Enhanced equivalence class formation by prior discrimination training:

Simulating the class-enhancing effects of meaningful stimuli

by

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Abstract

Enhanced equivalence class formation by prior discrimination training:

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This experiment documented the effects of manipulating the type, mastery criterion, and overtraining used during prior discrimination training on the likelihood of subsequent equivalence class formation. Seven groups of college students attempted to form two, 3-node, 5-member equivalence classes (ABCDE) using the simultaneous protocol. In the PIC condition, the A, B, D, and E stimuli were nonsense syllables while the C stimuli were pictures of common objects. In all other conditions, the stimuli were nonsense syllables. In the ABS condition, no prior discrimination training was conducted. In all remaining groups, some discrimination training was conducted with the C stimuli before participants attempted to form equivalence classes. In the 84-0-0 condition, participants received simultaneous discrimination training with the C stimuli. In the 84-5-0, 84-20-0, 84-20-100, and 84-20-500 conditions, participants received simultaneous and successive discrimination training but different numbers of successive discrimination trials were presented across groups. Ten percent and 85% formed classes (yield) in the ABS and PIC conditions. Simultaneous discrimination training alone produced a slight increase in yield relative to no discrimination training. Combined simultaneous and successive training produced a greater increase in yield than did simultaneous training only. Yields following increases in pre-class formation successive discrimination training remained stable around 50% until 500 overtraining trials were conducted, at which point, the yield was similar to

that obtained when a meaningful picture was used as a member of an equivalence class. Thus, the class-enhancing properties of meaningful stimuli can be replicated by providing a considerable amount of overtraining of one behavioral function served by a meaningful stimulus.

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Introduction

A stimulus equivalence class consists of a set of 3 or more physically dissimilar stimuli that become related after the direct training of (N-1) of the relations between the stimuli in the set (Fields & Verhave, 1987). For example, assume the stimuli in one class are represented by the letters A, B, C, D, and E. After the training of baseline conditional relations such as AB, BC, CD, and DE, the substitutability of stimuli in the set and their functionality as members of an equivalence class would be documented by the emergence of the untrained derived reflexive relations (AA, BB, CC, DD, and EE), symmetrical relations (BA, CB, DC, and ED), transitive relations (AC, AD, AE, BD, BE, and CE), and equivalence relations (CA, DA, EA, DB, EB, and EC) (Fields & Verhave, 1987; Sidman, 1994; Sidman & Tailby, 1982).

The majority of experiments that have studied equivalence classes have focused on procedural variables that influence the likelihood of class formation such as training protocol (Adams, Fields, & Verhave, 1993; Fields et al., 1995; Fields et al., 1997), training structure (Fields, Adams, & Verhave, 1993; Arntzen & Holth, 1997; Saunders & Green, 1999; Arntzen & Holth, 2000; Hove, 2003; Smeets & Barnes-Holmes, 2005), and trial format (Leader, Barnes, Smeets, 1996; Cullinan, Barnes, & Smeets, 1998; Leader, Smeets, Barnes-Holmes, 2000; Leader & Barnes-Holmes, 2001), among others. All of these experiments have used meaningless stimuli such as abstract symbols or nonsense syllables as class members to minimize the effects of stimulus meaningfulness on class formation and maximize sensitivity to the effects of the above mentioned procedural variables.

In everyday settings, equivalence classes most likely contain either meaningless and/or meaningful stimuli, and in different proportions. Thus, it would be important to study the effects of stimulus meaningfulness on equivalence class formation. Several experiments have explored the effects of stimulus meaningfulness on the likelihood of equivalence class formation (Arntzen, 2004; Arntzen & Lian, 2010; Arntzen & Nikolaisen, 2011; Bentall, Dickins, & Fox, 1993; Fields, Arntzen, Nartey, & Eilifsen, 2012; Garcia & Rehfeldt, 2008; Holth & Arntzen, 1998; Leslie et al., 1993; Lyddy, Barnes-Holmes, & Hampson, 2000; Smeets & Barnes-Holmes, 2005; Tyndall, Roche, & James, 2004; 2009). In these studies, the likelihood of class formation was measured as the percentage of participants in a group who formed all of the experimenter-defined equivalence classes, which was referred to as "yield."

One way of defining the meaningfulness of a stimulus is in terms of its connotative value. Connotative value refers to the associated attributes and feelings evoked by the stimulus (Bortoloti & de Rose, 2009; 2011). For example, the word "trapped" might evoke associated terms such as "bad" or "escape", and it might further elicit emotional responses such as an increase in pulse or breathing rate. A number of experiments reported that the likelihood of equivalence class formation was suppressed by the inclusion of such connotatively meaningful and emotionally negative stimuli (Leslie et al., 1993; Tyndall, Roche, & James, 2009), or of stimuli that had opposing emotive valences (Plaud, 1995). An explanation of this effect is that these stimuli had opposing values that were established pre-experimentally and, thus, were in different classes. Thus, their membership in opposing classes prevented their inclusion in the same class in the context of these experiments. This notion has been supported in other experiments (Grehan, 1998; Roche, Barnes, & Smeets, 1997; Tyndall, Roche, & James, 2004).

Other experiments found that the inclusion of a connotatively meaningful but emotionally neutral stimulus such as a picture of a cartoon character or of a common household object as a member of a to-be-established equivalence class enhanced the likelihood of class formation when compared to a matched class that contained all abstract stimuli only (Arntzen, 2004;

Arntzen & Lian, 2010; Arntzen & Nikolaisen, 2011; Bentall, Dickins, & Fox, 1993; Holth & Arntzen, 1998).

To illustrate with one example, in the Arntzen (2004) experiment, three different groups of college students attempted to form three, 3-node, 5-member equivalence classes. In two of three groups that consisted of 10 participants each, the students attempted to form equivalence classes that included one meaningful picture and four abstract stimuli as members. In another group, participants attempted to form equivalence classes in the same manner but using all abstract symbols as stimuli. The baseline relations were trained using a many-to-one training structure (i.e., A→B, C→B, D→B, and E→B). The AB relations were trained first, followed by the CB, then DB, and finally EB. The experimenters manipulated the point during the training of the baseline relations at which the meaningful stimulus was introduced. The meaningful stimuli were introduced as the A or the E stimulus. The likelihood of equivalence class formation was an inverse function of the point in training at which the meaningful stimulus was introduced. When introduced as the A stimulus, 100% of participants formed equivalence classes. When introduced as the E stimulus, 50% of participants formed equivalence classes. Only 30% of participants formed equivalence classes in the group that received equivalence class training with all abstract symbols as class members. Thus, despite differences in performances that were dependent on the point at which the meaningful stimuli were introduced during training, participants in the groups who received either a meaningful A stimulus or E stimulus still performed better than participants who received training to form equivalence classes with all abstract stimuli as members.

Tyndall, Roche, and James (2004) proposed one possible explanation for how the inclusion of a meaningful stimulus as one member of an equivalence class enhanced the likelihood of class formation. The researchers noted that meaningful stimuli serve simple discriminative functions that are probably established via reinforcement contingencies. To test this assertion, the researchers conducted an experiment wherein they first established S+ or S- functions for two different sets of 6 stimuli under a two-choice simultaneous discrimination procedure. Thereafter, participants attempted to form two, 6-member equivalence classes that contained different proportions of S+ and S- stimuli. The researchers found that establishing the same discriminative function for all abstract stimuli that served as members of an equivalence class led to an increased likelihood of immediate class formation relative to including stimuli that served opposing discriminative functions in a single class or including stimuli that served no pre-established discriminative functions.

