EFFECTS OF A MEANINGFUL, A DISCRIMINATIVE, AND A MEANINGLESS STIMULUS ON EQUIVALENCE CLASS FORMATION

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Thirty college students attempted to form three 3-node 5-member equivalence classes under the simultaneous protocol. After concurrent training of AB, BC, CD, and DE relations, all probes used to assess the emergence of symmetrical, transitive, and equivalence relations were presented for two test blocks. When the A–E stimuli were all abstract shapes, none of 10 participants formed classes. When the A, B, D, and E stimuli were abstract shapes and the C stimuli were meaningful pictures, 8 of 10 participants formed classes. This high yield may reflect the expansion of existing classes that consist of the associates of the meaningful stimuli, rather than the formation of the ABCDE classes, per se. When the A–E stimuli were abstract shapes and the C stimuli became S^Ds prior to class formation, 5 out of 10 participants formed classes. Thus, the discriminative functions served by the meaningful stimuli can account for some of the enhancement of class formation produced by the inclusion of a meaningful stimulus as a class member. A sorting task, which provided a secondary measure of class formation, indicated the formation of all three classes when the emergent relations probes indicated the same outcome. In contrast, the sorting test indicated ''partial'' class formation when the emergent relations test indicated no class formation. Finally, the effects of nodal distance on the relatedness of stimuli in the equivalence classes were not influenced by the functions served by the C stimuli in the equivalence classes.

Key words: Stimulus Equivalence, meaningfulness, acquired discriminative function, enhanced equivalence class formation, nodal distance effects, comparison selection in matching to sample trials, college students

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An equivalence class consists of a finite set of stimuli that do not resemble each other but become related after the direct training of relations between a subset of the stimuli. For example, if the stimuli are represented by the letters A, B, C, D, and E, after the training of relations such as AB, BC, CD, and DE, the emergence of the remaining untrained relations in the set (BA, CB, DC, ED, AC, BD, CE, AD, BE, AE, CA, DB, EC, DA, EB, and EA) would demonstrate that the set of stimuli were functioning as members of an equivalence class (Fields & Verhave, 1987; Sidman, 1994).

The majority of published experiments have explored how class formation is influenced by contingencies of reinforcement, training and testing protocols, trial formats, and the nodal structures of the classes (Fields& Moss, 2007; Sidman, 1994 for an extensive set of references). To maximize sensitivity to the effects of these parameters, the experiments minimized the effects of the stimuli themselves by use of essentially meaningless stimuli as members of the potential classes.

The stimuli that become members of an equivalence class, however, can be meaningless or meaningful, and can vary in degree of meaningfulness. The meaningfulness of a stimulus, a word, object, or action, can be characterized by its dictionary defining features (denotatively) and by its associated attributes and feelings (connotatively). Both have been indexed by free association tests (Glaze, 1928; Kent & Rosanoff, 1910; Bousfield & Sedgwick, 1944). The latter have been measured with the semantic differential (Bortoloti & de Rose, 2009; Osgood, Succi, & Tanenbaum, 1957), and the implicit relational assessment procedure or ''IRAP'' (Barnes-Holmes, Barnes-Holmes. Stewart, & Boles, 2010; Roche, Barnes-Holmes, Smeets, Barnes-Holmes, & McGeady, 2000; Roche, Barnes & Smeets, 1997). Stimulus meaningfulness has also been defined in terms of its implicitly acquired or explicitly established

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behavioral functions (Russell, 1921; Ryle, 1949; Skinner, 1957). These can include discriminative functions, conditional discriminative functions, and membership in a variety of categories such as perceptual classes, equivalence classes, and generalized equivalence classes. The present experiment explored how the formation of equivalence classes that contained essentially meaningless stimuli was influenced by the prior acquisition of discriminative function by one of those meaningless stimuli.

A number of experiments have demonstrated that the formation of equivalence classes is influenced by the inclusion of meaningful but emotionally neutral pictures. These pictures have been referred to as being familiar, nameable or have names that rhyme with other words. For the purposes of the present experiment, all of these terms will be considered to be synonymous with meaningful. In a study conducted by Dickins, Bentall, and Smith (1993), participants attempted to form equivalence classes that contained all nameable and preassociated stimuli, all nameable and nonassociated stimuli, or all abstract and difficult-to-name stimuli. The stimuli in the nameable and preassociated sets included pictures from the same normative category, one of which included pictures of the sun, Saturn, and the moon. The stimuli in the nameable nonassociated sets included pictures that were not from the same normative category, one of which included pictures of a Martini glass, an apple and a traffic light. The stimuli in the hard-to-name abstract sets included unusual shapes, some of which were similar to Arabic letters. Equivalence classes that contained the nameable preassociated stimuli were formed by most participants, most quickly and with fewest errors. In contrast, participants were least likely to form the equivalence classes that contained the abstract, hard-to-name stimuli.

The formation of equivalence classes composed of pictures was also influenced by the rhymability of the spoken names of the pictures in an equivalence class (Randell & Remington, 1999). When initially unrelated but nameable pictorial stimuli were used as potential members of equivalence classes (e.g., pictures of a gnat, a cat, a bat, and a hat), and the names of spoken names of the pictures rhymed with each other, most participants showed the immediate emergence of the equivalence classes. In contrast, participants did not form classes of pictorial stimuli that had spoken names that did not rhyme with each other.

Holth and Arntzen (1998) found that college students did not form three 3-member equivalence classes that consisted of all Greek letters (Group 1). All participants formed the classes when they contained two stimuli which were familiar pictures and one stimulus that was a Greek letter (Groups 2 and 3). In the three studies mentioned above, all or most of the stimuli in a class were meaningful. To what extent would the likelihood of class formation be affected by the inclusion of only one meaningful stimulus?

