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Conditional Discriminative Functions of Meaningful Stimuli and Enhanced Equivalence Class Formation

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CONDITIONAL DISCRIMINATIVE FUNCTIONS OF MEANINGFUL STIMULI AND ENHANCED EQUIVALENCE CLASS FORMATION

by

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Abstract

CONDITIONAL DISCRIMINATIVE FUNCTIONS OF MEANINGFUL STIMULI AND ENHANCED EQUIVALENCE CLASS FORMATION

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Adviser: Dr. Lanny Fields, Ph.D.

Two experiments explored how the formation of two 3-node, 5- member equivalence classes by college students was influenced by the prior acquisition of conditional discriminative functions by one of the abstract stimuli, designated as C, in the class. In Experiment 1, participants in the GR-0, GR-1, and GR-5 groups attempted to form classes after mastering 0, 1 or 5 conditional relations between C and abstract stimuli that were not included in the to-be-formed classes. Participants in the GR-many group attempted to form classes that contained four abstract stimuli and one meaningful, familiar picture that served as the C stimulus. In Experiment 1, the percentage of participants who formed classes in the GR-0, -1, and -5 groups was a direct function of the number of conditional relations that C formed with other stimuli in preliminary training, with the GR-5 group producing a yield similar to that produced when a meaningful picture was the C stimulus (i.e., in the GR-many condition). Two factors differentiated GR-1 and GR-5 pre-training: the number of conditional relations trained to C, and the number of training trials in the presence of the C stimuli. Experiment 2 found that the increase in yield produced by GR-5 was due to number of trained C-based relations and not to the amount of training. Furthermore, Experiment 2 showed that enhancement of class formation after GR-1 pre-training is not improved by linking the C stimulus with a meaningful picture instead of a meaningless stimulus. These results along with recently published research support the view that the class enhancing effect of meaningful stimuli can be attributed to their acquired conditional discriminative and simple discriminative functions, in addition to their connotative and denotative functions.

Keywords: conditional discriminative function, equivalence class formation, meaning, simultaneous protocol, card-sorting

Dedication

This work is dedicated to the loving memory of my grandfather who understood so much about the perseverance needed to complete a Ph.D., encouraged me along the way, and when completion of projects was most difficult reminded me that I cannot give up.

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Table of Contents

List of Tables

List of Figures

Introduction

An equivalence class consists of a finite number of physically disparate stimuli (N) that become related to each other through training of a number (N-1) of conditional discriminations. When the presentation of each stimulus in a set evokes selection of all the other stimuli in the set, in the absence of direct training, the set of stimuli has been converted to an equivalence class (Fields & Verhave, 1987). In a set of N stimuli there are N^2ordered pairs. After training of N-1 baseline relations the remaining number of ordered pairs is stipulated by the formula (N^2 - (N-1)). To conclude that the stimuli in such a set function as an equivalence class, (N^2 - (N-1)) of the ordered pairs in the set must emerge without direct training. Equivalence class formation has been demonstrated using a variety of stimuli, different sensory modalities (i.e. Annette & Leslie, 1995; Fienup & Dixon, 2006; Green, 1990; Hayes, Tilley, & Hayes, 1988, Sidman, 2009), and different experimental preparations (Fienup, & Critchfield, 2008; Saunders& Green, 1999).

When visual stimuli are used in equivalence classes, they are usually abstract shapes or nonsense syllables because such abstract stimuli increase sensitivity to procedural variables that can influence likelihood of class formation (Fields & Verhave, 1987); these include but are not limited to number of nodes, number of members in the class, directionality of training, type of training and testing protocols, and trial formats (Holth & Arntzen, 1998; Sidman, 1994).

Categories of abstract stimuli used in experiments were nonsense syllables consisting of 3-letter consonant-vowel-consonant strings, with no meaning in the lexicon (e.g. WUG, CAQ) (i.e. Moss-Lourenco & Fields, 2011; Plaud, 1995), symbols from an alphabet with which the participants were not familiar, such as Greek or Cyrillic letters (Holth & Arntzen, 1998; Fields, Arntzen, Nartey, & Eilifsen, 2012), or hard-to-name shapes (Bentall, Dickins, & Fox, 1993).

Studies on equivalence class formation demonstrated that when abstract stimuli are replaced by meaningful stimuli such as nameable pictures, or familiar spoken words to which most people tend to respond in the same way, they influence the formation of equivalence classes.

Before discussing the effects of meaningful and meaningless stimuli on likelihood of class formation, it is necessary to consider the meaning of these terms. Meaningful stimuli can be interpreted as being "meaningful" to the extent that they evoke real words, conceptually based associations, and/or differential responding. If this is the case, meaningfulness can be defined by the degree and range of evoked associations and responses. Conversely, a stimulus that is characterized as being abstract or meaningless, would be one that has a presumably small number of associates and evokes a limited number of responses. This analysis also implies that meaningfulness of a stimulus can be arrayed along a continuum of number of associates where the labels meaningful and meaningless as category labels can be arbitrarily set by any set of researchers. These quantitative distinctions, however, will not be used when considering the existing literature or when presenting the current experiments. Rather, the terms will be used in a categorical sense.

The meaningfulness of a stimulus has been defined by its pre-established denotative characteristics, i.e. its dictionary definition (e.g. cobra is a type of snake) and/or by its connotative characteristics, such as the emotional responses the stimulus elicits (e.g. fear of death), the real word associations it evokes, or the operant responses it occasions (such as avoiding to select that stimulus on a trial or moving away from it). When so defined, meaningful stimuli included in a to-be-formed equivalence class influence the formation of classes by delaying, suppressing (Leslie, Tierney, Robinson, Keenan, & Watt, 1993; Plaud, 1995), or enhancing their formation (i.e. Arntzen, 2004; Arntzen & Lian, 2010). Plaud (1995) as well as Plaud, Gaither, Franklin, Weller, and Barth (1998) reported a delay in the formation of classes for participants exposed to sets of stimuli consisting of meaningful but fear-related or sexually arousing words. Leslie, et al. (1993) documented suppression (decreased likelihood) of class formation by the meaningful stimuli for participants who were clinically anxious. Two groups of participants: one group of participants with an anxiety diagnosis and one group without anxiety, attempted to form two 3-member classes composed of one anxiety provoking stimulus (i.e. Job interview, Exam), one nonsense syllable (i.e. ZID, VEK), and one pleasant-state word (i.e. Relaxed, Comfortable). The suppressing effect was suggested by the smaller percentage of clinically anxious participants who formed classes in the anxious group (20% yield), compared with the greater percentage of participants who formed classes in the non-anxious group (75% yield).

Other authors (Arntzen, 2004; Arntzen & Lian, 2010; Fields, et al., 2012; Doran & Fields, 2012; Holth & Arntzen, 1998; Travis, 2013) found an enhancement effect produced by the inclusion of meaningful stimuli that presumably were emotionally neutral (i.e., a picture of a flower). Enhancement of class formation was documented when meaningful stimuli were included in a class of otherwise abstract stimuli and a significantly greater percentage of participants formed classes compared to when all the stimuli in a class were abstract. For example, Arntzen (2004) investigated the class-enhancing effects of a meaningful stimulus included in the training of two one-node 5-member equivalence classes. The author compared participants' performance under five different conditions. In each condition equivalence classes were established by using the many-to-one protocol and training AB, CB, DB, EB relations in this order. What differed across conditions was the type of stimuli used (meaningful vs. abstract) and when these stimuli were introduced (first in training sequence or last). The results showed that under the condition in which participants attempted to form classes with a meaningful stimulus introduced in the first trained relation (AB), with all the other stimuli abstract, there was a 100% yield (all the participant in this group formed classes); the condition in which the meaningful stimulus was introduced in the last trained relation (EB) produced a 50% yield (five of the ten participants in this group); the condition in which participants attempted to form classes in which all stimuli were abstract produced the smallest yield (30%). The meaningful stimulus had the greatest class-enhancing effect when it was introduced in the first task (as the A stimulus) and had a much smaller effect when introduced in the last task (as the E stimulus). The differential class-enhancing effects of the meaningful stimuli may have occurred as a result of more training trials with A-stimuli than with E-stimuli as a result of the training protocol. According to this protocol, once each relation was trained in isolation the experimenter conducted mixed trials of that relation and all previously trained relations; this sequence of training resulted in more exposure to the AB relations.

Class-enhancing effects of meaningful stimuli were also demonstrated by Doran and Fields (2012). The authors investigated the effects of nodal distance on the relatedness of stimuli in two 5-node 7-member equivalence classes. In Experiment 1, all the stimuli were abstract nonsense syllables and only one out of six participants formed classes (16% yield). In Experiment 2, one meaningful stimulus was substituted for one of the abstract stimuli and five of 13 participants (40% yield) formed classes. Thus, the inclusion of a meaningful stimulus enhanced class formation.

The influence of meaningful stimuli on likelihood of equivalence class formation may be attributable to their presumed acquired behavioral functions. Some of these functions are (a) membership in perceptual or equivalence classes, (b) discriminative functions, and (c) conditional discriminative functions (Fields et al., 2012). Recent studies explored the effects of the simple discriminative function served by meaningful stimuli (Fields et al., 2012; Tyndall, Roche, & James, 2004; Travis, 2013). Fields, Arntzen, Nartey, and Eilifsen (2012) employed a between group design with three conditions: an all abstract stimuli condition, a meaningful stimulus condition, and an acquired discriminative function condition. In each condition participants attempted to form three 5-member equivalence classes following a simultaneous training protocol by training AB, BC, CD, and DE relations. In the all abstract stimuli condition participants attempted to form classes consisting of five abstract stimuli in the form of Greek and Arabic letters (the participants were not familiar with these alphabets). In the meaningful stimulus condition participants attempted to form three classes, each consisting of one meaningful stimulus (i.e. a picture of a nameable and neutral item) and four abstract stimuli similar to those used in the abstract condition. In the acquired function condition, participants were exposed to all abstract stimuli, with the difference that the C stimulus in each class was initially trained to serve a discriminative function in a simple discrimination procedure (acquired function condition). The authors found that 85% of the participants formed five-member-equivalence classes in the meaningful stimuli condition, 0% of the participants formed classes in the abstract stimuli condition, and 50% of the participants formed classes in the acquired discriminative function condition. The fact that an intermediate proportion of the participants in the acquired function condition formed classes suggests that part of the enhancement effect produced by meaningful stimuli can be attributed to their discriminative functions.

