A Comparison of Match-to-Sample and Respondent Training of the Blocking Effect in Equivalence Classes

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ABSTRACT

Blocking occurs when previous conditioning with one stimulus reduces, or blocks, conditioning to a second stimulus when the stimuli are later presented as a compound. Basic research has suggested blocking may occur during equivalence class formation. Although both match-to-sample and respondent-type training are procedures used to facilitate emergent relations, research on blocking within equivalence classes has only been conducted using match-to-sample procedures. Since the two procedures are based on different types of conditioning, information on the presence of blocking in respondent-type equivalence classes would contribute to a more coherent explanation of equivalence class formation. Thus, the purpose of the present study was to compare match-to-sample and respondent-type training for their susceptibility to blocking in three-member equivalence classes. Results for the four participants who formed equivalence classes in the match-to-sample condition were mixed, with some displaying evidence of blocking and others displaying the formation of four-member equivalence classes. The two participants who formed equivalence classes in respondent-type training both showed the inclusion of the stimulus used in the blocking preparation and subsequent formation of four-member equivalence classes. Results are discussed with regard to implications for applied practitioners and directions for future research.

*Keywords***:** stimulus equivalence, match-to-sample, respondent-type training, blocking

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Of the many phenomena investigated by behavioral researchers, few have garnered more attention in the past few decades than stimulus equivalence (Sidman, 1971; Sidman & Tailby, 1982). Stimulus equivalence refers to the emergence of a number of untrained relations between stimuli after direct training of only some relations between the stimuli. Theoretically, the emergence of untrained relations is important because they provide an objective model of various behavioral phenomena traditionally thought to fall outside the realm of behavior analytic research, such as transfer of function and acquisition of symbolic language in humans (Chomsky, 1959; Clayton & Hayes, 2004; Sidman, 1994). From an applied perspective, the emergence of untrained relations has direct implications for teachers and students with regard to efficacy of instruction, since all relations between instructional stimuli may not need to be directly taught. Equivalence has been investigated in basic (Arntzen & Holth, 2000; Fields, Newman, Adams, & Verhave, 1993) and applied (Haegele, McComas, Dixon, & Burns, 2011; Taylor & O’Riley, 2000) research settings, with a variety of different populations such as typically developing adults (Smeets, Dymond, & Barnes-Holmes, 2000), individuals with autism (LeBlanc, Miguel, Cummings, Goldsmith, & Carr, 2003), and persons diagnosed with mental retardation (Saunders & McEntee, 2004).

Traditionally, stimulus equivalence has been regarded as a mainly operant phenomenon (Rehfeldt & Hayes, 1998). In match-to-sample training (MTS), which is the most widely utilized method to train these relations, an overt response is required from participants who are reinforced with feedback contingent on selecting the class-consistent comparison stimulus that correctly matches the sample during training sessions. After these initial sessions and initial relations are taught, tests for the untrained relations occur in the absence of reinforcement. If the participant responds with a high level of accuracy on testing trials for emergent relations, it is inferred that the stimuli have joined in an equivalence class and now function symbolically for one another (Sidman, 1994).

Other training procedures to teach the initial relations also typically employ some combination of an overt response requirement and reinforcement for responses in training (Leader & Barnes-Holmes, 1996). While reinforcement in training accounts for the acquisition of the explicitly taught relations, it does not account for the emergent relations that appear in testing phases (Rehfeldt & Hayes, 1998). This finding limits the extent to which operant conditioning alone can explain equivalence class formation, because the emergent relations themselves occur without any explicit reinforcement or training. In an attempt to examine the necessary and sufficient conditions for the emergence of untrained relations, Leader and Barnes-Holmes (1996) demonstrated a procedure, *respondent-type training* (ReT), resembling respondent rather than operant conditioning procedures that can reliably facilitate emergent relations between stimuli. Further, this procedure facilitates emergent relations without an overt response requirement of participants, subsequently calling into question what processes(s) may be involved in the formation of equivalence classes.

Stimulus Equivalence

Stimulus equivalence is a complex form of stimulus control demonstrated when direct training or instruction occurs for initial relations between stimuli and subsequently the individual reliably displays the emergence of a number of untrained relationships between stimuli (Cooper, Heron, & Heward, 2007; Sidman & Tailby, 1982). For example, a student may be taught to select a picture of a dog (B) when an instructor presents the auditory stimulus “dog” (A; A→B). Later, the student could be taught to select the printed word “DOG” (C) when presented with the picture of a dog (B; B→C). After the completion of this initial training, the student may display the emergence of several untrained relationships between stimuli indicative of equivalence class formation. These relations are *reflexivity*, *symmetry, transitivity*, and *equivalence*.

Reflexivity, also known as *identity matching*, occurs when the student is able to match a sample stimulus to itself in testing phases (i.e., A=A, B=B, etc.; Cooper et al., 2007; Fields & Verhave, 1987). Symmetry occurs if the student can display bi-directional relationships between sample and comparison stimuli (i.e., if A=B, then B=A, if B=C, then C=B). *Transitivity* occurs when an emergent relation (i.e., A=C, C=A) occurs after training two relations that share a common stimulus (i.e., A=B and B=C; Cooper et al., 2007). An *equivalence* relation occurs when a relationship between stimuli requires that some stimuli serve more than one function (Fields & Verhave, 1987). For example, if training the relations A→B and B→C, the relation of C→A would be an equivalence relation because for this relation to occur, symmetrical relations of B→A and C→B must have been established (Adams & Fields, 1993). All of these relationships must be present to meet the requirement for formation of an *equivalence class,* meaning that the stimuli are now presumably symbolic for, or related to, one another (Fields, Doran, & Marroquin, 2009; Fields & Verhave, 1987).

Using the above example on teaching a student an equivalence class consisting of stimuli related to dogs, after training a student who has formed an equivalence class will reliably tact the picture of a dog (i.e., symmetry; B→A), match the printed word “DOG” to the picture of a dog (i.e., symmetry; C→B), to receptively identify the printed word “DOG” (i.e., transitivity, A→C), and read the printed word “DOG” (i.e., equivalence, C→A) without direct instruction. Although these relations may appear in isolation of one another (i.e., the emergence of symmetry in the absence of transitivity or equivalence) all three are necessary to infer establishment of an *equivalence class.*

Features of equivalence classes. Several terms are used to describe features of the stimuli in equivalence classes and will subsequently be utilized throughout the remainder of the study. The term *members* refers to the number of stimuli being trained within a given class; and this is usually denoted with letters to represent the placement of the stimulus within the class. Further, membership within a *specific* class is denoted by a numerical subscript to illustrate the class to which the individual stimuli belong. For example, two 4-member equivalence classes would be notated as $A_1B_1C_1D_1$ and $A_2B_2C_2D_2$ so that the individual stimuli’s position and the class to which they belong to can be thus identified. The term *node* is used to refer to a stimulus linked to at least two stimuli within a stimulus equivalence class (Fields, & Verhave, 1987). For example, if the relations $A_1 \rightarrow B_1$ and $B_1 \rightarrow C_1$ were trained, B_1 would be a node, as it is linked to both

A_1 and C_1 within the equivalence class. Lastly, the *yield* refers to the number of emergent relations that result from direct training or association.

Applied research in stimulus equivalence. Numerous studies of applications of the equivalence paradigm have occurred since its discovery more than four decades ago. Sidman (1971) was the first to illustrate the emergence of stimulus equivalences in an applied setting in an effort to teach reading and reading comprehension skills to a 17 year-old with mental retardation and microcephaly. The participant showed good auditory comprehension skills and could receptively and expressively identify pictures. He could not, however, read printed words, receptively identify words, match pictures to words, or match words to pictures. Using MTS training, researchers taught the boy one of the relations: to receptively identify the printed word (i.e., A→C). During training, correct responses resulted in reinforcement and incorrect responses resulted in a correction procedure that delayed the trials from continuing until the participant made a correct selection. After training for 20 trials to 100% mastery, tests for emergent relations occurred and results indicated the emergence of relations enabling the student to read words (D→C), match pictures to words (B→C), and match words to pictures (C→B) all as a result of training only one relationship.

Since Sidman's (1971) initial use of equivalence training, the use of stimulus equivalence procedures in the context of instruction has expanded to teach many different skills in various populations. LeBlanc et al. (2003) used the equivalence paradigm to facilitate emergent relations between geographical stimuli in students with autism spectrum disorders. Two participants were taught geographic relations directly in the form of state names (A), state outlines (B), and the capital of the respective states (C). Results indicated both students displayed the emergence of relations between the geographical stimuli in all three classes. Haegele et al. (2011) used the equivalence paradigm to teach equivalencies between English and Native-American numbers and words to 36 typically developing pre-kindergarten students. Trained relations consisted of spoken English numbers to English digits (A→B) and spoken English numbers to Native American written numerals (A→C) after which tests for the emergence of derived relations occurred. Results indicated that the equivalence training group average on test of derived relations were significantly higher than students who received typical class instruction.

Lastly, Walker and Rehfeldt (2012) expanded the use of equivalence training by using selection-based equivalence training to teach single-subject research design to graduate students using the online Blackboard® application. Eleven students were taught equivalence classes consisting of names, definitions, graphical representations, and vignettes of single subject-research designs. The relations taught as prerequisites were name to definition (A→B), name to graph (A→C), and definition to vignette relations (B→D). Students were tested on emergent relations of B→A, C→A, D→A, and D→B, that required a typed response instead of selection of a stimulus. Results indicated that overall, (a) 6 participants displayed the emergence of the definition to name relation (B→A); (b) all 11 participants displayed the emergence of the graph to name tact relations (C→A); (c) and 7 of the participants displayed the emergence of the derived relations between the clinical vignette and name of the correct design relation (D→A).

This study was important for expanding the equivalence training technology to higher education as well as illustrating an initial integration of this training into web-based (i.e., Blackboard®) educational software.

Basic variables in class formation. A number of procedural variables that influence equivalence class formation have been identified through basic research including the training structure of the equivalence class, the training procedure used to form classes, class size, and training protocol (Arntzen, 2012; Arntzen & Holth, 2000). The interested reader is additionally referred to Fields and Verhave (1987) for a thorough analysis of additional variables within equivalence classes.

Training structure. Three basic methods are used to train the initial conditional discriminations between stimuli when facilitating equivalence class formation (see Figure 1; Arntzen, 2012). The following examples will use a four-member equivalence class (i.e., A→B→C→D). In a *linear series* training structure (LS), the initial relationships are taught in a manner where stimuli are related directly to one another with multiple stimuli serving as nodes (i.e., A→B, B→C, C→D, with stimuli B and C functioning as nodes). In a *many to one* (MTO) or *comparison as node* training structure initial relationships are taught in a manner where sample stimuli are related to one comparison stimulus (i.e., A→C, B→C, and D→C, where stimulus C functions as the node). Lastly, in a *one to many* (OTM) or *sample as node* training structure, the initial relationships are taught in a manner where one sample stimulus is related to the other comparison stimuli (i.e., A→B, A→C, and A→D, where stimulus A functions as the node) before emergent relations are assessed (Saunders & Green 1999; Saunders & Saunders, 1993).