While Tyndall, Roche, and James (2004) only explored one possible stimulus function on the likelihood of class formation, a meaningful stimulus can serve a number of behavioral functions, which include being discriminative for a particular response, being a member of a conditional relation with at least one other stimulus, and/or being a member of a perceptual class and/or an equivalence class (Fields, Arntzen, Nartey, & Eilifsen, 2012). Thus, the enhancement of class formation produced by the inclusion of a meaningful stimulus could be attributed to any or all of the above mentioned behavioral functions served by a meaningful stimulus.

Further, Tyndall, Roche, and James (2004) established discriminative functions for all of the abstract stimuli that were used as members of a class. The procedures employed by Holth and Arntzen (1998), Antzen (2004), and Arntzen and Lian (2010) demonstrated that the inclusion of a single meaningful stimulus as a class member increased the subsequent probability of equivalence class formation. If one were to train a behavioral function to a single abstract stimulus, what effect would it have on the likelihood of equivalence class formation if the stimulus that acquired that function was then used as a class member during subsequent class formation training? Could the class enhancing effect of using a meaningful pictorial stimulus as a class member be replicated by establishing a discriminative function for a single meaningless stimulus prior to class formation training?

This issue was first addressed by Fields et al., (2012). In their experiment, participants attempted to form three, 3-node, 5-member equivalence classes. The baseline relations for each class were trained using a linear series training structure (AB, BC, CD, and DE). All baseline relations were established first and the maintenance of the baseline relations and the existence of the derived relations were tested for in one large testing block: The simultaneous protocol. In one group, participants attempted to form classes that consisted of one meaningful picture as the C stimulus and four abstract symbols as the A, B, D, and E stimuli. A second group attempted to form classes using all abstract symbols as class members. A third group also attempted to form classes with all abstract stimuli as class members, but the C stimuli from each class were first used in a pre-class formation discrimination training procedure that was designed to train a discriminative function to each stimulus analogous to the discriminative functions served by the meaningful pictorial stimuli in the first group.

The experimenters found that the explicitly established discriminative function of a single meaningless abstract stimulus enhanced equivalence class formation to some degree, but not as much as the inclusion of a meaningful picture as a member of a class that contained abstract stimuli as its' other members. By implication, the discriminative function served by a meaningful stimulus accounts for only a portion of the class-enhancement effect served by a meaningful stimulus that is included as a member of a to-be-formed equivalence class.

Because all of the class enhancing effect of a meaningful stimulus was not accounted for after establishing a simple discriminative function for an abstract stimulus, the effects of meaningful stimuli on the likelihood of equivalence class formation must be attributable to additional behavioral functions served by such stimuli or to some of the particular parameters of the discrimination training procedure used by Fields et al., (2012).

With regard to the latter option, a meaningful stimulus most likely has served a longstanding pre-experimental discriminative function. A meaningful stimulus has received a great deal of discrimination overtraining. Perhaps, then, the amount of pre-class formation discrimination training in the Fields et al., (2012) study was not sufficient to match the amount of informal overtraining garnered by a meaningful stimulus in the course of an individual's life. Thus, the superior class-enhancement effect of a meaningful stimulus might be due to the presumably extensive amount of overtraining that has accrued to a meaningful stimulus.

In other contexts, overtraining has been shown to influence resistance to extinction (Williams, 1938), the acquisition of whole reversals in shift learning (Nakagawa, 2000; 2001), the resistance of accurate responding to distraction on tests of equivalence relations, the resistance of baseline relations to contingency reversals, and the speed of acquisition of emergent relations (Leon, 2006).

The fact that overtraining influences a variety of behavioral phenomena suggests that it might also influence likelihood of equivalence class formation. This notion was assessed empirically in the present study by determining whether parametric increases in the amount of overtraining of discriminations established prior to class formation would increase the likelihood of equivalence class formation.

A second question generated by the Fields et al., (2012) study involves the type of discrimination training that is used to establish a behavioral function for a meaningful stimulus during the course of one's life experience. Discrimination training can be conducted using the simultaneous or successive presentation of the discriminative stimuli (MacCaslin, 1954; Cuvo et al., 1980). During a simultaneous discrimination training procedure, a participant is presented with at least two stimuli on a concurrent basis. Across trials, the locations of the stimuli are randomized. Reinforcement is provided for the selection of the stimulus designated as the S^d and not for the selection of the other stimuli. In a successive discrimination training procedure, one learns to make different response topographies in the presence of different and separately presented stimuli (Guttman & Kalish, 1956; Guttman, 1959; Hanson, 1959, Reynolds, 1961).

In a manner most likely representative of learning outside of experimental contexts, participants in the Fields et al., (2012) study received both simultaneous and successive discrimination training trials, and the likelihood of equivalence class formation rose to 50% from 0% when no discrimination training was conducted prior to equivalence class formation. While this demonstrated the viability of pre-class formation discrimination training as one method for increasing the probability of equivalence class formation, it raised new questions about the contributions of both simultaneous and successive discrimination training to the overall outcome of the study. It could be the case that the use of either discrimination training type alone or some combination of the two types to establish discriminative functions for abstract stimuli accounted for the improved class formation yields that followed discrimination training in the Fields et al., (2012) study. The present experiment probed this possibility by manipulating the two types of simple discrimination training across experimental groups.

A third variable that could have contributed to the class enhancing effects of meaningful stimuli in the Fields et al., (2012) study was the mastery criterion used to establish the simple discriminations. Some studies have demonstrated that the retention of correct responding is a direct function of the parametric value of the mastery criterion used during training (Blair, 2000; Johnston & O'Neill, 1973; Semb, 1974). Thus, it could be the case that varying the mastery criteria for establishing the simple discriminations to levels below that used in the Fields et al., (2012) study might produce corresponding decreases in the likelihood of equivalence class formation.

To summarize, the present experiment determined how overtraining, the effects of each type of discrimination training, and mastery criterion influenced the likelihood of subsequent equivalence class formation for seven different groups of participants. A comparison of yields per group provided answers to the following experimental questions. 1) Would providing only simultaneous discrimination training trials using the abstract C stimuli from each class increase the likelihood of subsequent equivalence class formation relative to no pre-class formation discrimination training? 2) Would simultaneous training combined with successive discrimination training lead to a greater likelihood of equivalence class formation than simultaneous discrimination training alone? 3) Would parametrically increasing the mastery criterion used to complete pre-class formation successive discrimination training increase the likelihood of subsequent equivalence class formation? 4) Would increasing the amount of overtraining trials increase the likelihood of equivalence class formation? 5) Would the performances of the group receiving the most discrimination training match the high yields of the group in which a meaningful pictorial stimulus was used as a member of each class? 6) Last, would the class-enhancing effect of using a meaningful stimulus as one member of an equivalence class be replicated with the use of different types of abstract stimuli as the members of the equivalence classes?

Method

Participants

One hundred and twenty-eight college students participated in this experiment. They did not possess any prior formal knowledge of stimulus equivalence. An IRB approved the study and informed consent was obtained from each participant prior to beginning the experiment. Seven groups of students were created. Students were randomly assigned to one of the seven groups. The experiment was completed in a single session and took between 1.5 to 2.5 hours to complete depending upon condition.

Apparatus

Setting. The experimental sessions were carried out in rooms in a laboratory suite at an urban Northeastern college: a greeting room and an experimental cubicle.

Hardware. The experimental sessions were conducted on Dell Desktop computers that used 1828 MHz Intel Centrino processors, and had images transmitted to flat screen monitors that had a 16.8 inch diagonal dimension with a 16 x 9 horizontal to vertical ratio.