A further exploration of the effect of the discriminative function of meaningful stimuli was conducted by Travis (2013). The author established two 3-node 5-member equivalence classes for six groups of participants. The groups differed with respect to the amount of simultaneous and successive discrimination training they received in the presence of C stimuli prior to their inclusion in equivalence classes. Travis (2013) varied the numbers of pre-class formation discrimination training trials, and found that overtraining up to 100 trials resulted in only 50% of the participants in each group forming equivalence classes. Extensive overtraining of successive discriminations with the administration of 500 trials beyond acquisition and the subsequent inclusion of the discriminative stimulus in the to-be-formed equivalence class produced an enhancement effect as great as that produced by the inclusion of a meaningful stimulus in the class. Therefore, the enhancement of equivalence class formation by the inclusion of a meaningful stimulus can be accounted for by the extensive overtraining of a simple discriminative function acquired by one of the abstract stimuli in the to-be-formed class.

Most likely, meaningful stimuli also serve other behavioral functions such as (a) being a member of one or more conditional discriminations, (b) being a conditional eliciting stimulus or CS, or (c) being a member of different classes. To date, no studies have investigated the effect that a conditional discriminative function acquired by one of the abstract stimuli in a set has on the formation of an equivalence class from that set.

The current dissertation examined whether equivalence class formation can be enhanced by the prior acquisition of conditional discriminative functions by one of the abstract stimuli used as a member of a to-be-formed equivalence class. The effects of the function acquired by the abstract stimuli during conditional discrimination training was explored in conjunction with the effects of varying the number of conditional relations that C forms with other abstract stimuli prior to its inclusion in a class.

Experiment 1

Experiment 1 involved four groups with 12 participants each. In all groups participants attempted to form two, 3-node, 5-member equivalence classes in which the A→B→C→D→E baseline relations were trained serially and were subsequently presented together with derived relations in a series of testing blocks . Groups varied with regards to the number of preliminary conditional discriminations trained to C stimuli prior to their inclusion in a class.

In two of the four groups, labeled GR-0 and GR-many the participants attempted to form classes with A-E stimuli and then were tested for the emergence of classes. In the GR-0 group participants attempted to form equivalence classes in which all five stimuli were abstract stimuli in the form of nonsense syllables. For participants in GR-many, the middle node, C, was a meaningful, nameable stimulus, and the other four members in the class were abstract stimuli: A, B, D, E, identical to the abstract stimuli used in GR-0.

Participants in the other two groups received conditional discrimination training with the C stimuli before attempting to form the equivalence classes. The training of conditional discriminative function to C involved linking of C to one abstract discriminative stimulus by training C→X conditional relations (GR-1) or linking C to five other abstract stimuli through training of C→V, C→W, C→X, C→Y, C→Z (GR-5).

Previous research (Fields et al, 2012; Travis, 2013) has shown that when attempting to form three 5-member classes using the simultaneous protocol 85% of the participants formed classes in which one stimulus was a meaningful picture and 10% of the participants formed classes when all the stimuli were abstract. Findings of previous research support the use of yields in GR-0 and GR-many as reference points to evaluate the effects of the procedures used in the remaining groups: GR-1 and GR-5.

Method

Participants

The participants were 48 undergraduate students, with ages between 18-50, enrolled in an Introductory Psychology course taught at Queens College, City University of New York (CUNY). They received credit toward the research requirements of their introductory course in psychology in exchange for their participation in this study. The subjects were naïve with respect to the purpose of the experiment. The participants were assigned to four different groups by using block-randomization: for every set of four participants they were assigned without replacement to each condition.

Setting

The experimental sessions were carried out in rooms in a laboratory suite at Queens College. The laboratory included a greeting room and seven experimental cubicles 1.5m x 2m, each equipped with a desk, a chair, and a computer.

Apparatus

Hardware. The experimental session were conducted on Dell Desktop computers that use 1828 MHz Intel Centrino processors, and have images transmitted to flat screen monitors that had a 42.67 cm diagonal dimension with a 40.64 cm x 22.86 cm horizontal to vertical ratio.

Software. The training and testing to establish equivalence classes were controlled by a software program written in Visual Basic. This software controlled the presentation of all stimuli, recorded the number of trials, the stimulus relations being trained or tested, the number of responses to sample stimuli, correct/incorrect comparison selections, and the type of feedback provided on each trial.

Stimuli. All the stimuli used as conditional discriminative stimuli and as members of the equivalence classes were abstract nonsense syllables consisting of consonant-vowel-consonant combinations (CVC's) with the exception of the GR-many group which included four abstract CVC's and one familiar pictorial stimulus. All the stimuli used in preliminary training and equivalence class formation are listed in Table 1. The stimuli used during preliminary training are designated by alphanumeric labels as C1, V1, W1, X1, Y1, Z1, N1, C2, V2, W2, X2, Y2, Z2, N2. N1 and N2 served as nulls during the training of the conditional relations between the C and either X stimuli, or V-Z stimuli (N1 for C1, and N2 for C2). The nulls were negative comparisons that did not belong to an experimenter-defined class. The functional utility of nulls will be discussed in the procedure section. Each stimulus included in equivalence class formation is referred to by its alphanumeric labels as A1, B1, C1, D1, E1, and A2, B2, C2, D2, E2, with classes denoted by the numerals 1 and 2. Two "null" comparisons (N1 and N2) were also used in the training of baseline relations.

All abstract stimuli appeared on the computer screen in black font displayed on a white background. The pictorial stimuli used during discrimination training in GR-many groups were displayed in color on a white background. During training, the selection of the positive comparison was followed by the informative feedback "Right!" that was written in blue font on a white background and the selection of a negative comparison was followed by the feedback word "Wrong!" that appeared in magenta font on white background. During feedback reduction and the maintenance of baseline relations a "no feedback" written stimulus appeared on the screen, written in green font on white background.

Experimental design

The experiment was a between-group design. Table 2 presents the experimental manipulations conducted. In the first group each class contained five abstract stimuli (A, B, C, D, and E) and was labeled as GR-0 because there was no preliminary conditional discrimination trained to C. In the second group participants attempted to form classes containing four abstract stimuli (A, B, D, and E) and one meaningful picture, C, and was labeled GR-many because the meaningful picture, C, was presumed to have been part of many conditional discriminations prior to its inclusion in the group. Groups 3 and 4 attempted to form equivalence classes with all abstract stimuli as class members, but the C stimuli from each class were first used in different pre-class formation conditional discrimination training protocols.

Procedure

Keyboard Familiarization. For all the groups the experiment began with the presentation of instructions on the screen regarding the keys that the participants had to press in each block to progress from trial to trial. Once they read the instructions and pressed “enter” on the keyboard, participants in all groups completed a block of trials designed to familiarize them with the keys they had to press to complete a trial. This block contained 16 trials in which sets of related English words were presented in a match-to-sample format with three comparisons. Trials contained four English words such as FISH, WATER, LAND, and BEE. When the word FISH appeared as a sample, a press on “A” key brought up three comparisons. Selection of the correct comparison was made by pressing computer keys 1, 2, or 3. Selection of comparison WATER when the word FISH was the sample resulted in presentation of written feedback “Right”. Selection of any of the negative comparisons resulted in the presentation of written feedback “Wrong”. This block was repeated until participants selected the correct comparison on every trial in the block (100% correct responding). Following correct completion of the keyboard familiarization phase, the participants in GR-1 and GR-5 received conditional discrimination training.

Conditional discriminations established in preliminary training. Two groups took part in preliminary conditional discrimination training: GR-1 and GR-5.

GR-1. In the GR-1 group, the participants formed C→X conditional relations as a result of preliminary training, before attempting to form classes with stimuli A-E. In preliminary training C and X were both abstract, nonsense syllables. C was the sample and X was the positive comparison. Two conditional relations were trained between C1-X1 and between C2-X2, using a match-to-sample format with one sample and three comparisons. According to this procedure, when C1 was the sample, X1 was the positive comparison and X2 and N1 were the negative comparisons. When C2 was the sample X2 was the positive comparison, while X1 and N2 were the negative comparisons. N1 and N2 served as negative comparisons that did not belong to any experimenter-defined class and are referred to as “nulls”. According to the argument presented by Sidman (1987) the inclusion of the nulls on all trials ensured that selection of the positive comparisons is controlled by their relation to the sample stimuli rather than rejection of the negative comparison stimuli (Co-s). Each discrimination training block included 10 C1/X1-X2-N1 and 10 C2/X2-X1-N2 trials. The order of presentation of the two samples, C1 and C2, was randomized within a block of trials and occurred with equal frequency. One of the samples, C1 or C2, appeared in the middle of the screen. A press on “A” key made the comparisons appear on the screen. The comparisons were displayed below the sample in left, middle, and right positions. The positions of the comparisons were randomized across trials. Participants had to press on “1”, “2” or “3” keys to select a comparison. “1” corresponded to the comparison appearing on the left, “2” corresponded to the comparison in the middle position, and “3” to the comparison on the right. Selection of one comparison resulted in presentation of the written words on the computer screen: “Right” or “Wrong.” A press on “R” or “W” keys made the feedback words disappear and started the next trial. This block was repeated until participants responded correctly to all the trials (100%). Subsequent to reaching mastery, participants in this group began the training for equivalence class formation. The X stimuli were not used in the training of baseline relations for equivalence class formation.

GR-5. In the GR-5 group conditional discrimination preliminary training involved the training of conditional relations between C and five other stimuli labeled V, W, X, Y, and Z. The C and V-Z stimuli were abstract, nonsense syllables. In preliminary training, conditional relations were established between C1 and five stimuli V1, W1, X1, Y1, and Z1 and between C2 and five other stimuli: V2, W2, X2, Y2, Z2. The five different conditional discriminations were initially trained serially, C→V, C→W, C→X, C→Y, C→Z, and then were mixed. Training for each relation (CV, CW, CX, CY, CZ) was conducted in blocks that contained 20 trials. Training began with introduction of CV relations. Mastery of this relation resulted in the presentation of a block of CW trials. Once a participant mastered the first two relations in separate blocks (C→V and C→W), he/she progressed to a block of mixed relations in which the two relations alternated (C→V and C→W). This block contained 20 trials as well and was repeated until participants reached criterion responding of 100% accuracy. Following mastery of this block a participant progressed to learning of C→X, followed by C→Y, and finally by C→Z relations in a serial manner. Following accurate responding to C→Z relations participants completed blocks in which the C→X, C→Y, and C→Z relations were mixed in one block that contained 24 trials. Each block was repeated until a participant reached 100% correct responding in that block.

Finally a block of 40 trials in which all five CV-CZ relations were intermixed was presented. Mastery of all relations in this block was followed by the training of baseline relations for equivalence class formation These V-Z stimuli were not used as members of the to-be-formed classes ABCDE classes.