Research into the differential effectiveness of each training structure has been mixed as to which procedure is more effective (Arntzen, 2012; Kinloch, McEwan, & Foster, 2013). Spradlin and Saunders (1986) demonstrated the differential effectiveness of OTM and MTO in a series of four experiments using MTS training. In the first three experiments, the authors attempted to teach participants with learning disabilities equivalence classes using the OTM procedure. In these three experiments, none of the participants displayed the emergence of untrained relations between stimuli, even with refinements and simplifications to the training protocol. Only after changing the training procedure from OTM to MTO did participants display the emergence of untrained relations between stimuli in probe sessions. The authors mentioned that along with individual differences in participants, the number and nature of discriminations between MTO and OTM may be a plausible explanation for the differential results (Saunders & Green, 1999).

Fields, Hobbie-Reeve, Adams, and Reeve (1999) examined the differential effectiveness of the MTO and sample as node OTM training structures using a between subjects design with 70 undergraduate student participants. Results of the study indicated that training type did not influence the percentage of participants whom acquired the initial conditional discriminations within the five-member (100% for OTM; 93% for MTO) and seven-member (67% for OTM; 70% for MTO) classes. Arntzen, Grondahl, and Eilifsen (2010) also examined the issue of differential responding between training structures by using a within-subjects design. Twelve participants were each taught a three- and four-member equivalence class using MTS training with each of the three training structures. Results of the study indicated that the LS produced the lowest yield of equivalence relations and OTM yielded more emergent relations than MTO for three-member classes. Their results also indicated than the LS required more trials to produce relations that both OTM and MTO with both three- and four member classes. Lastly, Kinloch et al. (2013) examined the relative effectiveness of the three training structures using 94 undergraduate participants. Results of the study indicated that the MTO and OTM procedures were very similar in their efficacy in programming for class formation, with both being superior to LS. Clearly, more research needs to be done to pinpoint the exact variables that determine the most effective training procedure (Arntzen, 2012).

Training procedures. There are a variety of procedures utilized to teach initial relations between stimuli in equivalence classes. For the purposes of the current investigation three different procedures utilized to train classes will be discussed: match-to-sample (MTS), respondent-type training (ReT), and simultaneous pairing two-response (SP2R) procedure.

In MTS training initial conditional discriminations are taught by reinforcing correct matching of a sample stimulus to the correct comparison in a stimulus array of two or more stimuli in training before tests for equivalence relations occur (Kinloch et al., 2013). For example, in teaching the relation $A_1 \rightarrow B_1$ in a three-member LS using MTS would begin with a presentation of a stimulus (A_1) as the sample, and presenting an array of two or more stimuli as comparisons (i.e., $B_{1,}$ B_2, and B_3). This procedure continues until all initial prerequisite conditional discriminations for the procedure are taught. After this, MTS test trials occur to assess for the emergence of the untaught relations in the absence of feedback for responses. An issue with MTS is that it may lack ecological validity because it may not represent natural contingencies or conditions under which equivalence classes form such as observational learning or all instances of relational learning (Dymond & Whelan, 2010).

Research aimed at examining whether or not the equivalence paradigm was a product of the overt response requirement in MTS training identified a procedure that reliably yields emergent relations in lieu of overt responses (Clayton & Hayes, 2004; Leader & Barnes-Holmes, 1996; Rehfeldt & Hayes, 1998), *respondent-type training*. This procedure has several advantages when compared to MTS, namely participants do not have the opportunity to respond incorrectly in training due to position biases in the comparison field or erroneous stimulus control during training (Omori & Yamamoto, 2013).

In ReT, the participant only needs to observe the stimuli as they occur in front of them. The stimuli are “paired” through contiguous temporal arrangement with one another. Shorter delays occur within pairs of stimuli and longer temporal delays occur between different pairs of stimuli (see Figure 2; Clayton & Hayes, 2004; Leader & Barnes-Holmes, 1996). For example, in training a three-member equivalence class using a LS with ReT, stimulus A_1 would appear on the screen for 1 second. After this, the screen is cleared for half a second (within-pair delay). Stimulus B_1 would appear on the screen for 1 second. Lastly, a 3 second between-pair delay occurs in which the screen goes blank before a new trial begins. This procedure is similar to the trace conditioning procedures in respondent conditioning preparations, but differs in that ReT typically produces bi-directional relations in which the stimuli become interchangeable (Mazur, 2013, p. 61; Smyth et al., 2006).

A number of studies have been conducted to assess the relative effectiveness of MTS and ReT and have produced mixed results (Clayton & Hayes, 2004; Kinloch et al., 2013; Leader & Barnes-Holmes, 2001). Leader and Barnes-Holmes (2001) examined the differential effectiveness of the MTS procedure and ReT using 6 undergraduates as participants. Results of the first experiment indicated that 3 of the participants responded correctly more often with the ReT classes and the other 3 scored highly regardless of the training procedure, tentatively suggesting a superiority ReT. In a second experiment, participants were required to respond correctly on 12 consecutive MTS trials prior to progressing through phases of the experiment. Again, results favored ReT, with all 6 participants correctly responding on tests for derived relations more often when trained with the ReT procedure.

Clayton and Hayes (2004) examined the relative effectiveness of the MTS and ReT procedures in a series of three experiments. Participants were trained on six 3-member equivalence classes, three using MTS ($A_{1\text{-}3} \rightarrow B_{1\text{-}3}$; $A_{1\text{-}3} \rightarrow C_{1\text{-}3}$) and three using ReT ($A_{1\text{-}3} \rightarrow D_{1\text{-}3}$; $A_{1\text{-}3} \rightarrow E_{1\text{-}3}$), both using the OTM training procedure. Results of all three experiments indicated that MTS training was superior to ReT in producing emergent relations on tests of symmetry, equivalence, and extended equivalence. Finally, Kinloch et al. (2013) also evaluated the effectiveness of the two training procedures and the number of initial training trials (60 or 120) used in each procedure using 94 undergraduate participants who were divided into groups that differed on type of training procedure (MTS or ReT) and number of training trials (60 or 120). Results indicated that the two training procedures were similar in producing emergent relations and that 120 trials resulted in a greater number of participants displaying derived relations.

Lastly, in the stimulus pairing two-response format (SP2R; Fields, Reeve, Varelas et. al. 1997; Fields et al., 2009) participants were taught to make initial discriminations between stimuli by way of training trials used to establish both within and between class memberships. Participants were trained to respond “YES” or “NO” to indicate whether or not a presented pair of stimuli belonged to the same equivalence class (Fields, et al., 2009). For example, if the relations $A_1 \rightarrow B_1$ and $B_1 \rightarrow C_1$ were taught in a trial to assess for the emergence of a transitive relation the participant would answer “YES” to the test trial of $A_1 \rightarrow C_1$ and “NO” to the trial that presented the pair $A_1 \rightarrow C_2$ (Fields et al., 2009). This procedure occurred for all pairs of stimuli in the experiment.

Fields, Reeve, Varelas et al., (1997) utilized the SP2R to produce emergent relations between abstract stimuli (i.e., nonsense syllables) using 18 undergraduate students. Results indicated that of the 18 participants, 10 formed four-member equivalence classes using the SP2R procedure. Additionally, this performance was maintained on MTS tests conducted after the SP2R procedure, indicating that the SP2R procedure may facilitate the emergence of equivalence classes in a similar manner to MTS training. In a series of three experiments Fields et al. (2009) examined whether or not the response labels typically utilized in the SP2R procedure (i.e. “YES” and “NO”) had an effect on class formation. The authors found no effect of the label used to indicate class membership after presentations, with different types of labels (e.g., “SAME” and

"DIFF") producing comparable yields in class formation. Although the SP2R procedure has been used effectively to establish emergent relations in class formation, its relative effectiveness with regard to other procedures such as MTS and ReT training has not been thoroughly investigated.

Class size. Class size describes the total number of stimuli linked through training in an equivalence class. The number of stimuli determines the number of derived relations that can emerge from training (Fields & Verhave, 1987). Arntzen and Holth (2000) examined the interactive effects of the number of members within a class and the number of classes currently being trained. Participants were 50 undergraduate students taught equivalence classes containing symbols and pictures. The participants were randomly assigned to one of 10 groups containing a specific number of classes (i.e., 3-6 classes) and each class contained a certain number of members (i.e., 3-6 stimuli per class). Results of this study indicated that class formation was affected more by the class size rather than the number of classes being concurrently trained. For example, when participants were trained with six 3-member classes, the yield was 60%. Conversely, when taught three 6-member classes, the yield was 20%. These results indicate that researchers should be cognizant of these effects between class size and number of classes when programming for the emergence of derived relations.

Training protocol. There are three main ways that the training and testing of relations can be interspersed with each other when classes are being formed. In the *simultaneous protocol,* all of the baseline relations are taught first in a randomized order in a single training block, after which tests for derived relations occur in the same randomized manner (Fields, Reeve, Rosen et. al, 1997). In the *complex to simple protocol,* all baseline relations are taught, after which tests for complex relations, like equivalence, occur. If these tests do not indicate the emergence of relations, tests for the prerequisite relations of symmetry and transitivity need to be conducted (Adams & Fields, 1993). The logic behind this protocol is that if the more complex relations has emerged, the simple symmetrical ones already have developed as they are thought to be prerequisites for more complex relations. Finally, in the *simple to complex protocol*, participants are trained and tested on simple relations between stimuli before tests for more complex ones occur. For example, after training the relation A→B, symmetry tests of B→A immediately occur. Contingent upon passing this test for emergent relations, the relation B→C is taught to criterion followed by C→B tests for symmetry, and the same procedure is also conducted for transitive relations (A→C). After this procedure is complete for all prerequisite relations, tests for complex relations of equivalence (C→A) occur. The logic of this method is that by testing for prerequisite relations for equivalence first, the complex relations of equivalence can be induced more readily than in the other protocols.

Fields, Landon-Jimenez, Buffington, and Adams (1995) utilized the simultaneous protocol to teach equivalence classes to 12 undergraduate students to investigate the effects of nodal distance of equivalence class formation. Participants were taught a total of two 5-member equivalence classes using the simultaneous protocol, after which tests for emergent relations occurred. Results indicated that of the 12 participants, only two (17%) initially displayed the emergence of equivalence classes. Other research on the use of the simultaneous protocol has illustrated comparably low yields as well, ranging from 33%-58% as reported by Fields et al. (1995). Adams and Fields (1993) compared the simple to complex and complex to simple training protocols for their effects on intersubject variability in equivalence class formation with 35 undergraduate students. Results of this study indicated that the simple to complex protocol produced lower intersubject variability on emergent relations tests than the simple to complex protocol. Tests of the complex equivalence relation were also passed with less trials in the simple to complex protocol, providing some evidence that it may be superior to the complex to simple protocol in producing emergent relations with regard to efficacy and levels of variability in responding on test trials (Adams & Fields, 1993).