Software. The training and testing to establish equivalence classes and discriminative functions for some of the stimuli were controlled by a software program that was written in Visual Basic. In addition to controlling the presentation of all stimuli, the software also recorded trial number and type, which stimulus relation was being trained or tested, number of responses to sample stimulus, reaction time to sample and comparison stimuli, correct/incorrect comparison choice, and whether feedback was provided on each trial. Finally, the duration of the experiment, and number of baseline and emergent relations trials, was also recorded by the software.

Stimuli. The stimuli used as members of the equivalence classes were abstract Consonant-Vowel-Consonants (CVC) and familiar picture-stimuli as shown in the two top sections of Figure 1. Each stimulus was referred to symbolically by the letters A, B, C, D, or E, with classes defined by the numerals 1 and 2. The bottom section of the figure shows the negative comparison stimuli that were used during discrimination training. All stimuli in Figure 1 were displayed on a white background. The pictorial stimuli were displayed in color on the same white background. During both simple discrimination and conditional discrimination training, the selection of a correct comparison was followed by the feedback stimulus “Right!”, and the selection of an incorrect comparison was followed by the feedback stimulus “Wrong!”, both of which were presented in written form on the computer screen.

Procedure

Experimental design. As presented in Table 1, the experiment was a group design with seven experimental conditions. In each group, participants received training to form two, 3-node, 5-member equivalence classes with a training structure characterized as A→B→C→D→E, and formed under the simultaneous protocol. Participants in the ABS group attempted to form classes with all meaningless stimuli as class members. In the PIC group, participants attempted to form equivalence classes that included one meaningful picture and four abstract stimuli as members.

The five remaining groups were given numerical labels based on the number of training trials that they received in each of three experimental phases (e.g., xx-xx-xx). The first, second, and third numbers in the three-number sequence refer to the amount of correct simultaneous, successive discrimination mastery criteria, and successive discrimination overtraining trials that were employed during the pre-class formation discrimination training.

Participants in the 84-0-0 group first received pre-class formation training trials in which the abstract C stimulus from each of the two potential classes was presented in a simultaneous discrimination trial format along with one other negative comparison. Participants were required to accumulate 84 total correct trials to complete this portion of training. This was followed by equivalence class training. Thus, participants in this group did not receive any successive discrimination training trials.

Participants in the 84-5-0, 84-20-0, 84-20-100, and 84-20-500 groups received pre-class formation discrimination training trials that involved the presentation of the abstract C stimuli from each class in both simultaneous and successive trial formats. Completion of this training was followed by equivalence class formation training with five abstract stimuli as class members. For each of these four groups, the simultaneous discrimination training was identical to that used in the 84-0-0 group. In contrast, the number of trials to reach mastery during successive discrimination training (second number in group label) and the number of successive discrimination overtraining trials received across groups (third number in group label) was parametrically manipulated.

The dependent variable was the likelihood of equivalence class formation. This was measured as the percentage of participants who formed classes within each condition. When compared across groups the following six effects were discernible.

1) A comparison of the yields produced by the ABS and PIC groups documented the effect of the inclusion of a meaningful picture on the likelihood of equivalence class formation.

2) A comparison of the yields produced by the ABS and 84-0-0 groups documented the effects of the absence vs. presence of pre-class formation simultaneous discrimination training on the likelihood of equivalence class formation.

3) A comparison of the yields produced by the 84-0-0 and the 84-5-0 groups documented the effects of simultaneous training alone or combined simultaneous and successive discrimination training prior to class formation on the subsequent likelihood of class formation.

4) A comparison of the yields produced by the 84-0-0, 84-5-0, and 84-20-0 groups documented the effects of increasing the mastery criterion during pre-class formation discrimination training from zero to five, and then five to 20 correct successive training trials on equivalence class formation.

5) A comparison of the yields produced by the 84-20-0, 84-20-100, and 84-20-500 groups documented the effects of providing 0, 100, or 500 additional trials of successive discrimination training beyond mastery on the likelihood of equivalence class formation.

6) A comparison of the yields produced by the PIC and 84-20-500 groups determined whether extensive successive discrimination overtraining would approximate the effects of picture inclusion on the likelihood of equivalence class formation.

Pre-class formation discrimination training

Prior to receiving training to form equivalence classes, the participants in the 84-0-0, 84-5-0, 84-20-0, 84-20-100, and 84-20-500 conditions were given discrimination training to ensure that the abstract C stimuli that were used as members of the to-be-formed equivalence classes were discriminated from each other and from other stimuli. The phases of the discrimination training are presented in Table 2.

Participants in all five groups received the same 84 trial correct mastery criterion. This number reflects 100% correct performance on three blocks of 20 trials, and one block of 24 trials in phase 4 which are described below. Participants in the *84-5-0, 84-20-0, 84-20-100, and 84-20-500* groups, however, received different amounts of successive discrimination training.

Simultaneous discrimination training. Phases 1-3 consisted of two choice simultaneous discrimination trials that were used to insure that the C stimuli were discriminated from other concurrently presented cues designated formally as P (used in Phase 1), R (used in Phase 2), and S (used in Phase 3). Each phase consisted of blocks that contained 20 trials (10 C1–P1 and 10 C2-P2, 10 C1–R1 and 10 C2-R2, and 10 C1–S1 and 10 C2-S2 trials). Each block was repeated until all trials produced correct responses (100% correct mastery criterion).

Participants had to select the correct stimulus by pressing either “1” or “2” on the keyboard which corresponded to the left or right position on the screen at which the C stimuli were presented. Each response produced a feedback stimulus on the screen reading either “Right” or “Wrong”. Participants then needed to press “R” or “W” in the presence of the “Right” or “Wrong” feedback for the trial to end and the next trial to begin. None of the negative comparison stimuli used during the discrimination training phases were used as members of the equivalence classes in later training.

Phase 4 consisted of the presentation of a block of 24 trials in which the C stimuli were presented concurrently with each negative comparison (S-). This was done with the presentation of CP, CR, and CS trials altogether in the same block. The trial format was the same as that used in Phases 1 through 3.

During training in Phases 1 through 4, it was possible that participants might have learned to select the C stimuli by responding away from the S- presented on each trial. Such a stimulus control topography has been demonstrated in the equivalence class literature (Carrigan & Sidman, 1992). Thus, Phase 5 was designed to assess control of selection by the C stimuli through their presentation in combination with new negative comparison stimuli (labeled X, Y and Z). This phase consisted of the presentation of a block of 24 trials (4 C1–X1, 4 C2-X2, 4 C1-

Y1, 4 C2-Y2, 4 C1-Z1, and 4 C2-Z2) that were not followed by informative feedback. Maintenance of accurate responding would document control of behavior by the C stimuli. If, however, responding were to drop to chance levels during Phase 5, then picking the S+'s in the earlier phases probably reflected rejection of the S- on each trial. If participants met the mastery criterion of 100% correct during this phase they proceeded to the next block. All participants met this mastery criterion within 3 blocks. Thus, all participants demonstrated the control of responding by the S+ rather than by rejection of the S-.

After the completion of phase 5, participants in the 84-0-0 group began the equivalence class formation portion of this experiment.

Successive discrimination training. For participants in the 84-5-0, 84-20-0, 84-20-100, and 84-20-500 groups, Phase 6 employed a simple successive discrimination training procedure to teach each participant to make different fixed ratio responses when presented with the two different C stimuli. This procedure thus established a discriminative function for each C stimulus analogous to the “naming” of a picture (e.g., a picture of a church evokes a spoken or written “church” response). In this phase, a single abstract stimulus (C1 or C2) was presented on the screen at a time and in a randomized sequence. In the presence of this stimulus, participants were required to emit a response string that involved pressing the J key either three or six times followed by pressing the ENTER key on the keyboard. These sequences were the responses in the discriminations. Each response was followed by a feedback stimulus stating either “Right” or “Wrong.” Participants had to respond to the feedback stimulus by pressing R when presented with “Right” and W when presented with “Wrong.”