Equivalence-class formation. For the GR-0 and GR-many groups, the revised version of the simultaneous protocol was administered to form two 3-node 5-member equivalence classes at the start of the experiment. For the remaining groups, the same protocol was introduced after mastery of the initial conditional discrimination training with the C-X and C-VWXYZ stimuli respectively. Under this protocol AB relations were trained first, followed by the training of BC, CD, and DE relations respectively. Once participants acquired the baseline relations they completed six test blocks that contained mixed baseline, symmetry, transitivity, and equivalence probes.

Training of baseline relations. Baseline relations were established serially in individual blocks starting with A→B, followed by B→C, then C→D, and finally D→E conditional relations. Each block was repeated until the positive comparison was selected on every trial in the block: 100% accurate responding. Each block consisted of 16 trials each. For example, when training AB relations, a block contained eight A1B1 and eight A2B2 trials. On each trial a sample and three comparisons stimuli were presented: a positive comparison from the same set as the sample, a negative comparison from the other set, and a null which did not belong to either set. The positions of the comparisons were randomized across trials.

Each block was repeated until a mastery criterion of 100% correct responding was achieved for that block. After the training of last relation alone, e.g. DE, training was continued in a series of blocks of 16 trials each, in which pairs of the previously established baseline relations were mixed and presented in this order: AB and BC, CD and DE, AB and CD, and BC and DE. Each mixed block was repeated until a participant responded with 100% accuracy. Thereafter, all four baseline relations (AB, BC, CD, and DE) were presented concurrently in a block that contained 16 trials as well (ABCDE). This block was repeated until it evoked 100% accurate responding.

Maintenance of the baseline relations. Once the participants reached criterion responding in the blocks that contained all of the baseline relations and received feedback on every trial, the same 16 trials were presented in blocks that contained decreasing levels of feedback (75%, 25%, and 0% feedback for the trials in a block). During feedback reduction a “no feedback” stimulus appeared following 0%, 25% or 75% of the responses depending on the feedback reduction block. 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.

In each block of feedback reduction, participants were required to respond accurately on at least 93% of the trials. If a participant failed to meet this criterion, he/she repeated the block up to five times. If the participant still failed to meet criterion after repeating the block with the same level of feedback on five occasions, he/she was placed back into a block that contained the same trials (mixed ABCDE) at the last feedback level that he/she passed (e.g., if they failed to meet mastery in five attempts at the 25% percent feedback level they were placed back into the last ABCDE block with 75% feedback).

Testing for the emergence of derived relations. Once participants maintained responding to the baseline relations presented with 0% feedback (accurate responding 93% or higher), they proceeded to the testing phase. Testing consisted of a series of six 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 testing blocks. The test include some of the baseline relations (AB, BC, CD, DE) to assess their maintenance, and trials that assessed the emergence of symmetrical relations (BA, CB, DC, ED), transitive relations (AC, AD, AE, BD, BE, CE) and equivalence relations (CA, DA, EA, DB, EB, EC). Each of these derived relations was assessed once for one of the classes and the class representation was counterbalanced across relations. Table 3 contains a list of the tested relations. The criterion used to define class formation is $\geq$90% selection of class indicative comparison stimuli on at least two consecutive blocks of the derived relations test.

Card-sorting test. After completion of the derived relations test, a sorting test like that used by Fields, Arntzen, Nartey, and Eiliefsen (2012), was administered to assess the generalization of class consistent responding in a different experimental arrangement, and to determine whether the V, W, X, Y and Z stimuli X used in preliminary training were sorted in the same sets as the C stimuli to which they were linked by training.

The test was conducted with six of the participants in GR-5 group who had additional time remaining in a session to complete this test. The test involved sorting of index cards that had the name of all the stimuli used in the training of preliminary conditional discriminations and of baseline relations printed on one side. The experimenter instructed the participants to sort the cards in piles of related “words”. The experimenter did not tell the participants how many piles they should form. Card sorting has been shown to be a sensitive measure of class formation. In Fields et. al (2012), some of the participants who didn’t form classes as documented by the derived relations test showed the formation of at least one of the three experimenter-defined classes when having to sort the stimuli in distinct classes.

Results and Discussion

Emergence of Equivalence Classes

Figure 1 shows the percentage of participants who formed classes in each group. In this figure, no distinction was made between immediate or delayed emergence of the classes. The values listed on the horizontal axis refer to the number of stimuli linked to C in preliminary conditional discrimination training: 0 (in GR-0/ABS), 1 (in GR-1/C→X), 5 (in GR-5/C→VWXYZ) and "many" (in GR-many/PIC). The endpoint on the horizontal axis is labeled "many" because it refers to the presumed number of conditional discriminations of which a picture was a part, prior to its inclusion in the experimenter-defined set. The y-axis represents the percentage of participants who formed classes in each group.

Equivalence classes were formed by a small percentage of the participants in the GR-0, by a greater percentage of participants in GR-1, by an even greater percentage of participants in GR-5, and it further increased as the presumed number of links increased in the GR-many. The likelihood of class formation was a direct function of number of pre-class formation conditional discriminations established with the C stimuli. The trend depicted in Figure 1 was clear, and the most extreme pairwise differences were statistically significant as revealed by Chi Square tests: GR-0 vs. GR-5 ($p = .03$), and GR-0 vs. GR-many ($p= 0.01$.). The other differences in yield, however, were not significant.

The group yields were further analyzed in terms of the effects of each condition on the immediate and delayed emergence of the equivalence classes and presented in Figure 2. Immediate emergence was defined as the selection of class-indicative comparison stimuli on at least 90% of the trials (mastery criterion) in the first two testing blocks. Delayed emergence was defined as selection of class indicative stimuli on at least 90% of the trials in any two consecutive blocks beyond the first test block**.**

Figure 2 shows the yields produced on an immediate or delayed basis in each experimental group. The bottom, white, part of each bar represents the proportion of participants who showed immediate emergence of classes. The upper, shaded part of the bar represents data for those participants who showed delayed emergence. In each group, an approximately equal proportion of participants showed the immediate and delayed emergence of the classes. Thus, the experimental manipulations produced equal likelihoods of immediate and delayed emergence of classes. Pre-class formation training, then, did not differentially influence rate of emergence of the equivalence classes.

The data in Figure 3 clarify the process of emergence by showing block by block percentage correct responding for the last baseline maintenance block, and each of the six testing blocks. Data were averaged across participants and conditions because there were no between group differences with regards to proportion of participants showing immediate versus delayed emergence.

The upper panel represents the performance of the 10 participants who formed classes on an immediate basis. As depicted in this panel, there was no decrement in responding from the last block of maintenance to the first block of testing. Also, once a participant met criterion responding (in the first two blocks), their performances were maintained at 90% or above for the remaining testing blocks.

The bottom panel represents the data for the 27 participants who did not form classes, labeled No ECF. For all the participants who did not form classes there was a drastic decrease in accuracy of responding from the last maintenance block of baseline relations to the first block of testing. In addition, there was no improvement in accuracy with the repetition of the test blocks.

The second through fifth panels represent delayed emergence of equivalence classes for those participants (11 total) who showed criterion-level responding after one, two, three, or four blocks (DLY-1, DLY-2, DLY-3, and DLY-4).

For those participants who formed classes on a delayed basis there was a large decrease in responding from the last training block of mixed baseline relations to the first testing block in which the derived relations were presented for the first time. Their performance decreased from at least 94% accuracy during maintenance to about 70% in the first testing block. Following the first block of testing, the participants maintained class-consistent responding at about 70% accuracy before shifting abruptly to the criterion-level of responding (90% and above). The approximate 20% increase from the failing blocks to the mastery blocks was consistent across participants who showed delayed emergence, regardless of the number of blocks needed to show class formation. This sudden increase demonstrated that delayed emergence in the present experiment was not a gradual process; rather, it is better characterized by a sudden change in responding. Further, the pattern of emergence did not vary with the extent of the delay.

Card-Sorting Test

The sorting test was administered after the derived relations test and was used to evaluate how the participants in GR-5 group categorized the stimuli, V-Z, linked to C in preliminary training and those from the experimenter-defined classes (A-E). This group was the only group where there was the possibility of group merger. These data reveal possible mechanisms of class enhancement. All 12 participants in GR-5 sorted the A-E and V-Z stimuli prior to conditional discrimination training. After the completion of the last test block for the emergence of derived relations, only six of them had the time to complete a post-class formation sorting test. Their performance is represented in Table 4.

Table 4 consists of six boxes, each representing the sorting performance of one of the six participants who completed this test. The first box represents the sorting performance of one of the participant who did not show class formation in the derived relations tests. This participant, when given the index cards to sort, placed the A-E and V-Z stimuli in five different piles without sorting all A1-E1 in one pile or A2-E2 in a second pile. Rather, the stimuli from the same experimenter-defined class were spread across five different piles. The following two boxes depict the sorting data for two participants who formed the equivalence classes as documented in the derived relations tests. They placed the A-E stimuli into two distinct piles, with all A1-E1 in one pile and all A2-E2 in a different pile. These participants also placed some, but not all of the V1 through Z1 in the same stack as the A1-E1 stimuli and the others with the A2-E2 stimuli. Similarly they placed some of the V2-Z2 stimuli with A2-E2 and others with A1-E. Although these participants categorized the A-E stimuli in accordance with the experimenter-defined classes, they did not do the same for V1-Z1 stimuli linked to C1 or the V2-Z 2 linked to C2. The last three boxes depict the sorting performance for three other participants who formed classes. These participants placed the A1-E1 stimuli into one pile and the A2-E2 into a different pile. They also placed the V1-Z1 stimuli in the same pile as the A1-E1 stimuli and the V2-Z2 stimuli in the same pile as the A2-E2 stimuli. For these participants, V-Z merged with A-E stimuli forming two 10-member equivalence classes that contained the ABCDEVWXY and Z stimuli. This class had a hypothetical structure represented in Figure 4.

In Figure 4 the A→B→C→D→E notation represents the training structure of the experimenter-defined classes comprised of the stimuli A-E. The solid arrows above and below stimulus C represent all the relations formed in preliminary training and point from the sample to the comparison stimuli. The broken arrows represent some of the hypothesized derived relations that emerged during testing and sorting amongst V-Z and A-E stimuli.

Acquisition and Maintenance of Baseline Relations

The data presented thus far, focused on likelihood of equivalence class formation. The following sections focus on how the preliminary conditional discrimination training affected rate of acquisition and maintenance of baseline relations that were the prerequisites for class formation.

