

Within recent decades, more efficient and quicker strategies for teaching material have evolved. Equivalence-based instruction (EBI) is a methodology that is founded on stimulus equivalence rules (Blair & Dorsey, 2021). SE develops when physically different stimuli become associated without direct teaching because of shared relations with other stimuli (Sidman & Tailby, 1982). In order to achieve SE, EBI is the procedure utilized. Essentially, EBI involves teaching a small number of stimulus associations as shown in Figure 1. A, B, and C represent three different stimuli or pieces of information that can be related through teaching. For example, when teaching neuroanatomy (Pytte & Fienup, 2012), A might be a diagram depicting a particular brain region, B might be the name of the brain region, and C might be a brief description of the function of that region. For instance, the solid arrows represent trained relations (e.g., AB and CA) while the dotted arrows depict untaught relations (e.g., BA, AC, BC, and CB). To ensure EBI produces both taught and untaught relations, transitivity and symmetry are tested (Sidman & Tailby, 1982). Symmetry is demonstrated when BA and AC emerge because AB and CA were taught. Teaching the relation between the diagram of the brain region and name of the brain region (AB) can produce the opposite association between the brain region's name and its proper diagram (BA). Similarly, after AB and CA associations are established, transitivity is shown when BC and CB relations emerge. Therefore, stimulus equivalence will emerge with name of the brain region and function of the region or vice versa (BC, CB) even though they never were associated in training. Overall, the main goal of this procedure is to limit the amount of teaching trials needed to connect various untaught stimuli and to promote inference-making instead of rote learning.

Figure 1

Equivalence-Based Instruction Example



The solid arrows represent taught relations AB and CA. Symmetry is demonstrated with associations BA and AC, while transitivity is depicted with BC and CB.

The first person to describe EBI's effectiveness was psychologist Murray Sidman in 1971. During one of his first EBI experiments, (described in Sidman, 2009) participants consisted of special needs teenage boys who were unable to read and experienced difficulty matching words to pictures. There were three stimulus classes: auditory (A), visual (B), and word (C). Each class related to twenty random sample stimuli (dog, car, box, etc.). Participants first learned auditory-visual (AB) relations. In these trials, a dictated word was heard (sample stimulus), and eight pictorial stimuli were presented (comparison stimuli). For example, participants would hear the word "car" and were taught to match it to its appropriate picture. When answered correctly, reinforcement followed. After mastering 20 auditory-to-visual stimuli, participants learned auditory-to-word (AC) associations. For instance, "car" would be said out loud and they would learn the accurate printed word. This soon resulted in 20 AC stimuli relations. This particular teaching structure is called one-to-many because the sample stimulus is always A, whereas the comparison stimulus varies (either B stimuli or C stimuli). To test if the EBI procedure was advantageous, participants were assessed to see if they could identify untaught relationships between visual-to-word stimuli (CB, BC). Sidman found participants to be successful. These findings suggested that participants who previously had no reading ability had now comprehended the printed word without receiving direct training. Thus, 40 new stimuli relations had surfaced which represented transitivity. Ultimately, Sidman's SE discovery led to further research with the purpose to see what variables effected untaught stimulus relations to emerge. Applied researchers took interest in the implications that unlearned stimulus associations could develop naturally, which therefore elevated faster learning and understanding. Sidman furthered his research theory regarding SE (e.g., Sidman & Cresson, 1973, Sidman, 1994, & Sidman, 2000) and others continue to replicate his work.