Across the 84-5-0, 84-20-0, 84-20-100, and 84-20-500 groups, the numbers of trials that constituted mastery of the FR responses and the amount of overtraining of the successive discriminations were manipulated. The manipulation of these two variables is reflected in the changing second and third numbers of their respective group labels. Participants in the 84-**5**-0 group received a five trial block of successive discrimination training trials that was repeated until responding reached 100% correct. Participants in the 84-**20**-0, 84-**20**-100, and 84-**20**-500 groups were required to respond correctly to all of the trials in the 20 trial training block. Further, participants in the 84-20-**100** and 84-20-**500** groups received an additional 100 or 500 successive discrimination training trials beyond the 20 trial mastery, respectively. These trials were presented in blocks of 20. This constituted overtraining. Although differential feedback was presented for all the overtraining trials that followed mastery in Phase 6, no performance criterion had to be satisfied to complete this portion of training. Participants in these groups progressed through the overtraining blocks regardless of performance. Upon completion of phase 6, participants in these five groups began the equivalence class formation portion of the experiment.

Equivalence Class Formation

After preliminary training, all participants in the seven groups received training to form two, 3-node, 5-member equivalence classes under the simultaneous protocol. Previous studies have demonstrated that the likelihood of equivalence class formation under the simultaneous protocol is typically very low (0-58%). As such, it is ideal for studying variables that enhance the likelihood of equivalence class formation (Fields, Landon-Jimenez, Buffington, & Adams, 1995; Fields et al., 1997; Fields et al., 2012). Thus, the simultaneous protocol was used to establish equivalence classes in the present experiment.

Because no pre-class formation training was conducted in the PIC and ABS groups, the participants in these groups attempted to form classes at the start of the experiment. Once pre-class formation C-based discriminations were established by participants in the 84-0-0, 84-5-0, 84-20-0, 84-20-100, and 84-20-500 groups, all of the participants in these groups also attempted to form two 3-node, 5-member equivalence classes under the simultaneous protocol.

The simultaneous protocol. In the simultaneous protocol, all baseline relations for each class are trained first and, thereafter, trials that test for the maintenance of these baseline relations and for the emergence of the untrained derived relations among the stimuli in all classes are then presented concurrently and in a randomized order. The present study employed a modified version of this training format to replicate the training procedure that was used in Fields et al., (2012). In this procedure the baseline relations (AB, BC, CD, DE) for the two equivalence classes were trained serially in separate 16 trial blocks. Following the acquisition of these baseline relations, all baseline relations for the two classes were then presented concurrently in a single 16 trial block. Thereafter, feedback reduction was implemented and emergent relations probes were presented which will be described below.

Trial format and contingencies. Each trial started with the presentation of a sample stimulus in the upper center of the screen. A press of the “B” key on the keyboard in the presence of the sample stimulus was followed by the presentation of two comparison stimuli below the sample with the continued presence of the sample. All stimuli remained on screen until a participant selected one of the comparisons. A comparison was selected by pressing the “1” or “2” keys which corresponded to the left and right comparisons, respectively. Feedback stimuli were presented after the selection of a comparison, and were displayed in the middle of the screen. During training, “Right” and “Wrong” feedback stimuli were presented for correct and incorrect responses, respectively. During feedback reduction trials and testing trials, a “no feedback” stimulus appeared following some responses. Participants needed to press the “E” key on the keyboard to terminate this feedback stimulus. The termination of the feedback stimulus was followed by a 500 m sec inter-trial interval in which no stimuli were presented on the screen.

Block structure and mastery criteria. All equivalence class training and testing was conducted in blocks of trials. All baseline relations were established first in individual blocks presenting AB, BC, CD, and DE relations for each potential class. Each block consisted of 16 trials, and was repeated until a mastery criterion of 100% correct was achieved for the block. Thereafter, all baseline relations (AB, BC, CD, and DE) were presented concurrently in a 16 trial block. In this block, all trials were followed by informative feedback and 100% correct mastery criterion was required to progress through the block. Participants had to obtain 100% correct on three consecutive blocks. If they failed to meet this criterion within 20 presentations of this block, they were dismissed from the experiment. After this mastery criterion was met, the same 16 trials were presented in blocks in which trials were followed with a decreasing probability of feedback (75%, 50%, 25%, and 0%). During feedback reduction, participants were given three blocks within which to meet a 93% mastery criterion. If a participant failed to meet this criterion, they were placed back into the first block at the last feedback level that they passed (e.g., if they failed to meet mastery in three attempts at the 75% percent feedback level they were placed back into the first block of the 100% feedback level).

Once participants passed a block at the 0% feedback level, they were placed into a series of four 20-trial blocks in which baseline and derived relations probes were presented in a randomized sequence, without replacement, and without informative feedback. No mastery criterion was included in these four testing blocks. Thus, participants progressed through these testing blocks without repetition. These blocks assessed the presence/absence of the two stimulus equivalence classes. Once these blocks were completed, the experiment ended for all participants.

Results

The experiment consisted of two stages; 1) the training of the C-based simultaneous and successive discriminations, and 2) equivalence class formation. The data from each stage will be described in separate sections.

Acquisition of C-based discriminations

C-based simultaneous discriminations. All participants in the 84-0-0, 84-5-0, 84-20-0, 84-20-100, and 84-20-500 groups received the same pre-class formation simultaneous discrimination training procedure with the C stimuli from each respective class. A minimum of 5 blocks were required to demonstrate the acquisition of the simultaneous C-based discriminations. On average, participants required 9 blocks to reach criterion. This demonstrated that the simultaneous discriminations were acquired rapidly. There were no significant differences among groups in acquisition rates for the C-based simultaneous discriminations (ANOVA, $F(4, 83) = 0.51$, $p = 0.73$). In addition, there were no significant differences in the rates of acquisition for the C-based simultaneous discriminations between participants who did and did not form the equivalence classes ($t(86) = 0.88$, $p = 0.38$). Thus, acquisition of C-based simultaneous discriminations was not predictive of subsequent class formation.

Phase 5 of simultaneous discrimination training consisted of the presentation of the C stimuli from each class along with novel S- stimuli, in the absence of feedback. Selection of the C stimuli on trials that contained novel S- stimuli would indicate that the performances observed in the previous four blocks were indicative of responding controlled by the selection of the S+s and not by responding away from**,** or the rejection of the novel S-s. If participants failed to respond accurately on these test trials, it would indicate that their correct performances in previous blocks were indicative of responding away from the S-s in each trial. These trials thus tested for control of stimulus choice by the S+ or the S-.

Of the 88 participants in the five groups, 84 responded with 100% accuracy on the first presentation of this test block. The remaining four participants met the 100% mastery criterion on the second presentation of this block even though the trials in each block were presented without informative feedback. Thus, the performances in Phase 5 demonstrated the control of responding by selection of S+ stimuli, rather than by rejection of the S- stimuli.

C-based successive discriminations. After simultaneous discrimination training, participants in the 84-5-0, 84-20-0, 84-20-100, and 84-20-500 groups received successive discrimination training wherein FR3 and FR6 responses were trained to the C1 and C2 stimuli, respectively. The mastery criteria that defined acquisition of this discrimination was 100% correct responding on a single block of 5 trials in the 84-**5**-0 group or 20 trials in the 84-**20**-0, 84-**20**-100, and 84-**20**-500 groups.