Effects of C function on number of trials to acquisition. There were no between-group differences in the number of trials completed to reach mastery of all baseline relations ($F(3, 44) = 0.14$, $p=0.9$). Figure 5 shows the mean number of trials to acquisition of all the baseline relations separated for those participants who did (black bars) and those that did not form classes (gray bars) in each experimental condition.

For three of the four conditions, there were no significant differences between the number of trials to acquisition for those who did and did not form classes (GR-0, GR-5, and GR-many). A statistically significant difference was found in the GR-1 group, where participants who formed classes took a significantly greater number of trials to acquisition than those who did not.

Acquisition of baseline relations and predictability of class formation. The number of trials to acquisition did not predict subsequent class formation for three of the four groups (GR-0, GR-5, GR-many). The only predictive relation was found in the GR-1 group, where a statistically significant inverse correlation was found between trials to mastery and likelihood of equivalence class formation ($r(10) = .64$, $p=0.02$).

Effects of training order and C-history on baseline acquisition. Since the baseline relations were trained serially, would a learning set effect occur on this process whereby the AB relations would be acquired more slowly and the subsequent relations acquired more rapidly? Would this pattern of acquisition be present in those groups that had preliminary training with C stimuli, as in GR-1 and GR-5 or only in those that did not have such training as in GR-0 and GR-many? The phenomenon of learning set means a decrease in the number of errors to acquire new sets of discriminations as a result of a reinforcement history for other, unrelated, sets of discriminations (Fields, Garruto, & Watanabe, 2010).

For the groups that had preliminary training with C, would the acquisition of the baseline relations that included the C stimuli with reinforcement histories or pre-experimental histories (BC and CD) be acquired more rapidly than the relations that did not include the C stimuli (AB and DE)? Figure 6 illustrates the effects of these variables on the establishment of the baseline relations that were the prerequisites for the to-be-formed equivalence classes. In the GR-0 condition all the stimuli were nonsense syllables. The C stimuli were not linked to any stimuli prior to the training of the baseline relations. When the baseline relations were established, AB, the first trained relation, was acquired more slowly than all of the other subsequently trained baseline relations. All of the latter relations are acquired more quickly and in about the same number of trials. Thus, there was an order effect on acquisition speed that became asymptotic after the acquisition of the first baseline conditional discrimination.

In the GR-many condition, the C stimulus was a meaningful picture. When the baseline relations were established, AB, the first trained relation, was acquired more slowly than all other subsequently trained baseline relations. The baseline relations that included meaningful C stimuli, BC and CD, were acquired more rapidly than the relations that did not include the pictorial stimuli, AB and DE. Thus, the inclusion of meaningful stimuli in baseline relations appeared to accelerate acquisition speed relative to relations that did not include meaningful stimuli. In the GR-1 condition all the stimuli were nonsense syllables, but the C stimulus was linked by training to one other nonsense syllable (X) in pre-class formation training. When the baseline relations were established, all were acquired quickly and at the same rate. Thus, rate of baseline acquisition was not influenced by the inclusion of a C stimulus that had previously become related to one other stimulus.

A different outcome was obtained in the GR-5 condition, where the first trained relation, AB, was acquired more slowly than all the other subsequently trained baseline relations. All of the remaining relations were acquired more quickly and in a similar number of trials. As in GR-0, but not in GR-1, there was an order effect on acquisition speed, which became asymptotic after the acquisition of the first baseline conditional discrimination. In addition, the inclusion of the C stimuli in the baseline relations (BC and CD), had no effect on acquisition speed when compared to DE.

To summarize, there were no consistent trends in the acquisition of the baseline relations that were found in all four pre-class formation training conditions in this experiment. In three of the four conditions, the AB relations were acquired more slowly than the subsequently established baseline relations.

Figure 7 represents another way of looking at the rate of acquisition of baseline relations, by presenting the percentage of participants who took a minimum number of blocks (one) to acquire either AB or DE relations and comparing it with the percentage of participants who took the minimum number of blocks (one) to complete either BC or CD relations in each group. The data in this figure show that the preliminary acquisition of conditional discriminative function in

GR-5 influenced the subsequent acquisition of those relations that included the C stimuli either as comparisons in the BC relations or as samples in the CD relations. Fifty percent of the participants in GR-5 acquired BC or CD relations in the minimum number of blocks (one), which was much higher than the percentage of participants who completed the minimum number of blocks to acquire BC or CD relations in the other three groups.

Effects of C function on maintenance of baseline relations. Figure 8 shows the proportion of participants who took various numbers of blocks with feedback reduction to show maintenance of baseline relations at the 0% feedback level and to progress to testing. The data were aggregated across all conditions because there were no differences between groups with regard to completion of number of feedback reduction blocks. The cluster of bars on the right represents data for those participants who did not form classes and the cluster of bars on the left shows the data for those who formed. The dark bars in each cluster represent the percentage of participants who required the minimum number of blocks of feedback reduction (three) to show mastery of baseline relations in the maintenance block. The gray bars in this figure represent the proportion of participants who required additional blocks with feedback reduction before achieving mastery in the maintenance block, and the white bars represent the proportion of participants who repeated blocks with feedback reduction and also required retraining of some of the baseline relations to achieve mastery in the maintenance block.

Regardless of subsequent class formation, about two thirds of the participants maintained mastery level of responding on baseline relations during feedback reduction and completed that phase in the minimum number of programmed training blocks. A much smaller proportion of participants in each group required repetition of the feedback reduction blocks at a given level of feedback to achieve mastery criterion (the gray bars). For these participants, the reduction of feedback produced a decrement in response accuracy that then resurged to the mastery level with simple block repetition. The remaining small proportion of the participants showed decrements in responding with feedback reduction that did not resurge with block repetition; for them reacquisition of the mastery level of responding necessitated backing up to a higher density of reinforcement per block (the white bars).

As shown in this figure there were no systematic differences in the number of blocks with feedback reduction completed by the participants who formed and those who did not form classes in any of the experimental conditions, nor were any significant differences between groups with regard to number of feedback reduction block. Thus, performances during feedback reduction were not predictive of eventual class formation and were not correlated with pre- class formation conditional discrimination training.

Summary

Seventeen percent of the participants formed classes in GR-0 when all members of the class were abstract stimuli and C had not acquired a conditional discriminative function prior its inclusion in an experimenter-defined class. Thirty three percent of the participants formed class in GR-1 where one conditional relation was trained prior to class formation, and fifty eight percent of the participants formed classes in GR-5 where five conditional relations were trained prior to the training of baseline relations. The yield further increased in GR-many where a picture was used as the middle node, C, and all the other members of the class were abstract stimuli. The increase in yield from GR-0 to GR-1, to GR-5, and to Gr-many was a direct function of the number of conditional discriminations trained prior to the inclusion of C in an experimenter-defined class. The experiment appears to show that fact that class formation was substantially increased by the preliminary training of five different conditional discriminative relations to C stimuli as compared to training of 0 or to the training of only one such relation (GR-5 vs. GR-0 and GR-1). The preliminary training of 0, 1, 5 or the already existing "many" conditional relations produced an equal likelihood of emergence of derived relations on an immediate or delayed basis. The type of preliminary training did not differentially affect the rate of emergence of classes for any of the groups in this study. The speed of acquisition of baseline relations was not a predictor of class formation for three of the four groups; for one single condition, GR-1, an inverse correlation was found between number of trials to acquisition and class formation.

A secondary measure of equivalence class formation, the card sorting test, completed by the participants in GR-5 group, produced results consistent with the results of the test for emerging relations: the participants who met criterion in the emerging relations test also sorted the A-E stimuli into two experimenter-defined classes, and the participants who did not meet criterion in the initial test, sorted the A-E stimuli into five different classes (none of which contained all the stimuli from any of the experimenter-defined classes). Additionally, the sorting data also revealed that for some of the participants in GR-5, the previously trained conditional discriminations between C-VWXYZ together with the training of A→B→C→D→E relations led to the merger of the two into one class (containing all the 10 stimuli as members) whereas for others it did not. For those who did not sort the V-Z stimuli in the corresponding A1-E1 and A2-E2 classes it is possible that the formation of conditional relations alone, without the formation of another equivalence class C-VWXYZ, was responsible for the class-enhancing effects observed in GR-5. These data are suggestive of two mechanisms for class enhancement. Further research will be needed to assess the validity of the presented assumptions.

Experiment 2

In Experiment 1, the GR-5 condition produced a greater class enhancing effect than did the GR-1 condition. These two conditions differed in terms of the number of relations trained between C and other stimuli (five in GR-5 versus one in GR-1). These two conditions, however, also differed in terms of the number of training trials required to master these different relations. An average of 431 trials was needed to complete preliminary training by the participants in the GR-5 condition while an average number of 82 trials were needed for the participants in the GR-1 condition to master the C→X conditional relation. Thus, the number of relations and the number of trials to mastery of these relations were confounded factors in Experiment 1, either of which could have been responsible for the class enhancement effect produced by the GR-5 condition.

The effects of these two variables were separated in in Experiment 2 by employing a condition in which one single conditional relation, C→Q, was over-trained for 500 trials beyond acquisition. This group is labeled as GR-1-500. The overtraining was done for 500 trials for two reasons. One reason had to do with the number of trials required to master the GR-5 relations in Experiment 1, which approximated the total of 483 to master all C-V, C-W, C-X, C-Y, C-Z. A second reason had to do with the findings of Travis (2013) who used 500 overtraining trials for a simple discrimination task and showed that such a condition enhanced class formation as much as the inclusion of a meaningful pictorial stimulus. Therefore GR-1-500 was employed as a control for GR-5 in the second experiment. If GR-1-500 produces a yield greater than GR-1 alone and one that is similar to that produced by GR-5, then the sheer number of trials required to master the GR-5 relations was responsible for the class enhancing effect observed in Experiment 1. If GR-1- 500 does not produce yields greater than GR-1, it can be asserted that it was the number of relations established in GR-5 training that actually lead to a greater likelihood of class formation for participants in that group.

One other factor might be responsible for the low yield obtained after GR-1 preliminary training: the use of abstract stimuli, X, with which C formed a conditional relation. As shown in Experiment 1, and also in prior research (Arntzen & Lian, 2010; Fields et al, 2012) the inclusion of a meaningful stimulus as a class member greatly enhances the formation of an equivalence class. Thus, it is possible that the training of a single conditional relation between the abstract C stimulus and a familiar meaningful picture would substantially increase the class enhancing effect of the prior establishment of a single C-based conditional relation. This possibility was explored by the training of one single conditional relation between an abstract stimulus and a meaningful picture before the inclusion of the C stimulus as a member of a to-be-formed class. This group is labeled GR-1-Pic. If GR-1-Pic produces a yield significantly greater than that produced by GR-1 then it can be concluded that the content of the stimulus with which C forms a conditional relation prior to its inclusion in an experimenter-defined class is responsible for higher likelihood of class formation.