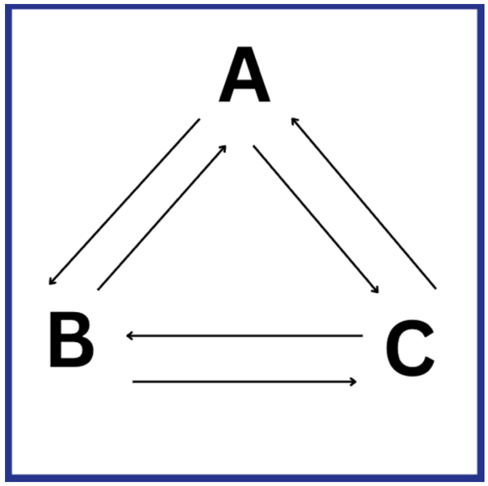
To provide an example of a more recent applied study, Bolanos et al. (2020) followed an EBI procedure to teach three kindergarten students to sort waste items based on three stimulus classes: trash, recycling, and compost. Within these classes, there were four class members: the printed word, "trash," "recycling," or "compost" (A), waste symbols (B), colored waste bin images (C), and waste material images (D). It is important to note that participants knew little to nothing related to proper waste sorting. The specific EBI teaching method was a one-to-many design. To re-emphasize this structure, the sample stimuli were always A stimuli and participants learned to respond by identifying multiple other stimuli (e.g., AB, AC, and AD). In this experiment, researchers taught how each printed word (A), matched two specific waste symbols (B). Once AB relationships were solidified in addition to accomplishing symmetry (BA), participants continued this process for stimuli associations AC, CA, AD, and DA. Then, transitivity was tested between the symbols, colored bins, and waste material images (BC, CB, BD, DB, CD, and DC). A retention test was conducted one week later to retest their knowledge and evaluate their comprehension of the material. Experimenters discovered that all three subjects had mastery scores of 96% and higher when they came back for posttests. These scores did not differentiate much from the previous week. If anything, some scores actually increased. Therefore, this data suggests that EBI was a beneficial teaching strategy, and the content of teaching was remembered well.

Pytte and Fienup (2012) serves as another example of EBI. The researchers observed if EBI would produce the same positive results in a naturalistic educational climate. This study included 93 undergraduate students enrolled in a Behavioral Neuroscience class. There were 14-three member stimulus classes. These three classes included the brain region's location on a diagram (A), name of the brain region (B), and particular function of the brain region (C). For three lectures, students learned EBI through a linear-series design, meaning the comparison stimuli in one type of trials (AB) became the sample stimuli in another type of trials (BC). Essentially, students were taught to associate the brain's diagram location and region name (AB). In addition, students also learned the relationship between the brain's region and particular function (BC). For half of the stimulus classes, an AC relation was also taught, whereas for the other half, AC relations were simply tested (i.e., transitivity). Two separate exams were taken during the same time period. Researchers focused part 1 on assessing AB and BC relationships, plus their symmetry BA and CB. Part 2 analyzed transitivity (AC). The researchers found that for the seven untaught AC relations, students had 83.33% accuracy, which was similar to the directly taught AC relations and substantially exceeded the 20% chance value. Therefore, EBI was effective.

Because EBI teaches only a small number of relations and leaves others to emerge, it is anticipated to be an efficient procedure because it saves effort not teaching everything directly. In other words, the objective is to have those relations emerge with minimal teaching. To assess this claim, it is necessary to evaluate how the efficiency of EBI compares to complete instruction (CI) in which all relations are taught (Figure 2). Few studies have been conducted on how CI and EBI learning procedures compare, but one example can be found in Fienup and Critchfield (2011). This study was completed in a college classroom during a psychology research methods course. The structure of the course separated students into four small groups that would meet weekly. Students were placed in SE (EBI), CI, or control (no instruction) groups. During specific semester weeks, the SE and CI groups learned various stimulus relations via computer-based instruction. In each of the three lessons, there was a pretest before training and a posttest after training to assess comprehension and group performance. Also, one paper posttest occurred at the end of Lesson 2 and another one week after Lesson 3. Researchers found that overall, there was not a significant difference between CI and SE groups in terms of knowledge mastery; both groups performed similarly on the paper posttests. However, differences in efficiency between groups were seen. For example, in Lessons 1 and 2, CI need a significantly more amount of time to finish training than SE groups. Also, Lesson 1 took the CI group 2.9 times more training trials, and 2.3 in Lesson 2. Thus, suggesting the SE group had more efficient learning.

Figure 2

Complete Instruction Example



Note. All associations are taught between stimuli (AB, BA, AC, CA, BC, and CB). There are six stimulus relations compared to two for EBI in Figure 1.

There are few studies assessing the efficiency of EBI relative to CI. However, Petursdottir and Oliveira (2020) and Oliveira et al. (2021) conducted several laboratory studies that utilized EBI procedures to create arbitrary relations with other stimuli. Petursdottir and Oliveira (2020) found that EBI and CI efficiency depended on the teaching phase's definition of mastery. One week after the initial study, a retention test to assess memory for taught and untaught relations took place. The retention test suggested no statistically significant differences between the groups. This potentially was because of the smaller number of participants who chose to return for the retention test. Oliveira et al. (2021), found that a one-to-many EBI training design was more efficient than CI for teaching three 4-member equivalence classes. Essentially, it required fewer training trials before symmetry and transitivity emerged at test.