On average, participants in the 84-5-0 group required 1.8 blocks and participants in the 84-20-0, 84-20-100 and 84-20-500 groups required 2 blocks to meet the 100% mastery criterion that demonstrated acquisition of the different FR responses. The acquisition of these discriminations was rapid. Further, there were no significant differences in the rate of acquisition of the C-based successive discriminations between the participants who did and did not form classes ($t(66) = 0.04$, $p = 0.97$). Thus, the rate of acquisition for the C-based successive discriminations was not predictive of subsequent equivalence class formation.

Equivalence Class Formation

Acquisition of serially trained baseline relations. The baseline relations for the two equivalence classes were first trained serially in different blocks (AB, BC, CD, and then DE).

Thereafter, all baseline relations were presented together in a single block and participants were required to meet 100% mastery criterion on three of these blocks. Thus, a minimum of 7 blocks were required to meet the criterion for the acquisition of the baseline relations for the two classes. On average, participants in all groups required 15 blocks to meet criterion. Across all seven groups, no significant differences were noted in the number of blocks needed to learn the baseline relations for participants who did and did not form the equivalence classes ($t(126) = 1.84$, $p = 0.07$).

Maintenance of concurrently presented baseline relations. After the acquisition of each serially presented baseline relation, all of the baseline relations were presented together in a mixed training block with 100% feedback. The mastery criterion used to define the acquisition of the concurrently presented baseline relations was 3 consecutive blocks at 100% accuracy. Mastery in only three blocks meant that the intermixing of all of the baseline relations did not produce any decrement in stimulus control exerted by each baseline relation. Mastery in more than 3 blocks would indicate that the mixing together of all the relations disrupted performances even though each baseline relation had been mastered separately.

A between-group comparison of the number of blocks needed to reach mastery when all baseline relations were presented concurrently showed no significant differences (ANOVA, $F(6, 119) = 1.78$, $p = 0.11$). Therefore, the data across conditions were combined and presented in Figure 2, which depicts the frequency of the number of blocks needed to reacquire mastery on responding by all participants on the concurrently presented baseline relations. The performance of all participants fell roughly into four distinct groupings that are indicated by the vertical dashed lines presented in the figure. The first grouping depicts the 13% of participants who maintained accuracy of responding by all of the baseline relations when presented together, i.e., in the first 3 training blocks. The second grouping depicts the 52% of participants who required between four and nine blocks to meet mastery. The third grouping depicts the 29% of participants who required between 10 and 17 presentations of blocks in which baseline relations were concurrently presented before they were able to meet mastery. The remaining 5% of participants in the fourth grouping required 19 to 20 blocks to meet mastery. Ultimately, all but two participants were able to reacquire the baseline relations with repeated exposure to these blocks. The two participants that failed to reacquire the baseline relations in 20 or fewer blocks were dismissed from the experiment.

Once mastery was documented, performances were maintained without disruption during the reduction of feedback. At the end of this phase of the experiment, all baseline relations were maintained at the mastery level in the absence of feedback. Therefore, the performances in these phases were not predictive of subsequent equivalence class formation.

Equivalence class formation. The results of primary interest were the effects of various parameters of pre-class formation discrimination training on the likelihood of equivalence class formation among the seven different groups in the experiment. This was measured by comparing the percentage of participants in different groups who formed equivalence classes. Emergence of equivalence classes was defined as $\geq$90% selection of class indicative comparison stimuli on the last two blocks of the derived relations test.

The data used to make these comparisons include the equivalence class yields for each group and are presented in the top panel of Table 3. Of the 128 total participants who participated in the experiment, 66 formed equivalence classes. When the performances were compared for all groups, the differences in the likelihood of equivalence class formation were significant (X^2 (6, N = 126) = 30.15, p = 0.0001). Pairwise comparisons of differences between individual groups using Fisher's Exact Tests are also presented in the bottom panel of Table 3 and will be discussed in the following three sections which separately consider the effects of each of the three parameters of discrimination training that were manipulated in the experiment on likelihood of equivalence class formation**.**

Effect of meaningful stimuli and simultaneous discrimination training on equivalence class formation. The data presented in the top panel of Figure 3 show the percentage of participants who formed equivalence classes that consisted of 5 abstract stimuli with no pre-class formation discrimination training histories (the ABS group), 4 abstract stimuli and 1 stimulus from each group that received pre-class formation simultaneous discrimination training only (the 84-0-0 group), and 4 abstract stimuli and 1 meaningful picture (the PIC group). Equivalence classes were formed by 10%, 38%, and 85% of participants in the ABS, 84-0-0, and PIC groups, respectively. Thus, the inclusion of a nameable picture as the C stimulus in a set of four other abstract stimuli in the PIC group enhanced the likelihood of equivalence class formation relative to the use of all abstract stimuli as class members in the ABS group (Fisher's Exact Test, $p = 0.000003$). Further, the pre-class formation simultaneous discrimination training to the C stimuli from each class in the 84-0-0 group produced a moderate increase in yield relative to the low yield of the ABS group. The increment in yield from the ABS to the 84-0-0 groups approached statistical significance (Fisher's Exact Test, $p = 0.10$). Last, the yield of the PIC group was significantly higher than that produced by the participants in the 84-0-0 group **(**Fisher's Exact Test, $p = 0.005$).

The effect of mastery criteria for successive discrimination training. The data in the middle panel of Figure 3 depict the likelihood of equivalence class formation for participants in the 84-***0***-0, 84-***5***-0, and the 84-***20***-0 groups. Participants in these three groups received identical simultaneous discrimination training that was then followed by successive discrimination training that continued until a participant responded correctly on 0, 5, or 20 consecutive training trials in the 84-***0***-0, 84-***5***-0, and 84-***20***-0 groups, respectively.

Across the three groups, the likelihood of class formation increased from 38% when no successive discrimination training was conducted (in the 84-***0***-0 group) to 55% and 45% when the mastery criterion that defined the acquisition of the C-based successive discriminations was either 5 or 20 consecutive correct training trials (in the 84-***5***-0, and the 84-***20***-0 groups). Although an increasing trend is present, the differences between conditions were small and none were significant.

The effect of overtraining. The bottom panel of Figure 3 depicts the likelihood of class formation for participants in the 84-20-***0***, 84-20-***100***, and 84-20-***500*** groups. The 84-20-***0*** group was a replication of the ACQ group from the Fields et al., (2012) study. Thus it served as the reference condition and included no overtraining trials. The 84-20-***100*** and 84-20-***500*** groups received 100 and 500 overtraining trials of successive discriminations, respectively. Yields between the 84-20-***0*** and 84-20-***100*** groups remained stable at around 50% and were not significantly different. Thus, the effect of successive discrimination training was unchanged when overtraining was conducted with up to 100 additional training trials. When, however, overtraining involved the administration of 500 additional trials beyond the 20 trial mastery criterion, the likelihood of equivalence class formation increased to 81%. Thus, a considerable amount of overtraining of pre-class formation successive discriminations produced a very large increment in class-enhancement. The performance of the 84-20-500 group was significantly different from the 84-20-0 group (Fisher's Exact Test, $p = 0.04$). The difference between the 84-20-500 and 84-20-100 groups approached significance (Fisher's Exact test, $p = 0.16$).