Therefore two groups of participants were included in Experiment 2. Participants in both groups took part in conditional discrimination training with abstract C stimuli prior to attempting to form two 3-node 5-member classes (A→B→C→D→E). In the first group, GR-1-500, participants mastered one conditional discrimination, C→Q, with 500 overtraining trials prior to the establishment of the baseline relations for equivalence class formation. In the second group, GR-1-Pic, participants mastered one conditional discrimination, C→Pic, that contained the C stimulus as the sample and a meaningful stimulus, Pic, as the positive comparison. The results of these conditions were compared to those obtained in Experiment 1.

Method

Participants

Twenty four students participated in this study and were assigned on a block-randomized basis to one of two groups: 12 to the GR-1-500, and 12 to the GR-1-Pic group. All participants were drawn from the same subject pool as those used in Experiment 1. Their ages were between 18 and 50 years old.

Setting and Apparatus

The setting and apparatus used in this experiment were the same as in Experiment 1.

Procedure

Training of preliminary conditional discriminations. Two groups completed preliminary training: GR-1-500 and GR-1-Pic

GR-1-500. Training of preliminary conditional discrimination for the participants in this group had two phases. The first phase was identical to C→X training procedures described in experiment 1 but this relation will be referred to as C→Q to distinguish it from C→X in the first experiment. Subsequent to participants reaching mastery in Phase 1, Phase 2 began. Phase 2 consisted of 500 additional CQ trials presented in 25 blocks of 20 trials each. Each block consisted of 10 C1-Q1Q2N1 and 10 C2-Q2Q1N2 trials. The trials in these blocks had the same structure and format as those in C→X training used in the first experiment. Although differential feedback was presented for all the trials in this phase, no mastery criterion was required to progress to the training of the baseline relations. Following completion of the 500 overtraining trials, participants in this condition learned the baseline relations for the ABCDE equivalence classes, using the protocol described in Experiment 1.

GR-1-Pic. In this procedure the C stimulus was abstract and the stimulus to which it was linked was a familiar picture denoted as Pic. This training procedure was similar to the C→X procedure described in the first experiment, except that X was now a meaningful stimulus, therefore the preliminary training conducted for this group is referred to as C→Pic. In each training trial null comparisons were also presented and they were identical to those used in C→X training. C→Pic training was conducted until mastery was reached: 100% correct responding in a C→Pic training block (20 trials of correct responding: 10 trial for C1→Pic1 and 10 trials for C2→Pic2 relations). Following mastery of the C→Pic relations, the participants in this group started training of the baseline relations for the formation of equivalence classes.

Equivalence class training and testing. The procedures for the training of the baseline relations for the ABCDE equivalence classes, and the testing for the emergence of the classes were identical to those described in the method section of Experiment 1.

Results and Discussion

Figure 9 shows how GR-1-500 and GR-1-Pic preliminary training influenced the subsequent formation of equivalence classes. In addition, the figure also includes the outcomes of GR-0, GR-1, GR-5, and GR-many conditions from Experiment 1, as reference points. After GR-1-500 and GR-1-Pic training, the yields produced by each of these conditions were quite similar to that produced by GR-1 training and somewhat greater than those produced by GR-0 training. GR-1-500 produced a yield smaller than GR-1 with no overtraining and less than half of what GR-5 produced in Experiment 1. Thus, the greater class enhancing effects produced by GR-5 training relative to GR-1 training in Experiment 1, was not due to greater number of trials completed by participants; rather, it was due to the number of conditional relations (five in GR-5 and one in GR-1) linked to the C stimuli prior to the establishment of the baseline relations for the ABCDE equivalence classes.

GR-1-Pic produced a yield slightly higher than GR-1 but still smaller than that produced by GR-5. The training of a single conditional relation between the abstract C stimulus and a familiar meaningful picture did not substantially increase the yield compared to GR-1. The small difference between GR-1 and GR-1-Pic suggests that the content of the stimulus with which C forms a conditional relation is not critical for class enhancement.

The findings of Experiment 2 documented that class enhancement produced by linking C to one abstract stimulus was not improved by overtraining; in addition, the sheer number of training trials similar to those used in GR-5 did not account for class enhancement documented for GR-5. The results of Experiment 2 further show no differences between the training of one single conditional relation between C and one other stimulus, whether the stimulus is abstract or meaningful. Both of these results are counterintuitive outcomes.

Many experiments (i. e. Holth & Arntzen, 1998; Doran& Fields, 2012; Travis, 2013), as well as Experiment 1, reported that the inclusion of a meaningful stimulus in a class of otherwise abstract stimuli substantially enhanced class formation**.** Also Bortoloti and De Rose (2009) showed that when abstract stimuli form conditional relations with meaningful pictures of faces expressing different emotions, those abstract stimuli acquired functions similar to those pictures. These findings suggest that an abstract stimulus that forms a conditional relation with a meaningful stimulus acquires some of the properties of that meaningful stimulus and enhances class formation. Therefore, the training of one conditional relation between C and a meaningful picture in the current experiment should have also enhanced class formation. The fact that it did not was a counterintuitive finding not consistent with other data.

Another counterintuitive finding is the absence of an overtraining effect in this experiment, particularly when Travis (2013) found that the overtraining of a discriminative function led to a systematic increase in yield that eventually equaled to that produced by the inclusion of a meaningful picture in a set of otherwise abstract stimuli.

To summarize, when Experiment 2 is considered in the context of Experiment 1, the results demonstrated that the number of conditional relations of which C was a part, prior to its inclusion in a class, was the critical factor for class enhancement. These findings support the view that meaningful stimuli serve conditional discriminative functions that may have been acquired through formation of conditional relations with many other stimuli.

General Discussion

General Findings

In Experiment 1, four groups of participants attempted to form two 3-node 5-member equivalence classes that consisted of A, B, C, D, and E stimuli, where training and testing were conducted using the simultaneous protocol. In these classes, the C stimuli served as the middle nodes. For some groups, the C stimuli were abstract and were initially used as samples in 0, 1, or 5 arbitrary conditional discriminations with comparisons designated as V, W, X, Y, and Z. After the formation of these C-based conditional discriminations, the C stimuli were used as members of the to-be-formed equivalence classes. The likelihood of class formation was a direct function of number of previously established C-based conditional discriminations (0, 1, or 5).

Prior research has shown that the likelihood of forming equivalence classes is low when training and testing are conducted under the simultaneous protocol (Fields, Landon-Jimenez, Buffington, & Adams, 1995).Yields under this protocol can be increased, however, with the prior establishment of simple discriminations with at least one of the stimuli in the class, or by the inclusion of a meaningful stimulus as a class member (Arntzen, 2004; Fields et al, 2012; Travis, 2013; Tyndal, 2004). The results of the present research extend those findings by showing that yields can also be increased by the prior acquisition of arbitrary conditional discriminative functions by one of the stimuli subsequently used as a member of a to-be-formed equivalence class.

Number of Links to C

The finding of the experiments was that the number of links between the C stimulus of other stimuli had a major effect on subsequent equivalence class formation. Specifically, the linking of the C stimulus to one other stimulus produced a much lower yield than the linking of the C stimulus to five other stimuli. What is not known, however, is how yield would be influenced by a systematic variation of number of links between the one and five stimuli used in GR-1 and GR-5 conditions. For example, how would the linkage of the C stimuli with three other stimuli (e.g., GR-3) influence yield? Three possibilities are that a GR-3 condition would produce an yield that was intermediate between that produced by GR-1 and GR-5, the same yield as that produced by GR-1, or the same yield as that produced by GR-5.

A yield that fell between those obtained from GR-1and GR-5 would confirm that yield is an essentially direct linear function of the number of C-based conditional relations established prior to the inclusion of the C stimulus in a class. A yield that was very similar to that produced by GR-1 would indicate that an abstract stimulus has to be linked to more than three stimuli to produce effects that are significantly greater than those produced by GR-0. A yield that was very similar to that produced by GR-5 would indicate that an abstract stimulus has to be linked less than three stimuli to produce effects that are significantly greater than those produced by GR-0. In general, such an experiment would identify how the number of pre class formation C links influence the enhancement of subsequent class formation; it would determine whether that functional relation is a continuous function or whether there yield is influenced in a stepwise manner.

Another finding involved the comparative effects of the GR-5 and GR-many conditions on likelihood of class formation. The GR-5 condition produced a yield that approached but did not equal the effect of the familiar pictorial stimulus on class formation. This finding suggests that the meaningful stimuli used in this experiment might contain more than the 5 associates that were linked to the abstract C stimuli in the

GR-5 condition. Thus, the training of more than five conditional relations might lead to a yield equal to that produced by the meaningful stimuli used in the GR-many condition. Such an outcome would imply that the pictorial stimulus in GR-many was presumably a member of an indeterminate number of arbitrary conditional relations prior to its inclusion in the class. Further research will be needed to assess the validity of all of these conjectures.

Conditional Discrimination Effects with Singles and Other Nodal Stimuli

In the present experiment, the C stimulus was used as the middle node in a class with a linear structure (A→B→C→D→E). The class contained two other nodes (B and D) and two singles (A and E). A node is a stimulus in a class that is linked through training to at least two other stimuli; a single is a stimulus that is not linked to any other stimulus in the class during the training of baseline relations (Fields and Verhave, 1987). Thus, to what extent did the class enhancement effect depend on the stimuli that received pre class formation conditional discrimination training?

For example, Arntzen (2004) found that a meaningful stimulus introduced as the first stimulus in the training of baseline relations (A) produced much higher yields than when introduced last as E. Will results similar to those of the present experiment be obtained if the stimulus that acquires conditional discriminative function serves as other nodes (B or D) or as singles (A or E)? This question can be addressed by replication of Experiment 1 but with the use of the A, B, D, or E stimuli as members of the arbitrary conditional discriminations established prior to the training of the baselines for the ABCDE equivalence classes.

Overtraining Effects

In a recent experiment, Travis (2013) found that a great deal of overtraining of C-based pre-class formation successive discriminations produced yields like those produced by the inclusion of one familiar picture as a class member. In contrast, Experiment 2 of the present study found no class enhancing effect of overtraining with a similar amount of overtraining of one conditional discrimination between C and one other abstract stimulus. The basis for these differences in the effect of overtraining of simple successive discriminations and arbitrary conditional discriminations is not clear at present. Additional research will be needed to clarify how overtraining has different effects on production based responding as evoked in simple discriminations (used by Travis (2013) who trained two responses to different discriminative stimuli) and selection based responding as evoked on conditional discriminations.