Complex control in class formation. Complex stimuli consisting of more than one element have been examined for their ability to exert control over responding in class formation (Rehfeldt & Hayes, 1998). A *complex* or *multi-element* stimulus consists of more than one element and both elements acquire stimulus control over responding (Stromer, McIlvane, & Serna, 1993). For instance, instead of training A→B→C, a complex stimulus consisting of AB can be conditionally related to C (i.e., AB→C) with similar results on emergent relation tests where A, B, and C will function independently. If the members of the multi-element stimulus can exert control over responding and meet the requirements of class formation, time may be saved in training class formation. Conversely, when a stimulus consists of two elements but the stimuli only control responding when presented together, they are referred to as a *stimulus compound* (Stromer et al., 1993).

Carpentier, Smeets, and Barnes-Holmes (2000) examined the use of multi-element samples in equivalence class formation and how the individual elements can function as both compounds and complex stimuli. A total of 16 participants were taught to match stimuli consisting either of compound or simple stimuli. The trained relations for the participants were a variety of AB→C and C→D combinations to examine control of the multi-element stimulus over responding (i.e., $A_1B_1 \rightarrow C_1$, $A_2B_2 \rightarrow C_1$, and $A_1B_2 \rightarrow C_2$). Tests for either symmetry or rearranged symmetry occurred to assess for the formation of class-consistent and class-inconsistent relations between the stimuli. Results showed participants displayed the emergence of class-consistent and class-like relations between stimuli, where stimuli functioned as a compound or exhibited individual control as well.

Maguire, Stromer, Mackay, and Demis (1994) examined complex stimulus control in class formation. Six participants with developmental disabilities were taught to match compound to simple sample matching (i.e., AB→D) in an effort to examine the extent the individual elements (i.e., A, B, and D) exerted control as both comparisons and samples. Results indicated that the individual stimuli exerted control over responding, although A and B were never presented individually during initial training. This substitutability of control within the elements of the compound also held true in later experiments when the compound consisted of three elements (i.e., ABC) trained to a single element comparison.

Similarly, Groskreutz, Karsina, Miguel, and Groskreutz (2010) examined equivalence class formation trained with complex samples utilizing 6 students diagnosed with autism. Each participant was trained to conditionally relate a complex sample to a single element comparison (i.e., AB→C), after which emergent relation tests were conducted for class formation between single elements that were part of the complex sample (i.e., A→C). Results indicated that posttest scores on the single element relation tests improved significantly compared to baseline measures, indicating that both elements of the complex sample exerted control over responding, consistent with Maguire et al., 1994. Taken together, these results indicate that single elements of a compound exert control over responding even without individually training such relations between them.

Stimulus equivalence as a whole has not been explained by examining it as a purely operant phenomenon. For a more complete analysis of equivalence class formation, Rehfeldt and Hayes (1998) point to the need for investigations of respondent processes that may be involved in class formation such as overshadowing and Kamin's blocking effect (1968). If these, or similar respondent processes are apparent in class formation, it may be that the equivalence phenomena is not strictly a product of operant conditioning.

The Blocking Effect

Blocking occurs when previous conditioning with one stimulus reduces, or blocks, conditioning to a second stimulus when the stimuli are later presented as a compound (Mazur, 2013 p. 76). Blocking illustrates an instance where stimulus control does not develop when otherwise it would be expected to do so. The importance of the blocking effect is that it illustrates that temporal contiguity between stimuli is a necessary, but not sufficient condition for the development of stimulus control as stimuli that are presented together do not come to elicit responses in these experiments (Rehfeldt & Hayes, 1998).

Basic research on blocking. In his seminal study on blocking, Kamin (1968) utilized two groups of rats as subjects in a respondent based conditioned suppression procedure. In the blocking group the initial training phase consisted of pairing a light with an unconditioned stimulus until the light elicited a conditioned response (L+). In the control group this phase did not occur. In the second phase of training, both blocking and control groups were presented with a stimulus compound that consisted of a light and tone together until they elicited a conditioned response (LT+). In the final phase of the procedure, both groups were exposed only to the tone (T) to examine the extent to which the tone would elicit a conditioned response (Mazur, 2013, p. 76). Results indicated that in the control group, suppression of the bar pressing response was much greater than that of the rats in the experimental group. In essence, the tone had become redundant, or was "blocked", after being presented with the light which had already acquired stimulus control in previous experimental phases. The different levels of conditioned responding between groups was significant because both groups experienced the same number of trials with the tone *and* the light, with the only difference being that the control group did not have the initial L+ phase.

The blocking effect has been shown to occur reliably in a variety of other non-human animals such as rabbits (Marchant & Moore, 1973) and snails using a similar two stage procedure (Prados, Alvarez, Acebes, Loy, Sansa, & Moreno-Fernandez, 2013). The previous overview of complex stimulus control (Carpentier et al., 2000; Maguire et al.,

1994) is directly relevant to investigations into the blocking effect; blocking essentially establishes a situation when stimulus control over responding is not established with multi-element stimuli when otherwise it has been shown to do so.

Research on blocking in humans. Overall, research demonstrating blocking in humans has occurred but with considerably less success than with animal subjects (Bergen, 2009), although notable exceptions are present in the literature. Arcediano, Matute, and Miller (1999) examined the blocking effect using 30 undergraduate psychology students and utilized a procedure similar to Kamin's (1968). Participants played a computer game in which they were instructed that an ongoing response (i.e., a spacebar press) could prevent an alien invasion on the computer screen. Screen colors were manipulated as conditioned and unconditioned stimuli to signal oncoming invasions, and participants were instructed to stop pressing the space bar in the presence in one stimulus (US). In the experimental condition, a blocking preparation occurred similar to Kamin's in which a stimulus (i.e., screen color change) was correlated with the onset of the US until both suppressed responding. In the control group, no such stimuli were correlated with the US onset. In the next phase of training, both groups received training in which a compound of the screen color change and a complex tone (AX+) were paired with the presentation of the US. Results of the study indicated that participants in the experimental condition displayed significantly lower levels of spacebar pressing to the tone relative to controls, which was indicative of blocking. Results were significant for demonstrating the blocking effect in humans as well as the development of an ethical procedure to examine blocking conditioned suppression procedures with humans.

Crookes and Moran (2003) also used a computer game to test for the blocking effect. The participants (*N*=222) were instructed to find invisible goals on the screen. To help them, the screen gave clues, acting as conditioned stimuli, as to where participants needed to position their character in the game. In initial training phases, only one conditioned stimulus (i.e., screen color) was presented as a clue of the location of the goal. In a second phase, another stimulus was added to signal the goal's location, forming a compound consisting of two clues as to the location of the goal. Results indicated that reaction times to find the goal were longer with the stimulus added in the second phase, indicative of the blocking effect.

Blocking in equivalence class formation. This may be due to a variety of factors, including intersubject variability, experimental preparation, and ethical considerations regarding aversive stimuli present in some conditioned suppression procedures (Arcediano et al., 1999). One area of research which shows promise in examining blocking in humans is equivalence class formation (Bergen, 2009). In the first study to extend the blocking phenomenon to equivalence class formation, Rehfeldt, Dixon, Hayes, and Steele (1998) examined how a prior history of conditional discrimination training with single elements in MTS training could block the inclusion of a second stimulus in an equivalence class. Ten undergraduate students were trained to relate stimuli in a manner analogous to blocking preparations (i.e., A→B, AX→B, and B→C, respectively), after which tests for blocking and derived relations occurred. Evidence of blocking was evaluated by comparing scores on test trials for emergent relations when X was a sample or a comparison. Five of the 10 participants showed the formation of three 3-member equivalence classes and subsequently showed evidence of a blocking effect. Additionally, the participants who showed the formation of equivalence classes also had the lowest scores on tests for within-compound relations between the stimuli that comprised the compound stimulus (i.e., A and X).

In a similar experiment, Rehfeldt, Clayton, and Hayes (1998) examined the blocking effect in equivalence classes with five-member equivalence classes. Six participants were trained to conditionally relate A→B, A→C, AX→B AX→C, and C→D. Evidence of blocking was evaluated by comparing scores on test trials for emergent relations when X was a sample or a comparison. The results demonstrated that only 2 participants displayed the formation of equivalence classes; one participant showed a reliable blocking effect while the other participant displayed the emergence of six-member classes, indicating the stimulus that was programmed to be blocked entered into the class with the other five stimuli.

In both of the studies on blocking in class formation, the majority of participants who formed equivalence classes between stimuli also exhibited a strong blocking effect (six of seven total). As mentioned, results such as these are the opposite of those normally found in research on complex stimulus control (Carpentier et al., 2000; Maguire, et al., 1994). Since equivalence class formation is normally treated as an operant phenomenon and studied using an operant based training procedure (MTS), examinations of the susceptibility of the ReT procedure (which is based on associative learning) to blocking would provide a clearer understanding of the processes involved in equivalence class formation in a more general sense. Thus, the purpose of the present study was to systematically replicate Rehfeldt, Dixon et al., (1998) and Rehfeldt, Clayton, et al., (1998) by examining both MTS and ReT for their susceptibility to the blocking effect while also utilizing control groups to provide a more experimentally sound demonstration of the blocking effect in equivalence classes.

Method

Participants, Settings, and Materials

Participants were 27 undergraduate students enrolled at Youngstown State University recruited using a sign-up sheet outside the Psychology Department. Informed consent was obtained from all participants prior to the study. Each participant was randomly assigned to one of the four groups: MTS control, MTS experimental, ReT control, or ReT experimental. Each participant was also assigned a unique subject number used in place of their name to identify their experimental data.

The training and testing sessions occurred in an 8.5m x 4.5m computer lab that contained 12 computers, tables, and chairs that was quiet and free from distractions. Each participant was tested individually. Participants sat at the table in front of the computer screen. Each experimental session ranged anywhere from 30 min to 1 hr for each participant, depending on their response speed during MTS trials. This allowed enough time to complete the training trials as well as subsequent tests for emergent relations and blocking.

Stimuli in all conditions consisted of twelve 5cm x 5cm abstract symbols presented using Microsoft PowerPoint® software (see Table 1). Data were recorded using paper and pencil by the experimenter (Appendix A and B) for all MTS training and testing phases. No data were recorded in ReT training sessions, as no overt participant response was required in this condition.