However, the linear-series structure did not produce those same results. Additionally, no retention test occurred in this study.

The present study's purpose was to assess retention test data conducted two weeks after an experimental replication of Oliveira et al. (2021). However, this current study replaced the one-to-many (OTM) training procedure with many-to-one (MTO) training. MTO differs in this regard because this design teaches participants to associate the same sample stimulus with several other comparison stimuli (e.g., BA and CA), whereas OTM teaches the opposite (e.g., AB, and CA). The initial experiment's data have already been analyzed and demonstrated that neither the MTO nor the LS training design required less trials than CI to achieve symmetry and transitivity. The data from the retention test were assessed to see if greater retention would be found in one or both EBI designs in comparison to CI. Higher retention for EBI groups were predicted due to high levels of maintenance found in applied EBI studies that have shown maintenance data (e.g., Bolanos et al., 2020).

Method

Participants

Sixty-one undergraduate students (88.5% self-identified as female, 9.8% as male, and 1.6%, transgender male; mean age 19.97 years; range, 18-26 years) agreed to participate in the study after registering through the Sona Systems research software used by the Department of Psychology. 62.3% self-identified as White or Caucasian, 14.8% Hispanic or Latinx, 8.2% Black or African, 6.6% Asian, and 8.2% as Other. Participants' majors varied (e.g., psychology, economics, child development, etc.). Table 1 depicts demographic information based on participants assigned experimental group (e.g., EBI-many-to-one (EBI-MTO), EBI-linear-series (EBI-LS), and CI).

Table 1

Age and Gender Identity by Group

Group	Mean Age (SD)	% Female
EBI-MTO	19.38 (1.32)	90%
EBI-LS	20.35 (1.57)	90%
CI	20.20 (1.91)	85%

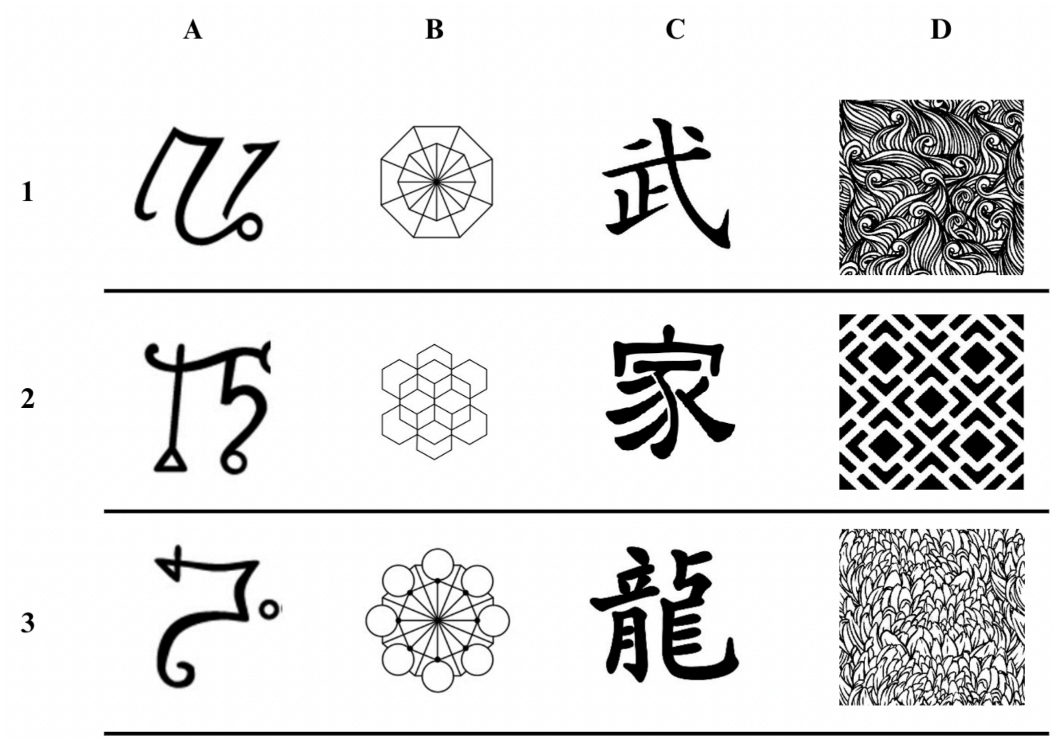
Note. SD stands for Standard Deviation.