Modalities and Valences of C-Linked Stimuli

As noted above, the training of many conditional relations in preliminary training might equate the yields produced by the meaningful stimulus. Another approach to yield enhancement might be to establish cross-modal conditional relations rather than visual-visual conditional discriminations. It natural settings, it is likely that meaningful stimuli acquire conditional discriminative functions by forming relations with other stimuli or dimensions of stimuli that are not only visual as the syllables used in the present experiment but also with stimuli from different sensory modalities such as gustative, olfactory, tactile.

A body of research examining the formation of classes with cross-modal stimuli demonstrated that auditory-visual, gustatory-visual, or olfactory-visual conditional discriminations formed faster than visual-visual discriminations (Fienup & Dixon, 2006; Green, 1990; Hayes, Tilley, & Hayes, 1988). It is likely that preliminary training of several conditional relations of this type to an abstract stimulus that will then be included in experimenter-defined classes may enhance class formation as much as a picture would. Future research should explore how the training of cross-modal conditional discriminations such as visual-olfactory or visual-gustatory relations to an abstract member of a to-be-formed equivalence class influences the likelihood of class formation.

In Experiment 2, linking C to a meaningful stimulus (in GR-1-Pic), enhanced class formation to a small extent. This outcome was surprising in light of present and past findings that documented the class enhancing effects of meaningful stimuli and the transfer of emotive or connotative functions of meaningful stimuli to abstract stimuli (i.e. Arntzen, & Lian, 2010; Bortoloti & De Rose, 2009). These results suggest that pre class formation linkage of the C stimuli with others that have stronger emotional valences than the ones used in the present study (such as pictures of car crash, or things on fire) might lead to greater class enhancement.

Degree of Meaningfulness of Meaningful Stimuli

The present experiments provided additional evidence regarding the effect of a meaningful stimulus on the likelihood of forming an equivalence class. In Experiment 1, although the GR-many condition produced a high yield, it was lower than that reported in other studies (Fields, et al, 2012; Travis, 2013). This difference in yield could be attributed to a disparity in meaningfulness of the meaningful stimuli used in the two studies. Specifically, the pictures in the GR-many group in the present experiment could have been *less meaningful* than those used in the prior studies mentioned above. This hypothesis, however, could not be evaluated because no measures of meaningfulness were included in any of those studies (Fields et al, 2012; Travis, 2013). That problem can be solved in future research by the formal assessment of the meaningfulness of the pictures by use of a Semantic Differential (Bortoloti & De Rose 2009), or a Free Association test (Glaze, 1928), among other psychometric measures, before inclusion of the meaningful stimuli as potential members of the to be formed equivalence classes.

Mechanisms of Class Enhancement by Meaningful Stimuli

When the simultaneous protocol is used to establish equivalence classes, the likelihood of class formation is very low if all of the class members are meaningless stimuli. When one stimulus in a set is a meaningful stimulus, however, the likelihood of class formation is substantially increased. Fields et al (2012) and Travis (2013) speculated that a meaningful stimulus is most likely a member of some pre-experimentally established category or equivalence class. The authors suggested that the enhanced likelihood of forming an equivalence class that contains N-1 abstract stimuli and one meaningful stimulus might reflect the expansion of a preexisting class (i.e., the pre-experimentally existing class of which the meaningful stimulus is a member), rather than the de novo establishment of a new equivalence class. According to this argument, the mechanisms through which preliminary training enhanced class formation in in the GR-many condition is that of the expansion of an already existing category C-VWXYZ, rather than the de novo formation of the ABCDE equivalence class. The sorting data obtained in the present experiments provide a basis for the evaluation of such an explanation. The training of the C→V, C→W, C→X, C→Y, C→ Z relations led to the formation of a C-VWXYZ class. That class then merged with the ABCDE class to form a ten member class, ABDE-C-VWXYZ. The sorting performances of three participants, who stacked all the A-E and V-Z stimuli that had been linked to a given C-stimulus into the same piles, suggest that the V, W, X, Y, and Z stimuli were functioning as members of a class prior to the formation of the ABCDE classes. Sidman, Kirk, and Willson-Morris (1985) and Saunders, Saunders, Kirby, and Spradlin (1988) both demonstrated expansion of an equivalence class when a conditional relation was trained between two members of the already existing equivalence classes.

The results of the sorting tests for other participants, however, suggest an alternative mechanism for class enhancement. When the sorting test was conducted, they sorted A-E stimuli into the experimenter-defined classes. Of most interest, however, they placed only some of the V1-Z1 stimuli with the A2-E2 stimuli, and only some of the V2-Z2 stimuli with A1-E1 (middle row in Table 4). Sorting performances such as these support the view that preliminary conditional discrimination training did not result in the formation of C-VWXYZ classes. Therefore, the enhanced formation of the ABCDE classes could not be characterized as class expansion. Rather, class enhancement resulted from the sheer number of associates that C stimuli had prior to the establishment of the ABCDE classes. By implication, the enhancement of class formation by the inclusion of a meaningful stimulus does not require that latter stimulus to be a member of a pre-experimentally existing category. Rather, it only has to be a member of some indeterminate number of conditional relations to enhance the formation of an equivalence class of which it is a member.

To summarize, the class enhancement effect of meaningful stimuli could be due to both of the mechanisms mentioned above. Clearly, this interpretation of class enhancement is based on a small corpus of data. Future research will be needed to assess these options. One approach would involve the administration of post-class formation tests that would assess the selection of the associates of the meaningful stimulus with the abstract stimuli that had become members of the same equivalence class.

Behavioral Functions of Meaningful Stimuli and Class Enhancement

Historically, meaningful stimuli have been defined by their denotative and connotative properties. Thus, class enhancement effects could be attributed to these properties. Fields et al, (2012) and Travis (2013) noted that meaningful stimuli can, and most likely do, also function as discriminative stimuli, conditional discriminative stimuli and members of a variety of classes and categories. The present study added to these findings by demonstrating the conditional discriminative function accounts for part of the class enhancing effect of meaningful stimuli.

Future research should explore other functions served by meaningful stimuli that could account for the increased likelihood of equivalence class formation. Some of these functions are: members of conditional relations established via cross-modal training (either as the sample or the comparison in that relation), being members of an already established equivalence class, or members of a functional class.

Table 1

Stimuli Used in Preliminary Training and Stimuli Used as Members of the Equivalence Classes in Experiment 1 and Experiment 2.

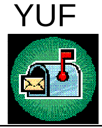
Condition	Stimulus	Classes	
		1	2
PIC	A	LEQ	XAH
	B	TYW	PYV
	C		
	D	HUK	BEW
	E	FOM	GAZ
ABS	A	LEQ	XAH
	B	TYW	PYV
	C	YUF	CAQ
	D	HUK	BEW
	E	FOM	GAZ
CX	C	YUF	CAQ
	X	ZUC	SIV
CVWXYZ	V	BAP	TAM
	W	BUH	REJ
	X	ZUC	SIV
	Y	DIH	VIF
	Z	XOL	RAB
C-1-Pic	C	YUF	CAQ
	Pic		
C-1-500	C	YUF	CAQ
	Q	ZUC	SIV
Null comparisons For preliminary training And for baseline relations	N	MEL	KUF

Table 2

Experimental Manipulations Used in Experiment 1

Variables Manipulated	GR-0	GR-many	GR-1	GR-5
Pre-class Formation Conditional Discriminations	0	presumably many	C→X	C→V C→W C-→X C→Y C-→Z
Mastery Level	n/a	n/a	20/20	20/20
V, W, X, Y, Z stimuli	n/a	n/a	X: Abstract	V-Z: Abstract
EQV Class Stimuli	5 Abstract	1 Meaningful 4 Abstract	5 Abstract	5 Abstract

Table 3

Type of Relations and Trials Presented in the Testing Phase

Relational Type	Trials
Baseline	A1-B1, B2, N1
Baseline	C1-D1, D2, N1
Baseline	B2-C2, C1, N2
Baseline	D2-E2, E1, N2
Symmetry	B1-A1, A2, N1
Symmetry	D1-C1, C2, N1
Symmetry	C2-B2, B1, N2
Symmetry	E2-D2, D1, N2
1 node transitive	A1-C1, C2, N1
1 node transitive	C1-E1, E2, N1
1 node transitive	B2-D2, D1, N2
2 node transitive	B1-E1, E2, N1
2 node transitive	A2-D2, D1, N2
3 node transitive	A2-E2, E1, N2
1 node equivalence	C1-A1, A2, N1
1 node equivalence	E1-C1, C2, N1
1 node equivalence	D2-B2, B1, N2
2 node equivalence	E1-B1, B2, N1
2 node equivalence	D2-A2, A1, N2
3 node equivalence	E2-A2, A1, N2

Trials listed in each row contain a sample, a positive, and two negative comparisons, listed in order from left to right. These trials were randomly presented without replacement during a test block, and the locations of the negative comparison stimuli were counterbalanced across blocks.

Table 4

Card Sorting Performances for Participants in GR-5

T1	No				
Sort	Cls1	Cls2	Cls3	Cls4	Cls5
A1	*				
B1				*	
C1					*
D1					*
E1					*
A2				*	
B2				*	
C2			*		
D2		*			
E2			*		
V1	*				
W1	*				
X1					*
Y1	*				
Z1				*	
V2		*			
W2		*			
X2			*		
Y2		*			
Z2			*		

T2	IE				
Sort	Cls1	Cls2	Cls3	Cls4	Cls5
A1	*				
B1	*				
C1	*				
D1	*				
E1	*				
A2		*			
B2		*			
C2		*			
D2		*			
E2		*			
V1	*				
W1	*				
X1	*				
Y1	*				
Z1		*			
V2		*			
W2		*			
X2	*				
Y2		*			
Z2		*			

T3	DE				
Sort	Cls1	Cls2	Cls3	Cls4	Cls5
A1	*				
B1	*				
C1	*				
D1	*				
E1	*				
A2		*			
B2		*			
C2		*			
D2		*			
E2		*			
V1		*			
W1	*				
X1		*			
Y1	*				
Z1	*				
V2		*			
W2		*			
X2	*				
Y2		*			
Z2		*			

T4	IE				
Sort	Cls1	Cls2	Cls3	Cls4	Cls5
A1	*				
B1	*				
C1	*				
D1	*				
E1	*				
A2		*			
B2		*			
C2		*			
D2		*			
E2		*			
V1	*				
W1	*				
X1	*				
Y1	*				
Z1	*				
V2		*			
W2		*			
X2		*			
Y2		*			
Z2		*			

T5	DE				
Sort	Cls1	Cls2	Cls3	Cls4	Cls5
A1	*				
B1	*				
C1	*				
D1	*				
E1	*				
A2		*			
B2		*			
C2		*			
D2		*			
E2		*			
V1	*				
W1	*				
X1	*				
Y1	*				
Z1	*				
V2		*			
W2		*			
X2		*			
Y2		*			
Z2		*			

T6	IE				
Sort	Cls1	Cls2	Cls3	Cls4	Cls5
A1	*				
B1	*				
C1	*				
D1	*				
E1	*				
A2		*			
B2		*			
C2		*			
D2		*			
E2		*			
V1	*				
W1	*				
X1	*				
Y1	*				
Z1	*				
V2		*			
W2		*			
X2		*			
Y2		*			
Z2		*			

Each of the large boxes in the Table represents the sorting performance of one of the six participants who completed the sorting test. Every box consists of six columns and 21 rows. The leftmost column contains the alphanumeric labels assigned to the stimuli in the experimenter defined classes as well as the stimuli used in GR-5 preliminary training. Cells 2-6 in this column include stimuli A1-E1 from Class-1 and cells 7-11 the stimuli A2-E2 from Class-2. Cells 12-21 include stimuli used in preliminary training, V-Z stimuli. The top first row in each box includes entries for the experimenter defined classes (Cls 1 and Cls 2) as well as additional participant-defined classes (Cls 3, 4, 5) suggested by the additional piles of cards the participants formed. The circles in each cell indicate the placement of the stimuli by each participant in groups corresponding to the different classes.