Experimental Design, Dependent Variable, and Interobserver Agreement

The relative effects of MTS and ReT in facilitating emergent relations and their susceptibility to blocking was evaluated by analyzing differences in percent correct between experimental and control groups on all tests for emergent relationships that contained the redundant stimulus included in the blocking preparation (i.e., a total of three of the nine relationships). Results were also analyzed for differences in susceptibility between the two training procedures for initial relations. In both conditions, participants in the experimental conditions were trained on three relations (A→B, AX→B, B→C; see Table 2). In both control groups, two relations were taught (AX→B, B→C) for both conditions. In all four groups, 9 derived relations were tested using MTS (see Table 3).

The dependent variable in this study was the percentage correct on test trials for emergent relations. Of particular interest was the percent correct on trials with the redundant stimulus included in the blocking preparation. During both MTS training and testing phases, a *correct response* was defined as selecting the appropriate comparison stimulus (i.e., pointing to or saying “left”, “center”, or “right”) in the comparison field belonging to the same class as the sample (i.e., selecting B_1 when it was a comparison and A_1 was the sample and not selecting comparisons B_2 or B_3). An *incorrect response* in MTS training and testing trials was defined as the participant selecting any other stimulus in the comparison field. In all testing phases, there was no feedback for responding.

An independent observer collected reliability data of during 53% of all MTS training sessions, 64% of all MTS testing sessions, and 41% of ReT testing sessions. Percentage agreement was calculated by using the total count method in which the smaller observed frequency of correct responses during interobserver agreement sessions is divided by the larger observed frequency of correct responses and multiplied by 100. The second observer did not provide any consequences or feedback to the participants at any time and was seated so that participants could not be influenced by the recorded data. Interobserver agreement was 100% in MTS training sessions, 99% in MTS testing sessions (range: 95%-100%), and 99% in ReT testing sessions (range: 97% to 100%). Data were also collected on the integrity of the experimenter's response during MTS training (i.e., saying "That's correct" or "That's incorrect") on 53% of MTS training trials and was calculated at 100%.

Procedure

Respondent-type training. During respondent-type training, participants sat at the computer workstation which displayed on-screen instructions for the first phase of the experimental procedure. These instructions are adapted from Leader and Barnes-Holmes (1996):

> "During the first stage of this experiment you will be presented with abstract shapes on the computer screen. Your job is to simply pay attention to the symbols as they appear. You should pay close attention to this first stage because it is relevant to the second stage of the experiment. Press the space-bar when you are ready to begin."

After this, ReT began and stimulus pairs were presented on the screen. Presentation consisted of the first stimulus element or compound displayed for 1 s, followed by a .5 s within-pair delay. The second stimulus was presented for 1 s, and followed by a 3 s between-pair delay (Figure 2). This procedure was repeated in randomized loop until all individual pairs were presented 10 times for a total of 120 pairs in the experimental condition and 90 pairs in the control condition.

A→B respondent-type training. In this phase the A stimulus was presented, followed by the B stimulus in a randomized order, 10 times each, for a total of 30 stimulus pairings. This phase only occurred in the experimental groups.

AX→B respondent-type training. In this phase a compound stimulus (AX) was initially presented followed by the B stimulus for each class (AX→B). Pairs were presented 10 times each for each class for a total of 30 pairs. Positions of the stimuli in the compound were randomly rotated between left and right but always appeared in the same location on the computer screen. This condition and all additional phases in training (B→C, Mix AX→B) occurred for both the experimental and control conditions.

B→C respondent-type training. In this phase the B stimulus for each class was presented and then followed by the C stimulus for each class. Each pair was presented 10 times for a total of 30 pairs.

Mix AX→B and B→C respondent-type training. In this phase the AX→B and B→C relations were presented in a randomized order 15 times each, for a total of 30 trials. The positions of the stimuli in the compounds were randomly rotated between left and right by the computer program, but always appeared in the same location on the computer screen.

Match-to-sample training. During MTS training, participants were seated at the computer workstation which displayed on-screen instructions for the first phase of the experimental procedure. These instructions were as follows:

> "During this stage of the experiment, your task is to find out which of the stimuli belong together. You will be presented with one symbol in the bottom of the screen and three more on the top of the screen. Your job is to select the one at the top that goes with the one on the bottom by telling the experimenter your choice by saying left, middle, or right to indicate the left, center, or right symbol as your choice. In some phases, you will receive feedback on your selection but in others you will not. The experimenter is always keeping your score, whether you get feedback or not. When you are ready to continue, please press space."

After this, MTS training began in the manner described above. On commencement of a MTS trial, sample stimuli appeared centered on the bottom portion of the screen, and 3 comparison stimuli appeared on the top portion evenly spaced from left to right. All presentations of trials as well as the position of the comparison stimuli were randomized. Contingent upon a correct response in MTS training, the experimenter said "That's correct" before the next trial was presented. Incorrect responses resulted in the experimenter saying "That's incorrect". Participants were required to score 86% correct on each of the MTS training phases in order to continue. If a participant failed to achieve a score of 86%, the training began again. When a participant failed a phase four times, he/she was eliminated from the study. Thus, the number of minimum trials was 120 for the experimental and 90 for the control group, but the actual number of trials could be higher due to individual differences in responding during training phases.

A→B match-to-sample training. In this phase the sample stimuli on the bottom was an A stimulus (A_1, A_2, or A_3) and comparisons were all three of the B stimuli (B_1, B_2, or B_3). The correct response in this condition was selecting the class consistent B comparison stimulus in the presence of the appropriate A stimulus (i.e., $A_1 \rightarrow B_1$). Each of these three relations was presented 10 times for a total of 30 trials. This phase occurred only in the experimental group during MTS training.

AX→B match-to-sample training. In this phase, a compound stimulus consisting of an A stimulus with an additional redundant stimulus was the sample (i.e., $AX_{1\text{-}3}$) and the B stimuli ($B_{1\text{-}3}$) were comparisons. The correct response was selecting the class consistent B stimulus in the presence of the compound (i.e., $AX_1 \rightarrow B_1$). This phase and all additional phases (B→C, Mix AX→B and B→C) occurred for both the experimental and control conditions in the MTS condition.

B→C match-to-sample training. In this phase the sample stimulus on the bottom was the B stimulus ($B_{1\text{-}3}$). Comparisons were all three of the C stimuli ($C_{1\text{-}3}$). The correct response was selecting the class consistent C stimulus in the presence of the B stimulus (i.e., $B_1 \rightarrow C_1$). Each of these three relations was presented 10 times for a total of 30 trials.

Mix AX→B and B→C match-to-sample training. This phase consisted of the presentation of 30 mixed trials of AX→B and B→C relations. The positions of the stimuli in the compound were randomly rotated between left and right, but always appeared in the same area of the screen. The correct response was to select the class consistent comparison as described above (i.e., $AX_1 \rightarrow B_1$).

Tests for emergent relations and blocking. After completion of all training relations, tests for emergent relations and blocking occurred for all participants. Prior to the testing phase, the following directions were displayed on the screen:

> "In this stage you must look at the symbol at the bottom of the screen, and then choose one of the symbols or group of symbols at the top that it goes with. You are to tell the experimenter your choice by saying left, middle, or right to indicate the left, center, or right symbol as your choice. You will not be presented with any feedback for correct or incorrect answers in this portion of the experiment, but the experimenter is still recording your score. Press the space-bar to continue. "

At this point, each participant was presented with MTS tests for emergent relations described above (i.e., A→X, X→A, B→A, B→X, C→B, A→C, X→C, C→A, C→X) for all three classes of stimuli three times, resulting in a total of 81 testing trials. No feedback for responding was presented in this phase of the experiment. After participants finished tests for emergent relations, their participation concluded and participants were debriefed, offered the opportunity to ask questions of the experimenter, or were dismissed.

Results

Of the 15 participants who began in one of the MTS conditions, 14 completed the initial conditional discrimination training before moving on to emergent relations and blocking tests. Tables 4 and 5 show the scores on emergent relations and blocking tests for participants in both the MTS and ReT training conditions. Table 6 shows the number of trials participants took to complete conditional discrimination training for each phase in the MTS condition. Overall, the average number of trials necessary to complete a single phase were similar between experimental (*M* = 1.67) and control conditions (*M* = 2.00). In addition to the 6 participants who demonstrated the formation of three 3-member equivalence classes, several participants demonstrated the formation of some, but not all emergent relations (see Table 7).

Overall average scores on test trials in the MTS condition were higher (*M* = 66.27, *SD* =26.22 in MTS; *M* = 50.39, *SD* = 34.17 in ReT) than in the ReT condition. Further, more participants in MTS training produced displayed the formation of all three 3-member classes, as well as displayed the emergence of more emergent relations overall. Of the 6 participants who displayed the emergence of three 3-member equivalence classes 4 were in the MTS condition and 2 were in the ReT experimental condition.

Blocking

The presence of blocking was evaluated by examining the differences between test trials that contained the X stimulus, which was programmed to be blocked in experimental groups, and test trials that did not contain the X stimulus. For the purposes of the current study, data were analyzed at three different levels: (a) for all participants, regardless of their performance on test trials; (b) for all emergent relations displayed by participants in the study; (c) for only those participants only who showed the emergence of three 3-member equivalence classes (see Table 3).

Blocking for all participants. Table 8 lists the scores on tests for emergent relations containing the X stimulus and trials without the X stimulus for all participants in both MTS and ReT conditions. For all participants, average scores on non-X trials in the MTS experimental group were higher (*M* = 72.22, *SD* = 21.51*)* than on trials containing the X stimulus (*M* = 52.38, *SD* = 26.81). Scores on non-X trials in the MTS control group were also were higher (*M* = 60.32, *SD* = 29.01) than scores on trials containing the X stimulus (*M* = 48.68, *SD* = 29.99). Scores on within-compound relations tests were similar in both groups in the MTS condition (see Figure 6). Overall, reduced scores on trials containing the X stimulus were not unique to the experimental group that contained the blocking preparation when data were examined for all participants who completed the study.

Average results in the ReT experimental group showed little evidence of the blocking effect. Scores on trials containing the X stimulus were slightly (*M* = 55.55, *SD* = 35.03) higher than scores on non-X trials (*M* = 54.63, *SD* = 35.89) in the ReT experimental condition. In the ReT control group, scores on non-X trials (*M* = 41.67, *SD* = 30.13) were slightly higher than on trials that contained the X stimulus (*M* = 39.51, *SD* = 19.33). Overall, the ReT condition resulted in lower scores on tests for equivalence and blocking than MTS and differences between test trials containing the X and those that did not in ReT were negligible. Scores on within-compound relations were lower in the ReT control condition relative to the scores in the ReT experimental condition (see Figure 6).