Overtraining and meaningful stimulus effects on equivalence class formation. The bottom panel of Figure 3 also depicts the equivalence class yields for the 84-20-500 and PIC groups. In the present experiment, the likelihood of equivalence class formation for the group that received 500 trials of overtraining (84-20-500) was similar to that produced when the classes contained a meaningful picture as the C stimuli (PIC group). Thus, the class-enhancing effects of using a meaningful picture as one member of an equivalence class were reproduced in the current experiment by providing simultaneous discrimination training and a considerable amount of pre-class formation successive discrimination training trials.

Simultaneous training alone and in combination with overtraining. The bottom panel of Figure 3 also depicts the performances of the 84-0-0 and 84-20-500 groups. A comparison of the equivalence class yields between these two groups documented the relative contributions of simultaneous discrimination training alone and in combination with successive discrimination overtraining. The 84-0-0 group received pre-class formation simultaneous training only, and the yield was 38%. The 84-20-500 group received simultaneous discrimination training followed by successive discrimination training to mastery and then 500 additional trials beyond mastery, and the yield was 81%. These differences were significant (Fisher's Exact Test, $p = 0.03$). Thus, the relative contribution of simultaneous training alone to the overall equivalence class yields across groups was moderate, but when combined with successive discrimination overtraining the effect was considerable and matched that demonstrated when a meaningful picture was used as a class member.

Discussion

Findings. The present study produced the following findings. (1) A very low percentage of participants formed equivalence classes that contained all abstract stimuli. (2) Most participants formed equivalence classes when each class contained a familiar picture and four abstract stimuli. (3) The inclusion of simultaneous discrimination training trials for the abstract C stimuli from the two classes prior to class formation produced a moderate increase in yield relative to no training. (4) This effect was enhanced still further when simultaneous and a relatively small amount of successive discrimination training was conducted. (5) Equivalence class yields were intermediate and identical across the groups that received different mastery criteria during pre-class formation successive discrimination training. (6) Training of the C-based pre-class formation successive discriminations beyond mastery produced similar yields until a large number of overtraining trials were presented, at which point the likelihood of equivalence class formation increased and was identical to that of a group of participants who received training to form equivalence classes that contained four abstract stimuli and one familiar picture as class members.

Generality across stimulus types. Results 1 and 2 replicated the results of Fields et al., (2012). Further, these findings also demonstrated the generality of the enhancement effect of training a discriminative function to an abstract stimulus across different types of abstract stimuli: abstract symbols in Fields et al., (2012) and nonsense syllables in the present experiment. Because similar outcomes were reported in both experiments, the enhancement of equivalence class formation by the inclusion of stimuli that have acquired discriminative functions prior to class formation did not depend on the types of stimuli used as members of equivalence classes.

Combined effects of simultaneous and successive discrimination training. Findings 3 and 4 above indicate the relative class-enhancing contributions of both pre-class formation simultaneous discrimination training alone and in combination with successive training. The introduction of simultaneous discrimination training alone produced a moderate increase in equivalence class yields. However, the simultaneous training alone cannot account for the total effect demonstrated across all the groups that received pre-class formation discrimination training because the addition of successive training in the 84-5-0, 84-20-0, 84-20-100, and 84-20-500 groups led to still further increases in class formation yields.

Nevertheless, while increases in successive training produced increases in yield, this occurred in the context of simultaneous discrimination training. Thus, the isolated effect of increases in successive discrimination training on class enhancement was not addressed in the current study but could be in a future experiment by running any or all of these groups with a pre-class formation discrimination training procedure that contained successive discrimination trials only.

Effects of mastery criteria. Outcome 5 above indicates that the likelihood of equivalence class formation was similar regardless of whether 5 or 20 correct trials were used as a mastery criterion during pre-class formation successive discrimination training. It follows that some value of training less than or equal to 5 consecutive correct trials was responsible for the incremental performance differences between the 84-0-0 and 84-5-0 groups. Further studies could evaluate this possibility by adding an additional training group that receives simultaneous discrimination followed by successive discrimination training that contains <5 total trials, or 5 successive trials in the absence of prior simultaneous discrimination training.

Effects of overtraining. The finding described in outcome 6 indicates that providing 100 successive discrimination overtraining trials did not increase the likelihood of equivalence class formation relative to the group that received no overtraining. However, the likelihood of equivalence class formation increased considerably when 500 successive discrimination overtraining trials were added to pre-class formation discrimination training. What remains unclear is at what point between 100 and 500 overtraining trials that the additional increase in likelihood of class formation is obtained. The precise value of training at which the additional benefit of successive discrimination overtraining is revealed could be addressed in future studies that employ smaller parametric changes between these two training values.

*Differential skills of participants who form equivalence classes***.** It is plausible to assume individuals in this experiment differed in terms of preexisting stimulus control topographies or skill sets. Because participants were randomly assigned to the experimental groups, there were no differences in the range of skill sets among the participants in the various groups. As documented by the results of the ABS group, without prior training, only 10% of participants formed classes under the SIM protocol. This implies that the remaining 90% of participants did not have the necessary prerequisite skills needed to form equivalence classes under these conditions.

With increasing levels of pre-class formation discrimination training, however, many more participants in a group formed classes. Of necessity, individuals with lesser skills formed the equivalence classes even though theoretically skill-matched individuals did not in the ABS condition. At the end of the experiment, however, all of the individuals who formed classes were behaviorally interchangeable with respect to class formation. This has some interesting implications. Suppose some additional test were then to be conducted after class formation, such as class expansion or discrimination training and function transfer. How would all of the class learners perform on these post-class formation tests? The results of such a post-class formation test would be most informative.

One possibility is that all participants who formed the classes would perform in the same manner on the post-class formation tasks. No performance based differences would emerge among individuals. Such an outcome would imply that once classes had been formed, indeed, all of the participants had become functionally equivalent to each other, regardless of pre-class formation skill deficits. The pre-class formation discrimination training remediated any differences in the pre-experimental skills of the participants.

The other possibility is that participants who formed the classes would perform differently on the post class formation tasks. These performance based differences among individuals would imply that once classes had been formed, even though all of the participants became able to form the equivalence classes, the underlying skill deficits were still present and were responsible for variations in the post class formation test performances. These possibilities could be addressed in a future experiment by comparing the performances of participants in each group on some post-class formation task.

"Mystery" repertoire responsible for the class-enhancement effect. All participants in the 84-0-0, 84-5-0, 84-20-0, 84-20-100, and 84-20-500 groups acquired the pre-class formation discriminations but only a fraction of them went on to form equivalence classes. These results, of necessity, imply that the acquisition of the discriminations per se was not sufficient to enhance the subsequent formation of equivalence classes. When the discriminations were acquired, the participants who subsequently formed the equivalence classes must also have acquired a stimulus control repertoire other than discriminative, which was responsible for increasing the likelihood

of equivalence class formation. Thus, the acquisition of the discriminations was sufficient but not necessary for the enhancement of equivalence class formation.

For those individuals who formed equivalence classes in the 84-0-0, 84-5-0, 84-20-0, 84-20-100 and 84-20-500 conditions, it might be argued that the class-enhancing stimulus control repertoires were present prior to the experiment. If true, the percentage of participants in the ABS condition who formed classes should have been similar to the percentage of participants who formed classes in the 84-0-0, 84-5-0, 84-20-0 , 84-20-100, and 84-20-500 conditions: between 38 and 81%. In actuality, the ABS condition produced a 10% yield.

This disparity in outcome has two implications. First, the class-enhancing stimulus control repertoire was not present in most of the participants prior to the experiment, and second, the class-enhancing stimulus control repertoire had been adventitiously induced during discrimination training in the present experiment. It also follows that overtraining of 500 trials increased the likelihood of inducing the class-enhancing stimulus control repertoire. Additional research will be needed to (a) identify the class-enhancing stimulus control repertoire that is established during discrimination training, and (b) the procedures that will directly establish that repertoire in most participants.