Table 5

Experimental Manipulations Used in Experiment 2

Variables Manipulated	GR-1	GR-1-Pic
Pre-class Formation Disc Training	C→Q 500	C→Q
Mastery Level	20/20	20/20
Overtraining	500	n/a
X/Q stimuli	1 Abstract	1 Picture
Equivalence Class Stimuli	5 Abstract	5 Abstract

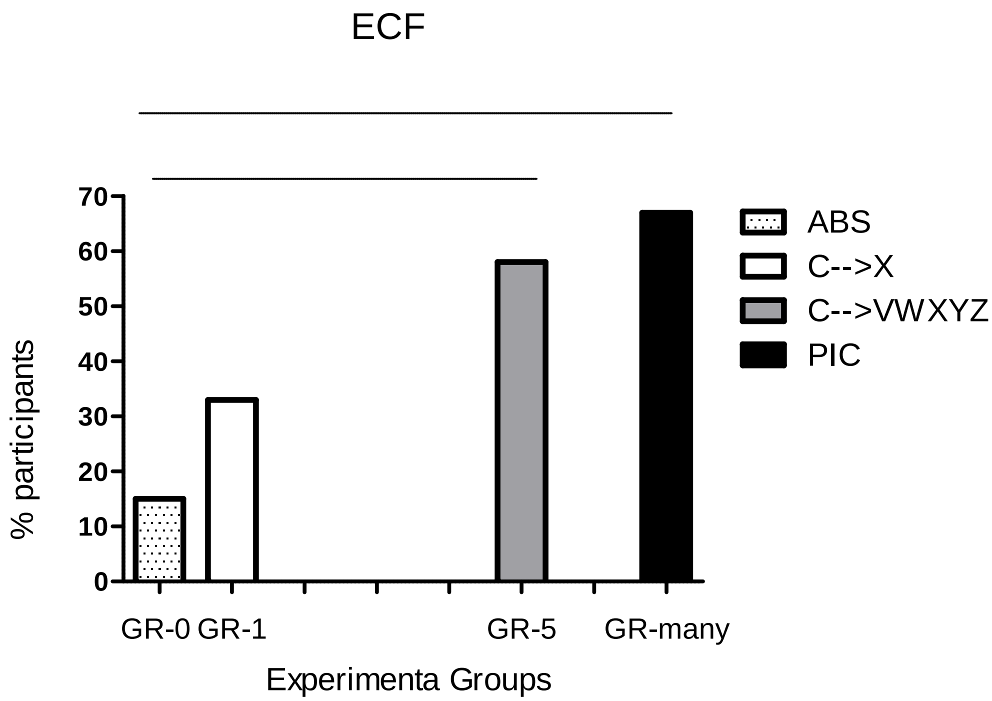


Figure 1. Percentage of participants who formed classes in each group in Experiment 1 (GR-0, GR-1, GR-5, and GR-many). The endpoints of each horizontal line indicate groups that produced statistically significant differences in yields.

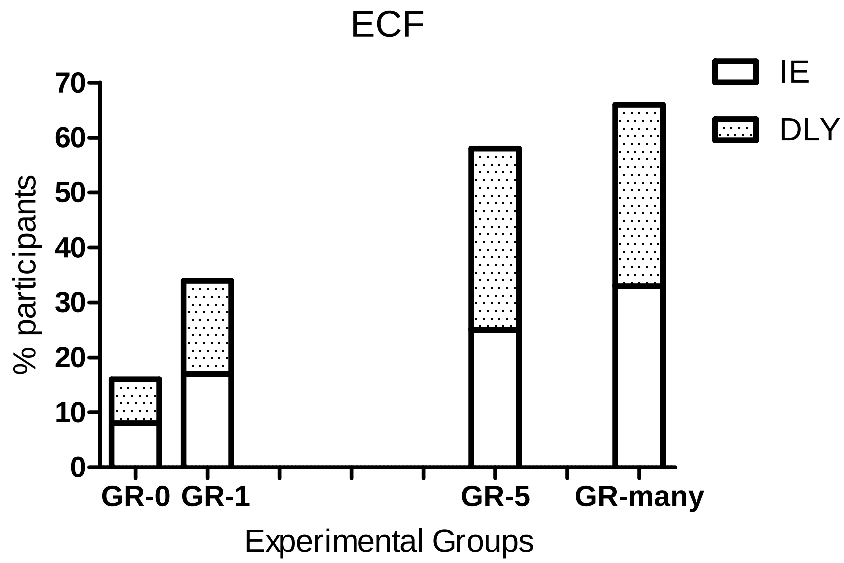


Figure 2. Percentage of participants who showed emergence of classes on an immediate basis (IE) and percentage of participants who showed emergence on a delayed basis (DLY) in each group.

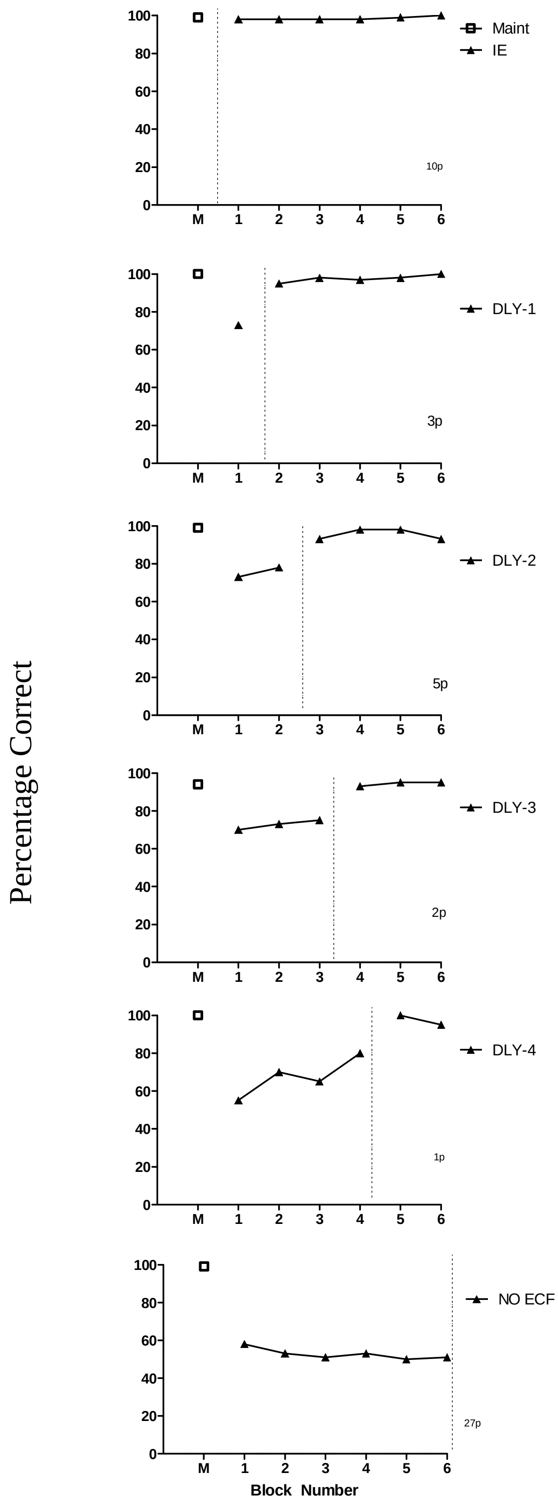


Figure 3. Percentage of correct responding in the maintenance block and each testing block for participants who formed classes on an immediate basis, (IE), delayed basis (DLY-1,-2, -3, and -4) and those who failed (No ECF)

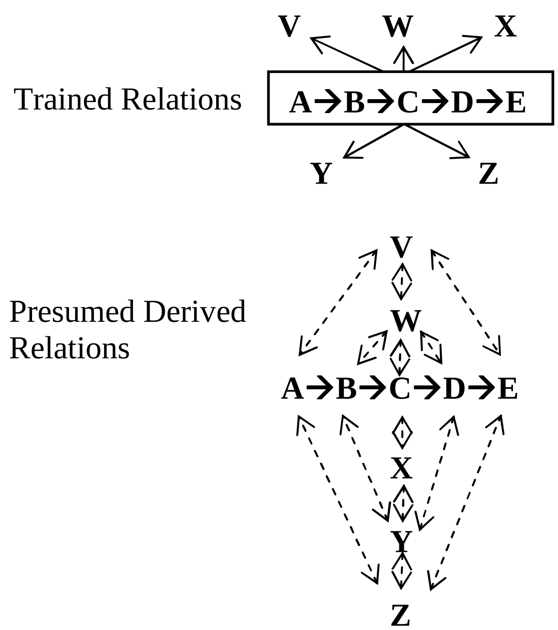


Figure 4. Hypothetical structure of the class that emerged after preliminary training of the C-V, C -W, -X, -Y, and -Z relations, and the training of the AB, BC, CD, and AE baseline relations.