All emergent relations. Table 9 lists the scores on blocking and non-blocking trials with respect to *all* emergent relations (defined as a minimum average score of 77%

on non-X test trials for a single relation) for both MTS and ReT conditions. This includes participants who formed three 3-member equivalence classes as well as those who displayed the emergence of some, but not all relations between stimuli. In the MTS condition, scores on non-blocking trials (*M* = 92.31, *SD* = 9.12) were substantially higher than on blocking trials (*M* = 60.00, *SD* = 35.55). Similarly, scores on non-blocking trials in the MTS control condition (*M* = 90.91, *SD* = 9.25) were also higher than those on blocking trials on non-X trials (*M* = 66.67, *SD* = 26.03). Overall, scores between control and experimental groups were not substantially different with regard to differences on scores for trials containing the X stimulus and those that did not, with both groups showing lower scores on X trials.

Scores in the ReT experimental condition were slightly higher on non-X trials (*M* = 98.77, *SD* = 3.49) than on trials containing the X stimulus (*M* = 96.83, *SD* = 11.66). In the ReT control condition, scores on non-blocking trials (*M* = 90.74, *SD* = 9.97) were also higher than on blocking trials (*M* = 46.30, *SD* = 14.93). Scores in the ReT experimental condition did not show differences between X and non-X trials apparent in the ReT control group and two MTS groups.

Scores by emergent relation type. Figures 7 and 8 displays the scores on tests for emergent relations for both MTS and ReT conditions for all participants who showed emergent relations. Figure 9 displays the scores on blocking and non-blocking trials for these relations by emergent relation type (i.e., symmetry, transitivity, and equivalence) in both MTS training conditions. In the MTS experimental group, scores on non-X trials were similar regardless of relation type. Scores on blocking were substantially lower than non-blocking trials for all types of relations, with differences varying slightly by relation type. For example, scores on blocking trials for transitive relations (i.e., X→C) were the highest in the MTS experimental group, followed by symmetry and equivalence respectively. Scores on non-X tests were also similar in the MTS control group regardless of relation type. Scores on trials containing the X stimulus in the MTS control group were slightly higher than in the experimental groups, with results on X trials for symmetry being much lower for transitive or equivalence relations.

Figure 10 displays the scores on blocking and non-blocking trials by relation type for emergent relations in the ReT training condition. In the ReT experimental group, scores on test trials were high regardless if they contained the X stimulus or not. In the ReT control condition, scores on non-X trials were much higher on tests for symmetrical and transitive relations and were the same on tests for equivalence relations.

Participants displaying the emergence of all classes. In sum, 6 of the 26 participants who completed the study displayed the emergence of all three equivalence classes. Single-subject analysis for blocking for these 6 participants provided mixed results with regard to blocking (Figure 11). In the MTS condition, there were participants who showed and did not show evidence of blocking. For instance, Participant 0103 displayed the formation of three 3-member equivalence classes and subsequently indicated a strong blocking effect (M = 91.67 on non-X trials compared to M = 25.93 on trials containing the X stimulus). Conversely, Participant 0102 (who underwent the same preparation) did not illustrate this effect (M = 97.22 on non-X trials compared to M = 92.59 on trials containing the X stimulus) and instead displayed the formation of three 4-

member equivalence classes. In the MTS control group (which did not contain the blocking preparation), Participant 0204 displayed the emergence of three 3-member equivalence classes and also displayed a strong blocking effect (*M* = 91.61 on non-X trials compared to *M* = 59.26 on trials containing the X stimulus). Conversely, Participant 0201 (who underwent the same preparation) did not display this effect (*M* = 91.67 on non-X trials compared to *M* = 96.30 on trials containing the X stimulus), instead showing evidence of the emergence of three 4-member equivalence classes.

In the ReT condition, there were 2 participants who showed the emergence of three 3-member equivalence classes, both of whom were in the ReT experimental group. Both participants displayed little evidence of blocking despite being in the experimental group. Participant 0302 scores indicated the emergence of four 3-member equivalence classes *(M* = 97.22 on non-X trials compared to *M* = 92.59 on trials containing the X stimulus). Similarly, Participant 0305 displayed the emergence of three 4-member equivalence classes by scoring perfectly on all tests (*M* = 100.00 on non-X trials and *M* = 100.00 on trials containing the X stimulus). No participants showed the emergence of all three 3-member equivalence classes in the ReT control group. In sum, the participants who displayed the emergence of equivalence classes in ReT did not display evidence of the blocking effect. This was in contrast to participants in the MTS condition whose results were mixed with some participants displaying evidence of blocking and others who did not.

Discussion

The current study addressed a limitation of past research on blocking in equivalence class formation by utilizing control conditions while subsequently expanding the literature by examining for blocking in respondent-trained equivalence classes. Analysis of scores based on average differences on scores between X and non-X trials scores or by differences with regards to singular emergent relations displayed evidence indicating blocking was prevalent in all but one group (ReT experimental). Thus, when data were analyzed for *overall* scores regardless of class formation or for scores of the and by *emergent relations* (both those participants who formed all classes and for those who showed the formation of some, but not all relations) in these three groups, scores were indicative of stimulus blocking and may be taken as tentatively systematic with Rehfeldt, Dixon et al., (1998) in which blocking was prevalent for all participants. Overall, the MTS procedure was more effective in facilitating the emergence of equivalence classes, but the ReT condition produced classes that were less susceptible to blocking.

When data were examined for *only* those participants who showed the formation of all three 3-member equivalence classes, results were more consistent with Rehfeldt, Clayton et al., (1998) in which some participants showed evidence of a strong blocking effect while the other did not. Similarly, of the four participants in this study who formed classes in the MTS condition, two showed evidence of blocking and two did not. Future research should aim to identify variables that influence class formation and could be responsible for the different individual scores present on X trials and non-X trials between participants trained with MTS. One such variable could be the use of a differential observing response (DOR) in which participants are made to explicitly attend to both of the stimuli used in training in compound training phases.

Conversely, the two participants in the ReT condition training who showed the emergence of all three equivalence classes displayed the inclusion of the redundant stimulus into the equivalence classes despite being in the experimental group which contained the blocking preparation. These results, although limited to the data of two participants, may provide evidence of different learning processes (associative and operant) involved in MTS and ReT training procedures (Rehfeldt & Hayes, 1998). Further, the current study was also the first to examine the use of ReT with complex samples (in the ReT control condition) as was done with Groskreutz et al. (2010) and Maguire et al., (1994) using MTS training. Results indicated that participants in the ReT control condition, which was similar to the procedure used in Maguire et al. (1994) and Groskreutz et al. (2010), showed few emergent relations and low overall scores on tests for emergent relations.

Although the current study represents an examination of blocking in class formation from a basic research standpoint, the results have implications for the applied practitioner. As mentioned, low scores on X trials were present in both experimental and control groups in the MTS condition, but this effect was not apparent in classes formed under ReT training. It may be that the ReT procedure, which is based on associative rather than operant conditioning procedures, may be less susceptible to blocking. While the data in the current study are limited, stimulus pairing may offer practitioners more flexibility in relating additional stimuli to one another without as great of a risk of blocking, but more research is needed before concrete recommendations can be made.

On a related note, the ReT training utilized in this study is not the only type existent in the literature on emergent relations. In the current study, the ReT preparation was analogous to trace conditioning procedures, as the two stimuli to be related were presented after short delays and never appeared together (Mazur, 2013 p. 61). A similar, but not identical procedure based on associative learning is called the *stimulus pairing observation procedure* and has received empirical support (Rosales, Rehfeldt, & Huffman, 2012; Smyth, Barnes-Holmes, & Forsyth, 2006). This procedure is analogous to short delay respondent conditioning preparations, as the second stimulus is presented *simultaneously* with the first after the short within-pair delay (Mazur, 2013 p. 61). Future research should examine different ReT preparations for their susceptibility to blocking and for their relative effectiveness compared to MTS in an effort to inform best practices for practitioners in applied settings. If other associative based preparations could be shown to be less susceptible to blocking and show improved scores relative to MTS training, practitioners would be afforded a simple yet effective method for programming for emergent relations when instructing their students.

Two limitations of the current study should be addressed in future research. First, the current study utilized the LS training model, which typically produces lower scores on emergent relation trials when compared with OTM or MTO procedures (Arntzen, 2012; Saunders & Green, 1999). Only six of 26 participants overall between both conditions displayed emergence of all classes relations and formations of three 3-member equivalence classes. Future research into blocking may benefit from the use of the other two training structures that have been demonstrated to facilitate emergent relations more reliably. Further, it would be of general interest to see how susceptibility to blocking may vary as a function of different training structures.

Secondly, the current study, in keeping consistent with the previous research on blocking in class formation utilized a mix condition following B→C training in all four groups. This phase may have served to weaken or dilute the blocking effect in the two experimental groups. It may be the case that this extra experience (and reinforcement of in the MTS conditions) on AX→B relations may have weakened the control exerted by the A stimulus relative to the compound AX, making it more likely A would function as a compound (i.e., AX instead of A). Typically, animal research on blocking does not contain similar phases on already learned or acquired responses to stimuli when blocking is demonstrated. Future research should examine the effects of eliminating this extra phase to examine if evidence of blocking may become more consistent as a result.

One point for future research was noted anecdotally during experimental sessions. As discussed, both participants in the ReT condition who formed all three classes also showed the inclusion of the redundant stimulus and the subsequent formation of four 3-member equivalence classes. These results were not consistent with the findings of the MTS condition, in which those participants who displayed the formation of all three-member classes did not necessarily show inclusion of the redundant stimulus and subsequent formation of four 3-member equivalence classes. In post-experimental debriefings, both participants who displayed the emergence of full equivalence classes in

ReT indicated that they formulated names for each of the stimuli that appeared on the screen. These indications, although anecdotal in nature, may provide evidence consistent with Horne and Lowe's (1996) *naming hypothesis,* which identifies naming as the basic unit of verbal behavior. Future research could examine this effect by requiring participants in some conditions to learn nonsense or formulate labels for abstract stimuli before progressing through ReT training of equivalence classes. As a result, researchers may begin to gain a more complete understanding of the sufficient and necessary conditions for equivalence class formation for respondent-based training procedures, and thus a more coherent account of the equivalence phenomena overall.

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Table 1.

Stimulus designations for each symbol used in the study for all groups

A, B, C Stimuli			X Stimuli
♋	✠	♉	⌘
⌧	♑	♒	♓
♐	❖	♍	♎

Table 2.

Trained relations in both training procedures across conditions

	Training	
Conditions	MTS	ReT
Experimental	A→B, AX→B, B→C, Mix	A→B, AX→B, B→C, Mix
Control	AX→B, B→C, Mix	AX→B, B→C, Mix

Table 3.