Apparatus and Stimuli

The study took place during the COVID-19 pandemic via Zoom, an online software platform which enabled participants to speak with the researcher and access the study. Superlab® 6 (Cedrus Corporation, San Pedro, CA) was the software package which displayed the experimental stimuli and documented data. An HP laptop computer with Superlab® 6 was with the researcher. Zoom allowed participants to access Superlab® 6 on their own device through a share screen feature. The remote-control component enabled participants to have screen control, which allowed them to complete the study on the experimenter's computer. Participants were instructed to be in a quiet location where they would not be distracted. There were twelve different black and white visual stimuli labeled A1 through D3 (see Fig 3). On the screen, stimuli appeared on an all-white background.

Figure 3

Experimental Stimuli and Responses



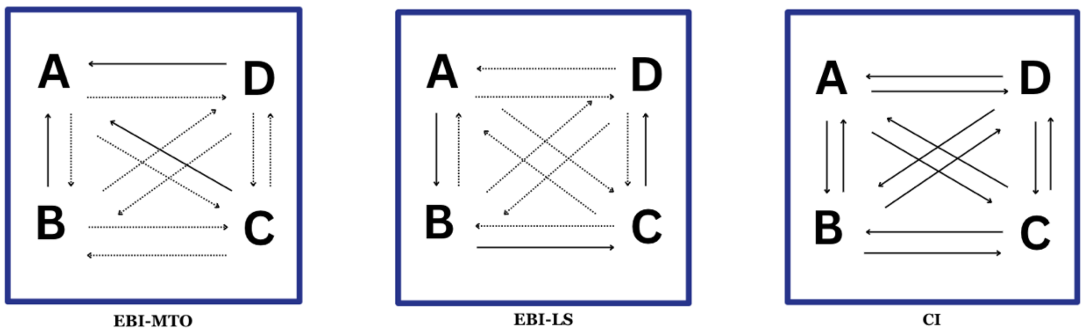
Procedure

Participants were randomly assigned to three groups. The EBI-MTO group (n = 21) was taught through EBI-MTO training procedure (BA, DA, CA), the EBI-LS (n = 20) learned via EBI-LS instruction (AB, BC, CD), and the CI group (n = 20) experienced CI (AB, BA, AC, CA, AD, DA, BC, CB, BD, DB, CD, DC). Examples for each teaching group are shown in Figure 4.

At the beginning of the study, a consent form to participate in the study was presented to each participant. The consent form stated that participants understood that they would be instructed to work on a computerized learning assignment. However, questions and the assignment information were not specifically described. After collecting the consent form, a demographic survey was presented for participants to complete. Then, the study started, and participants heard the experimenter say, “I will now start the computer program. The program will let you know what to do and when you are done.”

Figure 4

Experimental Groups



Note. The solid arrows show the trained relationship for each group, while the dotted arrows demonstrate symmetry and transitivity for EBI groups.

Phase 1: Class Establishment

In the beginning, participants were taught and tested on three 4-member stimulus classes (A1B1C1D1, A2B2C2D2, A3B3C3D3). A single sample stimulus was shown in the screen’s center for trials in both training and testing procedures. Three comparison stimuli were presented in the corner of the screen after the participants clicked a sample stimulus, which also continued to be displayed on the screen. Participants were instructed to do their best to select a stimulus from one of the corners. After selecting a comparison stimulus, all stimuli on the screen were removed. If participants clicked on the correct comparison stimulus during training, the screen’s center would display the word in green letters, “CORRECT!” However, if the selected comparison was wrong, red letters reading “INCORRECT” appeared. The feedback was shown for 1 s and then a 1-s intertrial interval occurred (ITI). A new trial commenced after each ITI was completed.