Exposure learning. In the present experiment, an increase in the amount of pre-class formation discrimination training for the C stimuli from each class resulted in an increase in the likelihood of equivalence class formation across groups. As a result, the C stimuli were presented with increasing frequency across groups, and there was a corresponding increase in the likelihood of class formation. Several studies have documented that the amount of exposure to a stimulus in the absence of a response requirement can enhance the subsequent formation of discriminations (see Hall (1980) for a review). Thus, it is possible that the increased likelihood of class formation that was correlated with increases in the amount of pre-class formation discrimination training in the present study was due to increased exposure to the C stimuli from each class. This could be addressed in future studies by including a control group which would receive the same amount of exposure to the C stimuli during pre-class formation discrimination training as that of the OVR500 group, but would not require a participant to respond to the stimuli. If similar yields were obtained in this exposure control group and the OVR500 group, one could conclude that perceptual learning was responsible for the class enhancing effect of the prior discrimination training. If a considerably lower yield were obtained, one could conclude that the class enhancing effects of the pre-class formation discrimination training were attributable to the reinforcement contingencies of the training procedure rather than to mere stimulus exposure.

Enhanced class formation or class expansion? A very small proportion of participants formed equivalence classes when given training with abstract C stimuli that had not previously acquired a discriminative function. In contrast, most of the participants formed equivalence classes when the C stimuli were meaningful pictures. This class-enhancing effect in the latter condition can be understood by assuming that a meaningful stimulus is associated pre-experimentally with many other stimuli (Tyndall et al, 2004; 2009). Indeed, that set of stimuli is analogous to a generalized equivalence class in which some stimuli in the set share common physical features and many others do not (Barnes, & Keenan, 1993; Lane, Clow, Innis, & Critchfield, 1998; Fields, 2009; Fields, & Reeve, 2001; Galizio, Stewart, & Pilgrim, 2004; Rehfeldt, & Root, 2004). Although there are no direct demonstrations of this possibility, a number of experiments that involve the expansion of already-existing equivalence classes provide suggestive support for this analysis (Eikeseth & Smith, 1992; Goyos, 2000; Saunders, Drake, & Spradlin, 1999; Saunders, Saunders, Kirby, & Spradlin, 1988; Sidman, Kirk, Willson-Morris, 1985). Thus, the high yield in the PIC group could reflect the expansion of an already existing category rather than the de novo formation of an equivalence class (Fields et al., 2012). A more definitive method of testing for the class expansion hypothesis for the outcome of the PIC group would be to test for and find the emergence of relations between the abstract stimuli and other stimuli that are associative correlates of the pictures that were used as members of the same equivalence class.

The present study, however, suggests that class expansion is not the only possible explanation of the class-enhancement effect. The fact that yields for the group that received the highest level of pre-class formation overtraining matched those produced by a group that formed equivalence classes with meaningful stimuli as class members indicates that the very high yields produced by the inclusion of meaningful stimuli can be attributed to the extensive history of acquired discriminative functions served by such stimuli. Thus, the present study documented one behavioral process that could account for the enhancement of class formation that occurs when a meaningful picture is used as a class member: The acquisition and extensive overtraining of the discriminative function served by meaningful stimuli.

To summarize, meaningful stimuli serve a number of behavioral functions, such as their discriminative functions, their conditional discriminative functions, their respondent functions, and/or their membership in perceptual and/or equivalence classes. The present experiment suggested that the discriminative function and its overtraining could account for the class enhancing effect of a meaningful stimulus. Perhaps, class enhancement is also influenced by the other behavioral functions of meaningful stimuli. Additional research will be needed to explore these options.

Apart from these theoretical considerations, the results of the current experiment also document how the likelihood of equivalence class formation can be enhanced by the use of three different pre class formation training variables: type of discrimination training, mastery criteria used in discrimination training, and the overtraining of one of these discrimination training types. Thus, explorations of factors that enhance the formation of equivalence classes also elucidated some of the class enhancing factors embedded in meaningful stimuli. The study of equivalence class formation then also informed a better understanding of the properties of meaningful stimuli.

Table 1.

Variables	Experimental Groups ABS	84-0-0	84-5-0	84-20-0	84-20-100	84-20-500	PIC
Sim Disc Mastery	0	84	84	84	84	84	0
Succ Disc Mastery	0	0	5	20	20	20	0
Overtraining	0	0	0	0	100	500	0
Stimuli	5 Abstract	5 Abstract	5 Abstract	5 Abstract	5 Abstract	5 Abstract	1 Meaningful, 4 Abstract

This table depicts the variations in the three discrimination training parameters that were conducted across the seven groups in this study. The group name is depicted in the top row, and the independent variables are listed in the first column. The numbers in the cells of the first, second, and third rows indicate the number of trials that defined the mastery criteria for the acquisition of the simultaneous, successive, and successive discrimination overtraining portions of the experiment, respectively. Any zeros reflect the absence of training. The last row indicates the type of stimuli that were used to form the two equivalence classes for each group: either abstract CVC's or meaningful pictures. The five groups in the columns between the ABS and the PIC groups were given numerical labels based on the number of training trials that they received in each of three possible portions of pre-class formation discrimination training. The meaning of these numerical labels becomes clear as one looks down the columns. Each number refers to the number of training trials that were used in each portion of pre-class formation discrimination training. Any variations across groups reflect the manipulation of that variable.

Table 2.

Phase	Trial Format	Stimuli	Group 84-0-0	84-5-0	84-20-0	84-20-100	84-20-500
1	Simultaneous	C1-P1 & C2-P2	√	√	√	√	√
2	"	C1-R1 & C2-R2	√	√	√	√	√
3	"	C1-S1 & C2-S2	√	√	√	√	√
4	"	All above	√	√	√	√	√
5	"	C1-X,Y, Z and C2-X, Y, Z	√	√	√	√	√
6	Successive	C1, C2	X	5 trials	20 trials	20 + 100 trials	20 + 500 trials

This table depicts the six phases of pre-class discrimination training for each group. Trial format and the stimuli used on each trial are presented. Different groups received different aspects of pre-class formation training. Checks indicate that a group received that portion of training, and X indicates that they did not.

Table 3.

	Group						
Outcome	ABS	84-0-0	84-5-0	84-20-0	84-20-100	84-20-500	PIC
Yes	2	6	8	9	11	13	17
No	18	10	8	11	9	3	3
Yield (%)	**10**	**38**	**50**	**45**	**55**	**81**	**85**

Statistical Significance

	Group					
Group	84-0-0	84-5-0	84-20-0	84-20-100	84-20-500	PIC
84-20-500	----	----	----	----	----	1
84-20-100	----	----	----	----	0.16	0.08
84-20-0	----	----	----	0.75	**0.04**	**0.02**
84-5-0	----	----	1	1	0.14	**0.03**
84-0-0	----	0.72	0.74	0.34	**0.03**	**0.005**
ABS	0.1	**0.01**	**0.03**	**0.006**	**0.00002**	**0.000003**

This table depicts the equivalence class yields for all seven groups (top panel) and Fisher's Exact Tests for significance between each group (bottom panel). All significant differences are presented in bold typeface.

Figure Captions

Figure 1. This figure depicts the pictorial and nonsense syllable stimuli used as members of equivalence classes (top two sections) and used in pre class formation discrimination training (third section).