Standard test trials and their corresponding blocking trials in the current study

Trial Type	Symmetry	Transitivity	Equivalence
Standard (Non-X trials)	B→A, C→B	A→C	C→A
Blocking (X trials)	B→**X**	**X**→C	C→**X**

Table 4.

Percent correct responses on derived relations tests by trial type participants in the MTS condition

	Testing Trial Type								
	Non-Blocking Tests					Blocking Tests			
Participant	B-A	C-B	A-C	C-A	*M(SD)*	B-X	C-X	X-C	*M(SD)*
0101	66.67	77.78	22.22	44.44	52.78 (24.64)	0.00	22.22	55.56	25.93 (27.96)
0102	**88.89**	**100.00**	**100.00**	**100.00**	97.22 (5.56)	100.00	77.78	100.00	92.59 (12.83)
0103	**88.89**	**100.00**	**77.78**	**100.00**	91.67 (10.64)	33.33	11.11	33.33	25.93 (12.83)
0104	55.56	88.89	44.44	55.56	61.11 (19.25)	88.89	44.44	55.56	62.96 (23.12)
0105	66.67	55.56	55.56	66.67	61.11 (6.42)	44.44	33.33	33.33	37.03 (6.41)
0106	100.00	77.78	66.67	55.56	75.00 (18.97)	88.89	55.56	44.44	62.96 (23.12)
0107	55.56	100.00	44.44	66.67	66.67 (24.00)	66.67	55.56	55.56	59.26 (6.41)
0201	**88.89**	**88.89**	**88.89**	**100.00**	91.67 (5.55)	100.00	100.00	88.89	96.30 (6.41)
0202	33.33	77.78	33.33	22.22	41.67 (24.63)	66.67	11.11	11.11	29.63 (32.07)
0203	66.67	22.22	33.33	55.56	44.44 (20.28)	33.33	22.22	0.00	18.52 (16.97)
0204	**100.00**	**100.00**	**100.00**	**77.78**	94.44 (11.11)	44.44	55.56	77.78	59.26 (16.97)
0206	11.11	77.78	33.33	11.11	33.33 (31.42)	55.56	33.33	33.33	40.74 (12.83)
0207	66.67	66.67	55.56	55.56	61.11 (6.41)	88.89	44.44	22.22	51.85 (33.94)
0208	33.33	100.00	55.56	33.33	55.56 (31.42)	11.11	66.67	55.56	44.44 (29.39)

Note. Participant 0205 did not complete the initial conditional discrimination training.
Bold type indicates formation of three-member equivalence classes.
Underlined scores indicate singular emergent relations.

Table 5.

Percent correct responses on derived relations tests by trial type participants in the ReT condition
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	Testing Trial Type								
	Non-Blocking Tests					Blocking Tests			
Participant	B-A	C-B	A-C	C-A	*M*(SD)	B-X	C-X	X-C	*M*(SD)
0301	11.11	33.33	11.11	33.33	22.22 (12.83)	33.33	66.67	11.11	37.03 (27.96)
0302	**100.00**	**100.00**	**100.00**	**88.89**	**97.22** (5.55)	77.78	100.00	100.00	92.59 (19.24)
0303	33.33	0.00	22.22	66.67	30.55 (27.78)	11.11	33.33	11.11	18.51 (12.83)
0304	100.00	33.33	66.67	66.67	66.67 (27.21)	100.00	33.33	33.33	55.56 (38.49)
0305	**100.00**	**100.00**	**100.00**	**100.00**	**100.00** (0.00)	100.00	100.00	100.00	100.00 (0.00)
0306	33.33	0.00	55.56	44.44	33.33 (24.01)	33.33	33.33	22.22	29.62 (6.41)
0401	33.33	88.89	33.33	11.11	41.67 (33.18)	44.44	88.89	11.11	48.14 (39.02)
0402	22.22	100.00	22.22	22.22	55.56 (38.88)	44.44	22.22	55.56	40.74 (16.97)
0403	33.33	100.00	33.33	22.22	47.22 (35.57)	33.33	22.22	33.33	29.62 (6.41)
0404	33.33	100.00	33.33	22.22	47.22 (35.57)	33.33	33.33	33.33	33.33 (0.00)
0405	33.33	22.22	0.00	11.11	16.67 (14.34)	33.33	44.44	33.33	37.03 (6.41)
0406	22.22	44.44	77.78	77.78	55.56 (27.21)	11.11	77.78	44.44	44.44 (33.33)

Note. Bold type indicates formation of three-member equivalence classes.
Underlined scores indicate singular emergent relations.

Table 6.

Trials to criterion during training for MTS groups

Group	Participant	A-B	AX-B	B-C	Mix	Total
MTS	0101	3	2	2	3	10
Experimental	0102	1	1	1	1	4
	0103	4	1	2	1	9
	0104	1	1	2	1	5
	0105	2	1	3	1	7
	0106	1	1	2	1	5
	0107	2	1	2	2	7
MTS Control	0201	-	3	2	2	7
	0202	-	2	2	1	5
	0203	-	2	3	1	6
	0204	-	2	1	1	4
	0205	-	4	4	-	-
	0206	-	4	2	2	8
	0207	-	2	2	2	6
	0208	-	2	2	2	6

Note. Participant 0205 failed to complete the second phase (B-C) of conditional discrimination training.

Table 7.

Number and type of emergent relations displayed by all participants in each condition

Group	Participant	Symmetry	Transitivity	Equivalence	Total
MTS Experimental	0101	1	0	0	1
	0102	2	1	1	4
	0103	2	1	1	4
	0104	0	0	0	0
	0105	0	0	0	0
	0106	2	0	0	2
	0107	1	0	0	1
MTS Control	0201	2	1	1	4
	0202	1	0	0	1
	0203	0	0	0	0
	0204	2	1	1	4
	0205	-	-	-	-
	0206	1	0	0	1
	0207	0	0	0	0
	0208	1	0	0	1
ReT Experimental	0301	0	0	0	0
	0302	2	1	1	4
	0303	0	0	0	0
	0304	1	0	0	1
	0305	2	1	1	4
	0306	0	0	0	0
ReT Control	0401	1	0	0	1
	0402	1	0	0	1
	0403	1	0	0	1
	0404	1	0	0	1
	0405	0	0	0	0
	0406	0	1	1	2

Note. Two tests assessing for the emergence of symmetrical relation (B-A and C-B) existed.
Emergent relation refers to an average score of 77% or above for a single relation across all three stimulus classes (i.e. B-$A_{1\text{-}3}$)

Table 8.

Average scores on trials containing the X stimulus and non-X trials by group for all participants

	Non-X Trials	X Trials	Difference
Group	*M (SD)*	*M (SD)*	*M*
MTS Experimental	72.22 (21.51)	52.38 (26.81)	19.84
MTS Control	60.32 (29.01)	48.68 (29.99)	11.64
ReT Experimental	54.63 (35.89)	55.55 (35.03)	-0.92
ReT Control	41.67 (30.13)	39.51 (19.33)	2.16

Table 9.

Average scores on trials containing the X stimulus and non-X trials for emergent relations

	Non-X Trials	X Trials	Difference
Group	*M (SD)*	*M (SD)*	*M*
MTS Experimental	92.31 (9.12)	60.00 (35.55)	32.31
MTS Control	90.91 (9.25)	66.67 (26.03)	24.24
ReT Experimental	98.77 (3.49)	96.83 (11.66)	1.94
ReT Control	90.74 (9.97)	46.30 (14.93)	44.44

Note. Emergent relation refers to the same relation type being tested using the X stimulus (i.e., B-A and C-B vs B-X; C-A vs C-X; A-C vs X-C)

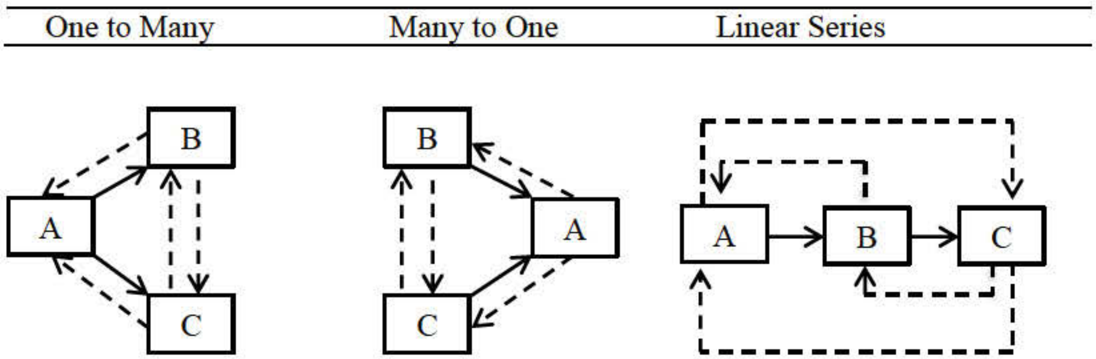

Figure 1. Representation of different training structures used to teach the initial conditional discriminations in equivalence class formation. Solid lines indicate trained relations and dotted lines represent tested relations.

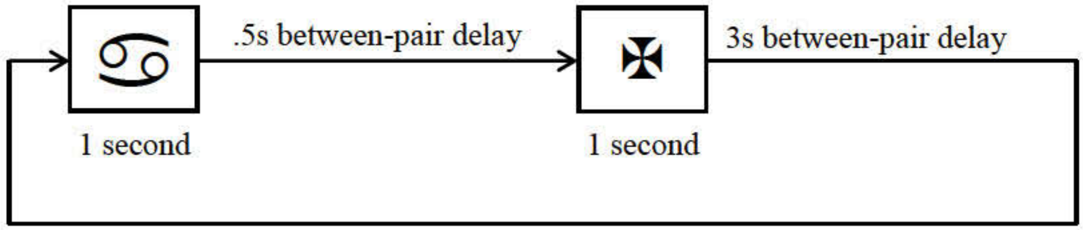

Figure 2. Schematic representation of a single respondent pairing session for a single stimulus pair.

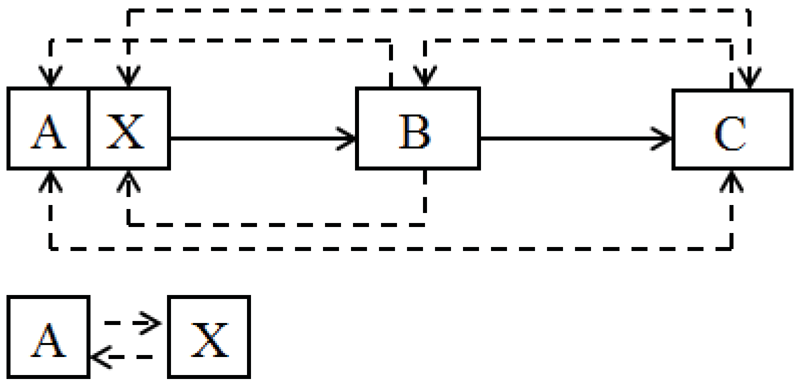

Figure 3. Trained relations in the current study using the linear training structure. Trained relations are in solid lines while derived relations tested for are in dotted lines.