Table 2

Trained and Tested Relations

	EBI-MTO	EBI-LS	CI
Trained	BA, CA, DA	AB, BC, CD	AB, BA, AC, CA, AD, DA, BC, CB, BD, DB, CD, DC
Tested	AB, BA, AC, CA, AD, DA, BC, CB, BD, DB, CD, DC	AB, BA, AC, CA, AD, DA, BC, CB, BD, DB, CD, DC	AB, BA, AC, CA, AD, DA, BC, CB, BD, DB, CD, DC

Training. Participants saw these instructions at the beginning of training:

"You will see a stimulus appear in the middle of the screen. When you click on this stimulus with your mouse, you will see three other stimuli in three corners of the screen. Choose one of these stimuli by clicking on it. The computer will tell you if you have chosen the correct stimulus or not. The more correct responses you make, the sooner you will be done. Good luck!"

36-trial blocks occurred in the training procedure, which can be seen in Table 2. The CI group's 36 trial types (three different AB trials, three different BA trials, etc.) were presented randomly once per block. There were only nine potential trial types for MTO (three different BA, CA, and DA trials) and LS (three different AB, CB, and CD trials). Therefore, these possibilities were shown randomly four times. To move forward, participants had to respond in a single block accurately on 32 out of the 36 trials.

ABCD Test. Following training mastery, participants advanced to ABCD testing, in which the screen displayed these instructions:

"In the next phase of the study, the computer will not tell you if your responses are correct or incorrect. Please continue to do your best. The more correct responses you make, the sooner you will finish."

Tested relations are seen in Table 2. All groups received two 36-trial blocks, which totaled 72 trials for the ABCD test. In the second 36-trial block, if participants scored 90% or higher, they passed the ABCD test. Delayed emergence was the reasoning behind paying attention specifically to the second block for EBI groups (Holth & Arntzen, 1998). If participants did not pass the second test block for the ABCD test, they were required to complete more training and then took the ABCD test again. If this occurred, this message was shown:

"You will now continue to receive feedback on correct and incorrect responses. Please do your best, and remember that the more correct responses you make, the sooner you will be done."

This process continued until the ABCD test was completed at 90% or higher or until the study time (one hour) ran out.

Phase 2: Retention Test

Participants who achieved the 90% score were asked to come back for a retention test two weeks later. They were granted extra credit and an Amazon gift card for their return. The retention test was identical to the ABCD test. Groups consisted of EBI-MTO (n = 9), EBI-LS (n = 9), and CI (n = 10).

Results

Retention data were analyzed using Statistical Package for Social Sciences (SPSS). A 2 (test block) x 3 (training condition) mixed-model ANOVA was used to analyze the effects of test block (repeated measures) and training condition (between-subjects factor) on retention test scores.

There was a large, significant main effect of block, with higher scores in Block 2 than Block 1, $F(1,25) = 12.17$, $p < .01$, $\eta^2_p = .33$. For Block 1, mean scores were 56.2% for EBI-

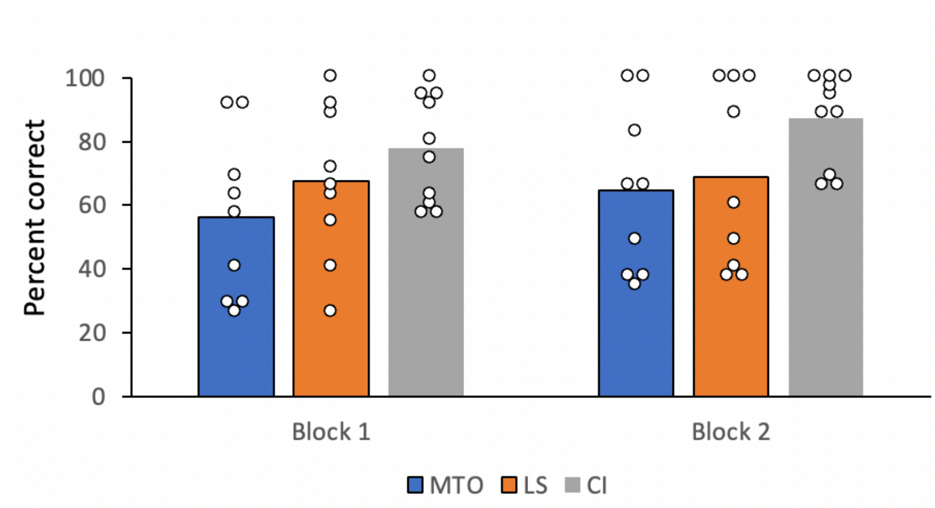
MTO, 67.6% for EBI-LS, and 77.8% for CI. In Block 2, mean scores were 64.5% for EBI-MTO, 68.8% for EBI-LS, and 87.2% for CI.