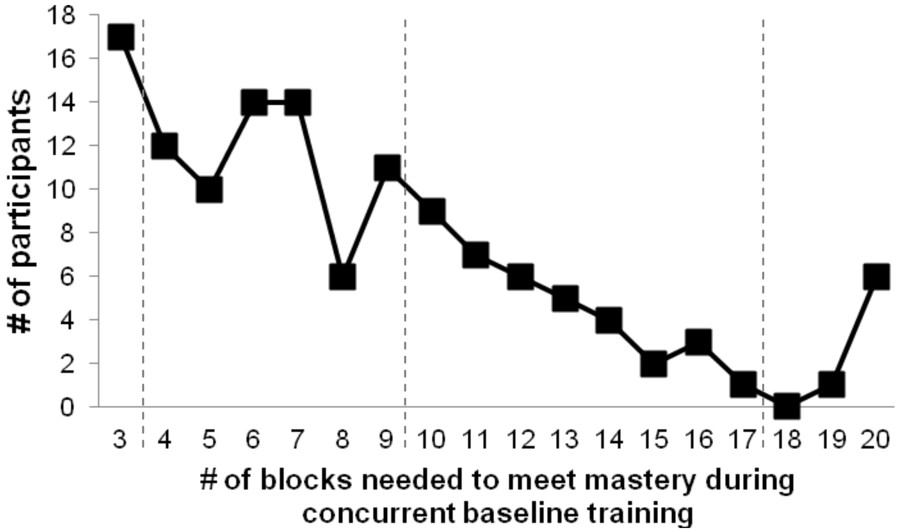
Figure 2. This figure depicts the frequency with which participants in all seven groups needed a given number of blocks to meet mastery criterion when the baseline relations for the two equivalence classes were presented concurrently and with 100% feedback.

Figure 3. This figure depicts the effect of the manipulation of the three different parameters of pre-class formation discrimination training on the likelihood of equivalence class formation. The top panel depicts the percentage of participants in the ABS, 84-0-0, and PIC groups who formed equivalence classes. The middle panel depicts the percentage of participants in the ABS, 84-0-0, and 84-5-0 groups who formed equivalence classes. The differences in yields across groups reflect the effect of different mastery criteria. The bottom panel depicts the percentage of participants in the 84-20-0, 84-20-100, and 84-20-500 groups who formed equivalence classes. The differences in yields across groups reflect the effect of overtraining of the pre-class formation C-based successive discriminations. The horizontal dashed line in the middle and bottom panels reflect the percentage of participants who formed equivalence classes after receiving pre-class formation simultaneous discrimination training only.

Figure 1.

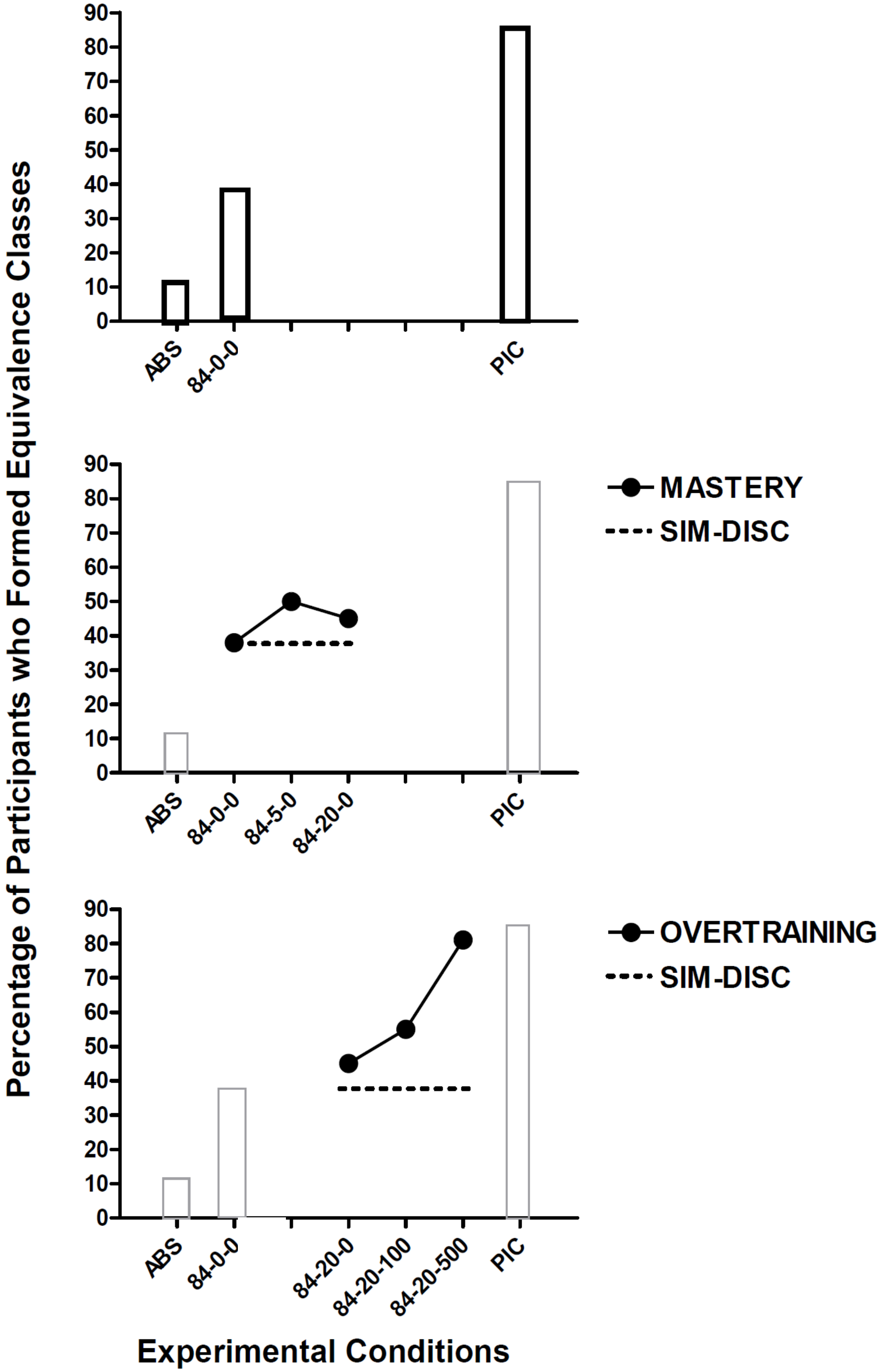
		Classes	
Condition	Stimulus	1	2
PIC	A	LEQ	XAH
	B	TYW	PYV
	C		
	D	HUK	BEW
	E	FOM	GAZ
84-0-0, 84-5-0, 84-20-0, 84-20-100, 84-20-500 and ABS	A	LEQ	XAH
	B	TYW	PYV
	C	YUF	CAQ
	D	HUK	BEW
	E	FOM	GAZ
Additional stimuli used for simultaneous discrimination training	P	BAP	REJ
	R	PIW	WEX
	S	TUD	NUV
	X	ZUC	SIV
	Y	DIH	MEL
	Z	FOS	JAF

Figure 2.



18
16
14
12
10
8
6
4
2
0
# of participants
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
# of blocks needed to meet mastery during concurrent baseline training

Figure 3.



Percentage of Participants who Formed Equivalence Classes
90
80
70
60
50
40
30
20
10
0
ABS
84-0-0
PIC
MASTERY
SIM-DISC
ABS
84-0-0
84-5-0
84-20-0
PIC
OVERTRAINING
SIM-DISC
ABS
84-0-0
84-20-0
84-20-100
84-20-500
PIC
Experimental Conditions

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