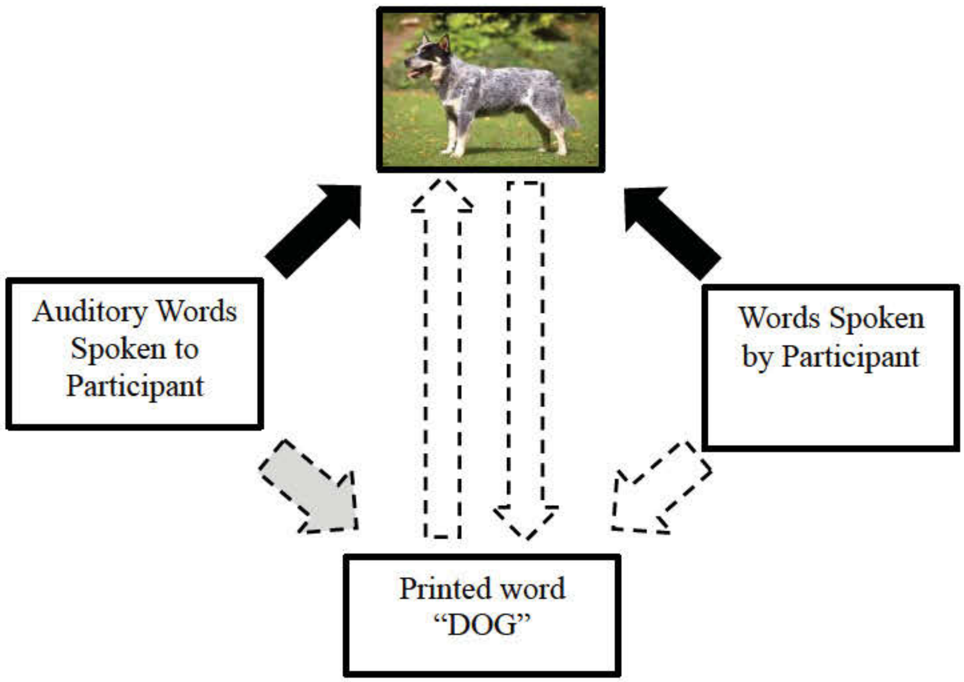

Figure 4. Schematic representation of Sidman (1971). Pre-existing relations are dark arrows, the taught relation is in grey, and emergent relations in white.

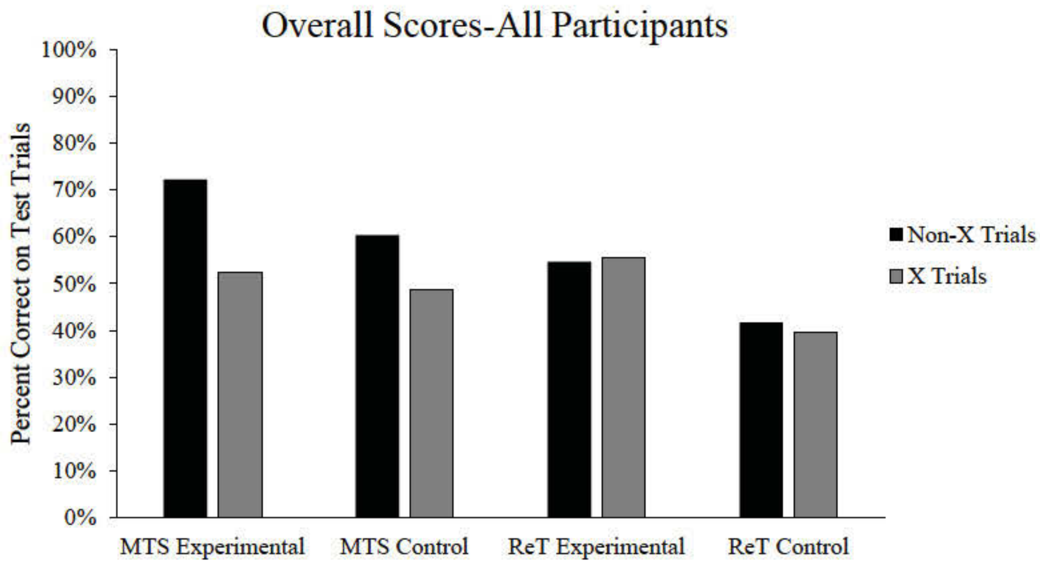

Figure 5. Percentage correct on tests for emergent relations by training type for all participants.

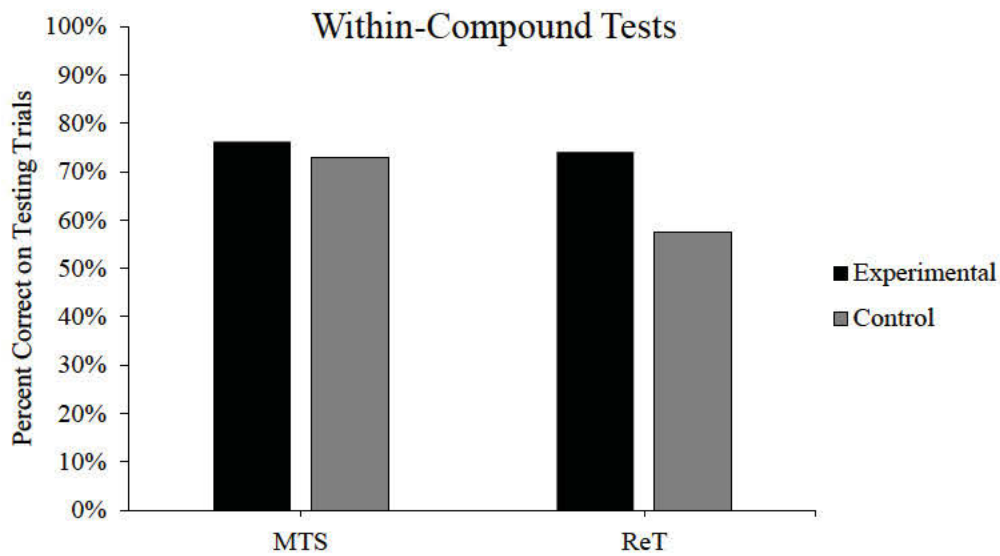

Figure 6. Percentage correct on within-compound tests for all participants between the MTS and ReT conditions.

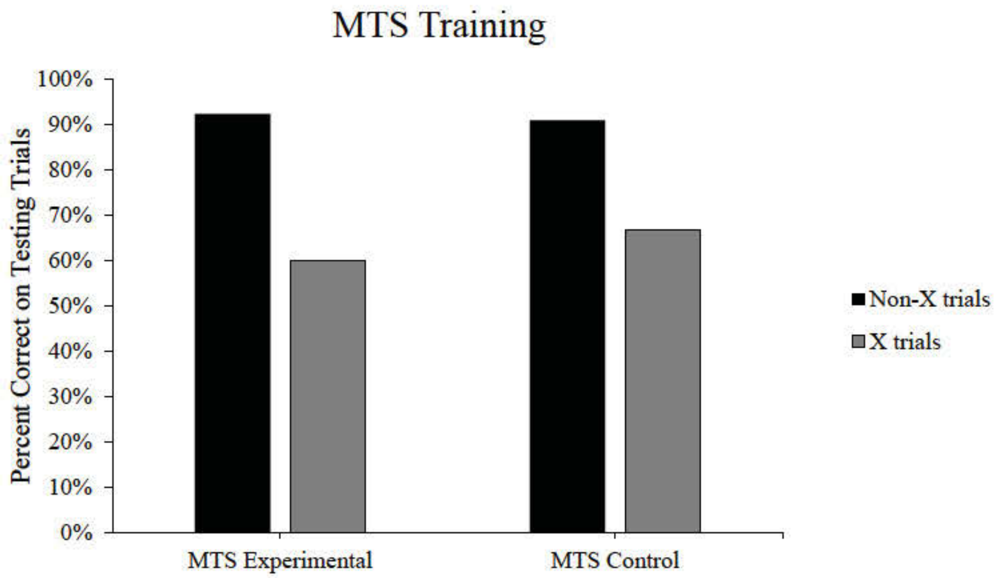

Figure 7. Percentage correct on blocking and non-blocking trials for all emergent relations displayed.

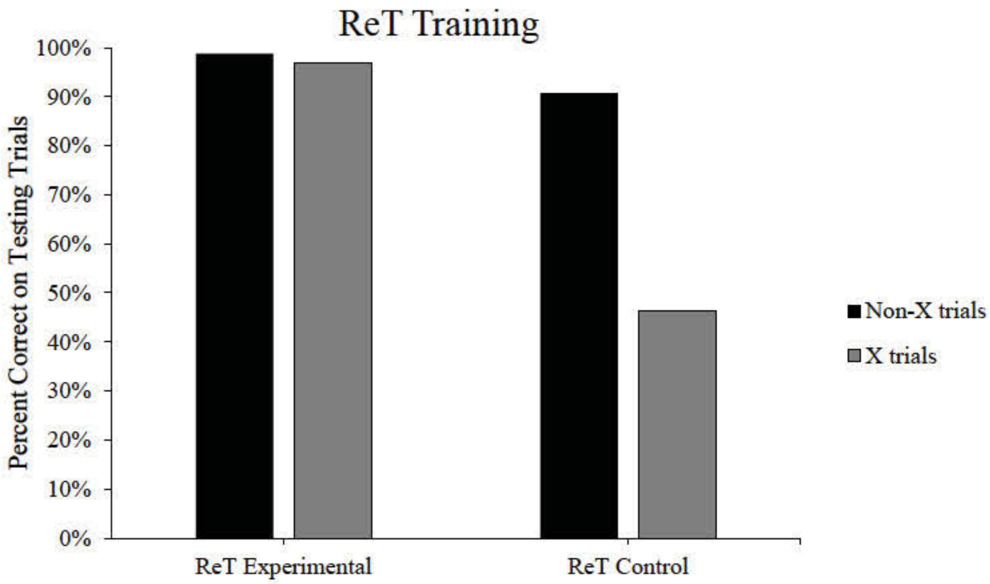

Figure 8. Percentage correct on blocking and non-blocking trials for all emergent relations displayed by participants.