In comparison to EBI groups, CI demonstrated higher scores on the average as shown in Figure 4. However, the main effect of training condition was not statistically significant, $F(2,25) = 2.49$, $p = .17$. Additionally, no significant interaction was found between the test block and training condition $F(2,25) = 1.99$, $p = .16$.

When considering Block 2, participants who had a mastery score of 90% or above included two in EBI-MTO, three in EBI-LS, and five in CI. Therefore, these participants demonstrated that they had retained stimulus associations and their original mastery scores during the 2-week time frame.

Figure 4

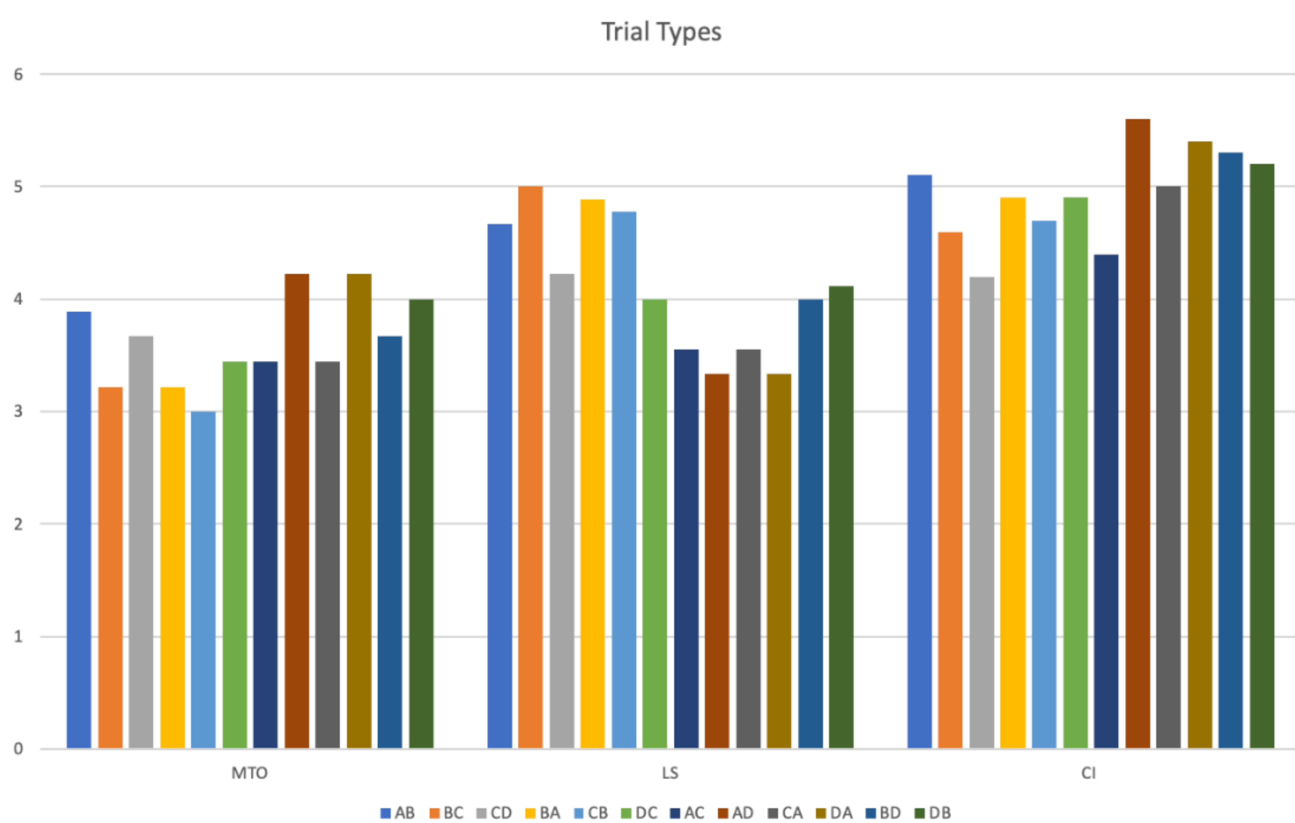
Retention Block Data



There were 12 stimulus associations (e.g., AB, BC) that appeared 6 possible times throughout the retention test as seen in Figure 5. The charts show each group's mean number of correct responses. In a repeated-measures ANOVA, each EBI group's total percentage correct in baseline, symmetry, and transitivity trials was compared. There was no significant effect of trial type in the EBI-MTO group, $F(2,16) = .58$, $p = .570$. However, the EBI-LS group showed a significant effect of trial type, $F(2,16) = 7.57$, $p < .05$ with Greenhouse-Geisser correction. Scores were significantly lower for the EBI-LS group in transitivity trials (AC, CA, AD, DA, BD, DB) than in the AB, BC, and CD baseline trials ($p < .05$) and the BA, CB, and DC symmetry trials ($p < .05$) as shown in Post hoc LSD tests. Scores in baseline and symmetry trials demonstrated no difference ($p = .51$)

Figure 5

Trial Type Means based on Experimental Group



The individual data underlying these differences are shown in Table 3, which shows the percentage of correct responses for each participant in the first three columns (trained, symmetry, and transitivity). Additionally, the mean for each group is listed in a separate row. The total error column accounts for the 72 total trials and the number of mistakes each participant made.

Table 3

Individual Participant Data based on Relations

	Trained	Symmetry	Transitivity	Total Errors
MTO01	88.9%	100.0%	97.2%	3/72
MTO03	33.3%	50.0%	38.9%	43/72
MTO05	72.2%	77.8%	50.0%	25/72
MTO07	27.8%	27.8%	41.7%	47/72
MTO08	44.4%	55.6%	30.6%	43/72
MTO10	77.8%	66.7%	52.8%	27/72
MTO12	94.4%	77.8%	66.7%	17/72
MTO13	11.1%	22.2%	47.2%	49/72
MTO14	94.4%	100.0%	94.4%	3/72
Mean	60.5%	64.2%%	57.7%	
LS01	55.6%	55.6%	27.8%	42/72
LS02	33.3%	33.3%	33.3%	48/72
LS03	94.4%	88.9%	97.2%	4/18
LS04	100.0%	100.0%	100.0%	0/72
LS05	100.0%	94.4%	63.9%	14/72