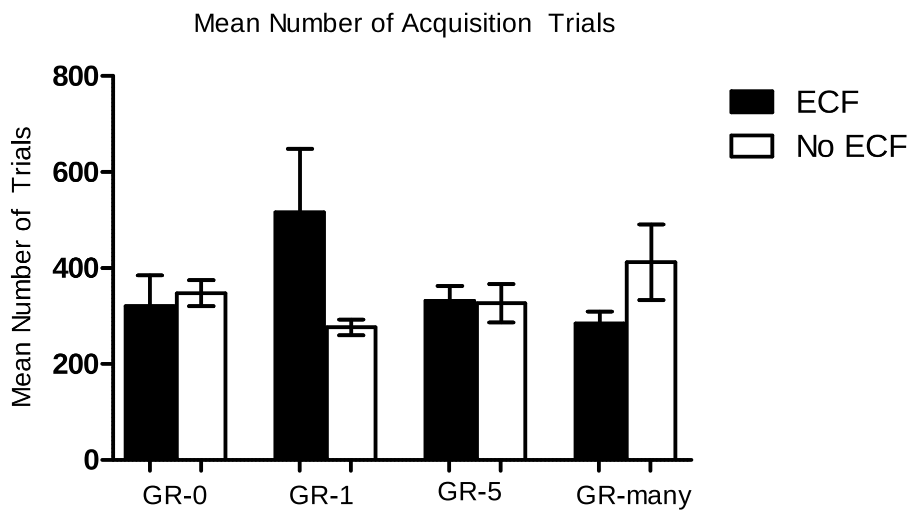


Figure 5. Mean number of trials to acquisition of all baseline relations for the participants who formed and those who did not form classes in each experimental group.

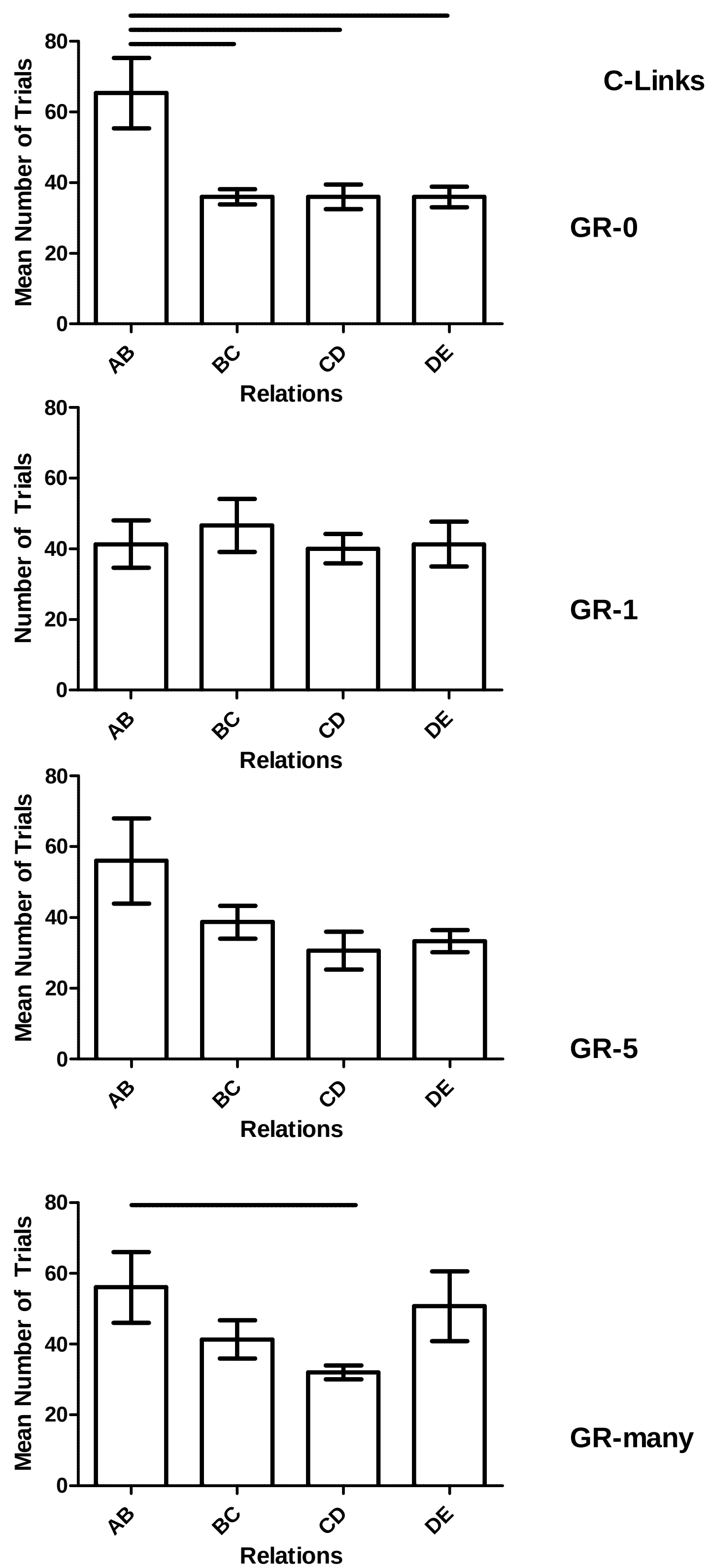


Figure 6. Mean number of trials to acquisition of each baseline relation in each experimental group

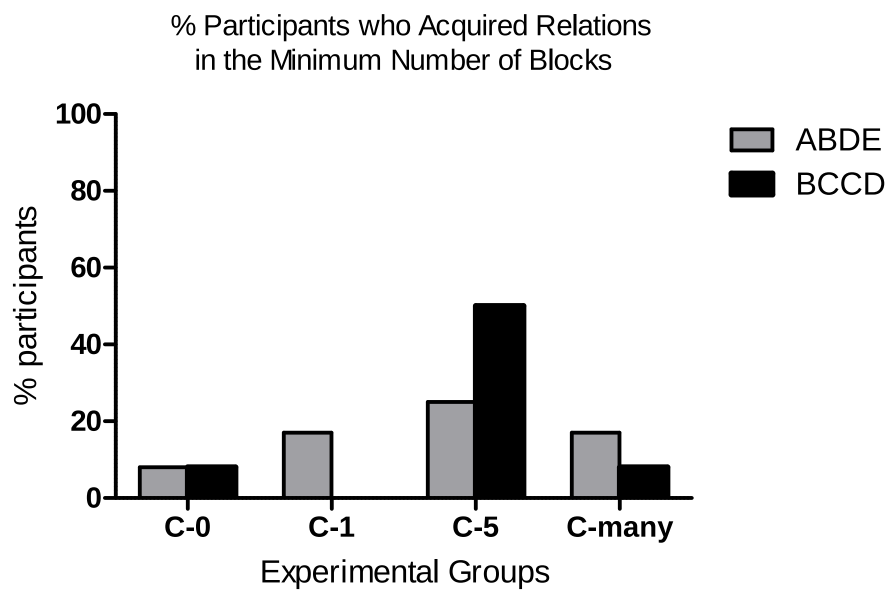


Figure 7. Percentage of participants who took the minimum number of blocks (1) to master the AB or DE relations, and the BC or CD baseline relations, in each experimental group.

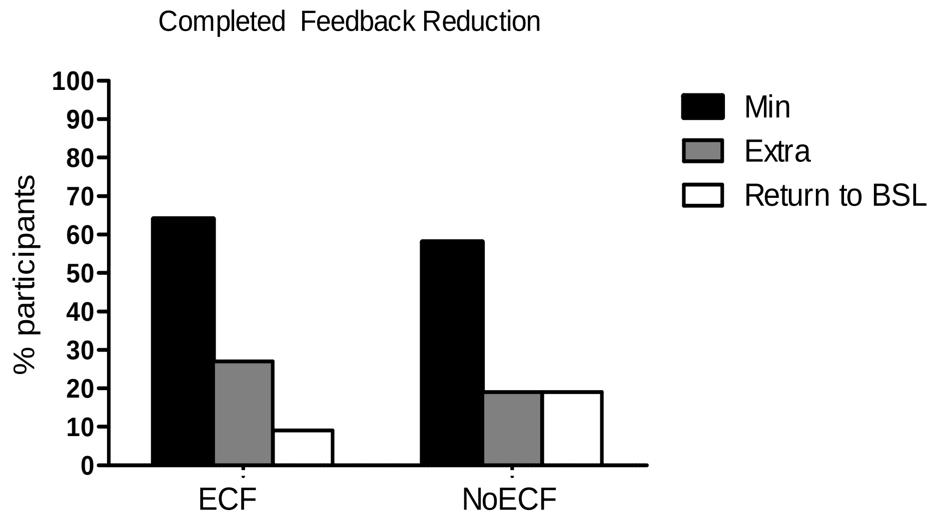


Figure 8. Percentage of participants who completed the minimum number of blocks of feedback reduction (3), participants who required extra blocks of feedback reduction, and participants who returned to training of the last blocks of training (mixed baseline relations block with 100% feedback) for those participants who did and those who did not form classes.

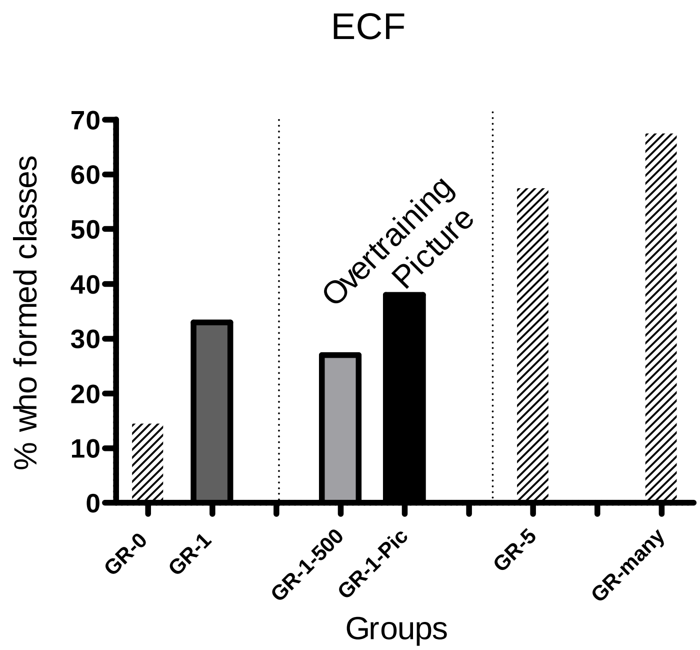


Figure 9. Percentage of participants who formed classes in each group in Experiment 2 (GR-1-500, GR-1-Pic) compared with percentage of participants who formed classes in Experiment 1 (GR-0, GR-1, GR-5, and GR-many)

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