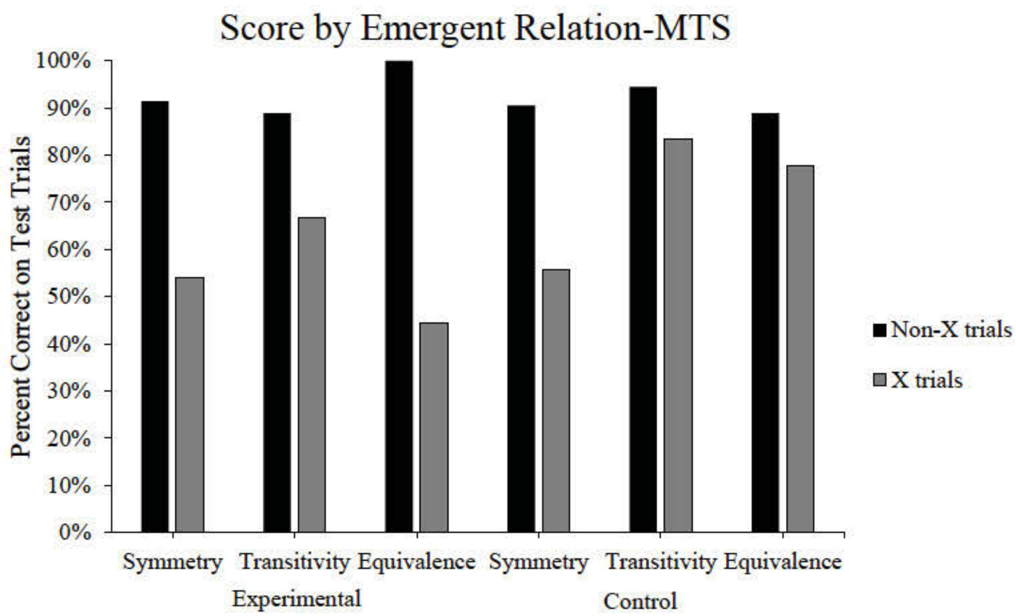

Figure 9. Percentage correct by relation for all emergent relations and their corresponding blocking trials for both MTS experimental and control conditions.

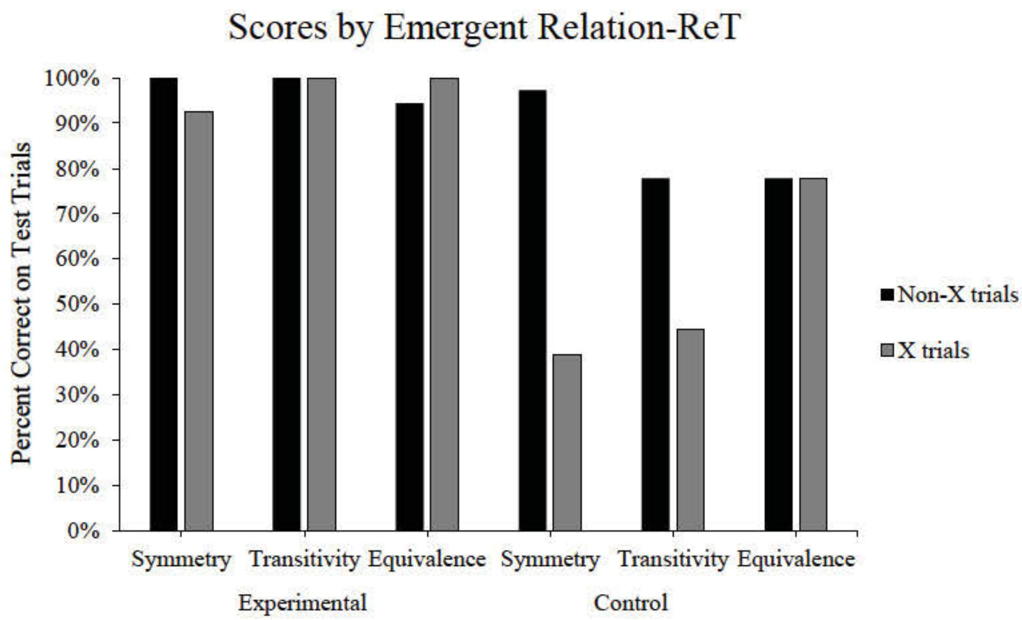

Figure 10. Scores by relation type for all emergent relations displayed and their corresponding blocking trials for both ReT experimental and control conditions.

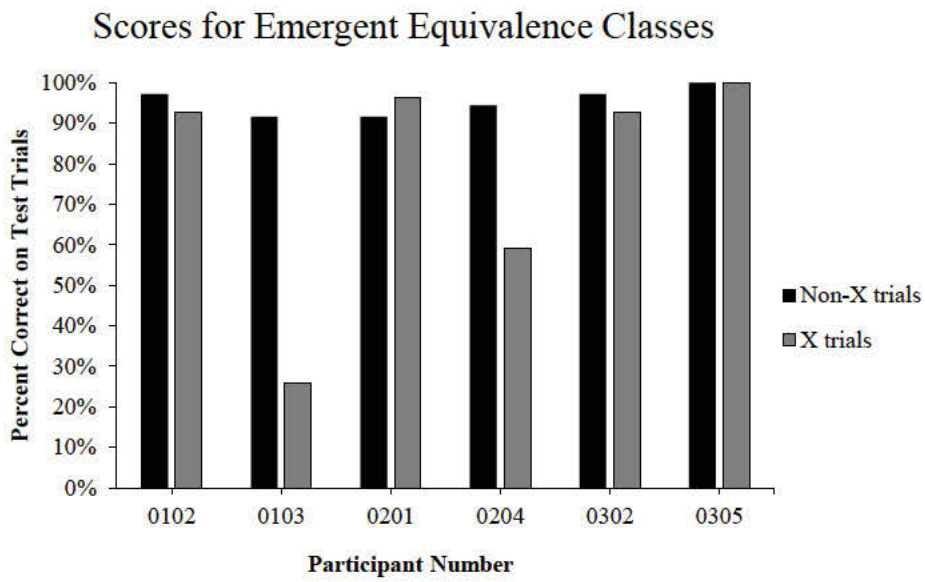

Figure 11. Percent correct on all testing trials for only those participants who displayed the emergence of three 3-member equivalence classes.

APPENDIX A

Date: ________________

Participant Number/Condition: ____________________________

(Circle One): Primary Observer IOA

Phase: ______________________

Trial	Block 1	Integrity	Block 2	Integrity	Block 3	Integrity
1	+ -	+ -	+ -	+ -	+ -	+ -
2	+ -	+ -	+ -	+ -	+ -	+ -
3	+ -	+ -	+ -	+ -	+ -	+ -
4	+ -	+ -	+ -	+ -	+ -	+ -
5	+ -	+ -	+ -	+ -	+ -	+ -
6	+ -	+ -	+ -	+ -	+ -	+ -
7	+ -	+ -	+ -	+ -	+ -	+ -
8	+ -	+ -	+ -	+ -	+ -	+ -
9	+ -	+ -	+ -	+ -	+ -	+ -
10	+ -	+ -	+ -	+ -	+ -	+ -
11	+ -	+ -	+ -	+ -	+ -	+ -
12	+ -	+ -	+ -	+ -	+ -	+ -
13	+ -	+ -	+ -	+ -	+ -	+ -
14	+ -	+ -	+ -	+ -	+ -	+ -
15	+ -	+ -	+ -	+ -	+ -	+ -
16	+ -	+ -	+ -	+ -	+ -	+ -
17	+ -	+ -	+ -	+ -	+ -	+ -
18	+ -	+ -	+ -	+ -	+ -	+ -
19	+ -	+ -	+ -	+ -	+ -	+ -
20	+ -	+ -	+ -	+ -	+ -	+ -
21	+ -	+ -	+ -	+ -	+ -	+ -
22	+ -	+ -	+ -	+ -	+ -	+ -
23	+ -	+ -	+ -	+ -	+ -	+ -
24	+ -	+ -	+ -	+ -	+ -	+ -
25	+ -	+ -	+ -	+ -	+ -	+ -
26	+ -	+ -	+ -	+ -	+ -	+ -
27	+ -	+ -	+ -	+ -	+ -	+ -
28	+ -	+ -	+ -	+ -	+ -	+ -
29	+ -	+ -	+ -	+ -	+ -	+ -
30	+ -	+ -	+ -	+ -	+ -	+ -

APPENDIX B

Date: __________________

Participant Number/Condition: ______________________________

(Circle One): Primary Observer IOA

Phase: MTS TEST: ______________________

Trial	Result	Trial	Result	Trial	Result
1	+ -	31	+ -	61	+ -
2	+ -	32	+ -	62	+ -
3	+ -	33	+ -	63	+ -
4	+ -	34	+ -	64	+ -
5	+ -	35	+ -	65	+ -
6	+ -	36	+ -	66	+ -
7	+ -	37	+ -	67	+ -
8	+ -	38	+ -	68	+ -
9	+ -	39	+ -	69	+ -
10	+ -	40	+ -	70	+ -
11	+ -	41	+ -	71	+ -
12	+ -	42	+ -	72	+ -
13	+ -	43	+ -	73	+ -
14	+ -	44	+ -	74	+ -
15	+ -	45	+ -	75	+ -
16	+ -	46	+ -	76	+ -
17	+ -	47	+ -	77	+ -
18	+ -	48	+ -	78	+ -
19	+ -	49	+ -	79	+ -
20	+ -	50	+ -	80	+ -
21	+ -	51	+ -	81	+ -
22	+ -	52	+ -		
23	+ -	53	+ -		
24	+ -	54	+ -	Score= ____/81	
25	+ -	55	+ -		
26	+ -	56	+ -	________%	
27	+ -	57	+ -		
28	+ -	58	+ -		
29	+ -	59	+ -		
30	+ -	60	+ -		

APPENDIX C

Youngstown
STATE UNIVERSITY

One University Plaza, Youngstown, Ohio 44555
Office of Grants and Sponsored Programs
330 941.2377
Fax 330.941.2705

November 12, 2013

Dr. Michael Clayton, Principal Investigator
Mr. Kristopher Brown, Co-investigator
Department of Psychology
UNIVERSITY

RE: HSRC PROTOCOL NUMBER: 013-2014
TITLE: An Analysis of Respondent Training of the Blocking Effect

Dear Dr. Clayton and Mr. Brown:

The Human Subjects Research Committee has reviewed the modifications you have made to the above-mentioned protocol and finds that your project continues to meet the condition of minimal risk and the modifications are approved.

Any other changes in your research activity should be promptly reported to the Human Subjects Research Committee and may not be initiated without HSRC approval except where necessary to eliminate hazard to human subjects. Any unanticipated problems involving risks to subjects should also be promptly reported to the Human Subjects Research Committee.

The HSRC would like to extend its best wishes to you in the conduct of this study.

Sincerely,

[redacted]

Dr. Scott Martin
Interim Associate Dean for Research
Authorized Institutional Official

SCM:cc

c: Dr. Karen Giorgetti, Chair
Department of Psychology

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