LS06	77.8%	83.3%	47.2%	26/72
LS10	100.0%	100.0%	100.0%	0/72
LS11	61.1%	66.7%	77.8%	35/72
LS17	72.2%	61.1%	77.8%	34/72
Mean	77.2%	76.0%	69.4%	
CI02	63.9%			26/72
CI07	84.7%			11/72
CI08	95.8%			3/72
CI10	95.8%			3/72
CI11	100.0%			0/72
CI13	87.5%			9/72
CI14	76.4%			17/72
CI15	62.5%			27/72
CI16	61.1%			28/72
CI19	95.8%			3/27
Mean	82.4%			

Discussion

Overall, the groups that received EBI and CI teaching procedures did not differ significantly in retention two weeks after passing the original ABCD test. Although the EBI-MTO demonstrated the lowest scores and CI the highest scores, this difference was not statistically significant. This finding might suggest that retention is not influenced by whether some or all relations are being directly trained. However, it is possible that teaching all stimulus associations (CI) might produce higher retention than EBI, but the insufficient statistical power in the study could not distinguish that difference. Essentially, the small number of participants who returned for the retention test was based on two reasons. First, if participants did not pass the 90% ABCD test during Phase 1, they were unable to return for the retention test. This rule eliminated 6 participants in EBI-MTO, 10 in EBI-LS, and 7 in CI. Also, there were some participants who passed the ABCD test in Phase 1, but voluntarily chose not to return for the retention test (5 in EBI-MTO, 1 in EBI-LS, and 3 in CI). Also, it is important to note that one MTO participant experienced a software malfunction with the retention test, and therefore was eliminated from the analyzation. Evaluating how EBI effects retention with a larger number of participants should be studied in the future. Furthermore, this data suggests that transitive associations could be at greater risk for decreased retention after linear-series training, which could also be investigated through more research.

The data in this study did not support the prediction that EBI groups would perform better than CI on a longer-term retention test. Although applied EBI research (e.g., Bolanos et al., 2020) has shown positive retention results, the current study showed that only a small number of EBI participants had retained correct responding from the test two weeks prior. It is possible that this study's arbitrary stimulus associations, instead of real-world knowledge might have impacted this outcome. It is necessary to conduct further research to examine if CI might have an advantage over EBI at producing long-term retention.

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