Arntzen (2004) extended the exploration of these effects by studying the formation of larger equivalence classes. One-node 5-member equivalence classes were established by training of AB, CB, DB, and EB in that order, after which emergent relations probes were presented to assess the percentage of participants who formed equivalence classes. In the NO PICTURE CONTROL group all of the stimuli were Greek or Arabic letters, stimuli unknown to the participants. In the PICTURE FIRST group, the A stimulus in each class was a nameable and familiar picture and the B–E stimuli were the same as in the NO PICTURE CONTROL group. In the PICTURE LAST group, the E stimulus in each class was a nameable and familiar picture and the A–D stimuli were the same as in the NO PICTURE CONTROL group. Equivalence classes were formed by 30% of participants when all stimuli were unfamiliar and not nameable, and by 100% of participants when a nameable picture was the first stimulus to be introduced in training. Only 50% of participants formed classes when a nameable picture was the last stimulus to be introduced in training.

These results along with those reported by Holth and Arntzen (1998) showed that the use of a nameable picture enhanced the formation of equivalence classes as long as it was introduced as a sample in the first conditional discrimination established during training. These experiments, however, did not explore the use of meaningful stimuli as singles instead of nodes. Thus, Arntzen and Lian (2010) determined whether the inclusion of a meaningful stimulus as a node would influence the formation of equivalence classes. Equivalence classes that contained one node and three members were established by training AC and BC, where the C stimulus was the node. Participants in one group first attempted to form classes with stimuli all of which were abstract shapes, and subsequently attempted to form a new set of classes in which the A and B stimuli were the same abstract shapes while the C stimuli were familiar pictures. In another group, the order of forming each type of class was reversed. Regardless of training order, the participants were more likely to form the classes when the nodal stimuli were pictures instead of abstract shapes.

To summarize, the likelihood of equivalence class formation was enhanced if the to-be-formed class contained at least one meaningful stimulus in a set of otherwise meaningless stimuli. In these studies, the meaningfulness of each stimulus was established by life experience that preceded exposure to the procedures used to establish the classes; stimulus meaningfulness was not established by experimentally controlled operations. Would similar effects be found with stimuli that acquired specific behavioral functions during the course of the experiment?

Tyndall, Roche, and James (2004) noted that meaningful stimuli exert simple discriminative functions which are most likely established through contact with operant contingencies of positive or negative reinforcement. Thus, they explored whether the initial acquisition of discriminative function by all stimuli to be used as members of equivalence classes would influence the likelihood of class formation.

Twelve abstract stimuli were used as potential members of equivalence classes in each of six groups. Participants in a control group attempted to form classes using these stimuli although none occasioned prior discrimination training. For the participants in the other groups, six of the stimuli became S^Ds (i.e., discriminative stimuli for reinforcement) and six others became S^Δs (i.e., discriminative stimuli for extinction) through a two-choice simultaneous discrimination training procedure. Thereafter the stimuli were used in five combinations, one per group, as the members of to-be-formed three-member equivalence classes. When immediate emergence was measured, 30% of participants formed equivalence classes in the control group and also when two combinations of stimuli that served as S^Ds and S^Δs were used as class members. In contrast, 60% of participants formed classes that consisted of other combinations of stimuli that served as S^Ds and S^Δs. With all groups, however, if participants did not show immediate emergence, most of them showed the delayed emergence of the classes with extended exposure to the tests. Thus, delayed emergence was insensitive to the combinations S^D and S^Δ stimuli that served as members of equivalence classes.

In Tyndall et al. (2004), all of the stimuli to be used as members of equivalence classes had acquired specific behavioral functions prior to class formation. Arntzen (2004), Arntzen and Lian (2010), and Holth and Arntzen (1998) found that equivalence class formation was enhanced by the inclusion of single meaningful stimuli. How, then, would equivalence class formation be influenced by the inclusion of a single stimulus that had acquired a discriminative function prior to being included as a member of a to-be-formed equivalence class?

The present experiment was also informed by another aspect of the research reported by Arntzen (2004), Arntzen and Holth (2000), Holth and Arntzen (1998), Arntzen and Lian (2010), and Tyndall et al. (2004, 2009). All of these experiments studied the enhancement effects with classes that contained only one nodal stimulus. Larger multimodal equivalence classes are less likely to be formed than smaller classes with fewer nodal stimuli (Fields, Hobbie-Reeve, Adams, & Reeve, 1999). Thus, attempting to form larger multimodal classes might provide a more sensitive measure of the effect of including a meaningful or a discriminative stimulus as a member of the to-be-formed class.

In the present experiment, participants attempted to form three 3-node 5-member equivalence classes by training AB, BC, CD, and DE relations. In a control group the A–E stimuli represented abstract shapes that were difficult to name. In the meaningful stimulus group, the C stimuli were nameable and meaningful pictures, while the A, B, D, and E stimuli were the same abstract shapes used in the control group. In the acquired function group, the C stimuli were established as S^Ds prior to class formation. To rule out any confounding of the effects of acquired behavioral function and order of introduction effects, all of the baseline relations were trained in the serial order: AB, BC, CD, and DE. Based on the results of the published research mentioned above, we expect a relatively high percentage of participants to form equivalence classes in the Meaningful C Stimulus (PIC) group, and a minimal percentage of participants to form classes in the Abstract C Stimulus group (ABS). Similar likelihoods of class formation produced by the PIC group and the Acquired Discriminative Function (ACQ) group would imply that the discriminative functions served by a meaningful stimulus were sufficient to account for its class enhancement effect. Similar outcomes occasioned by the ACQ and ABS groups would imply that the implicit discriminative function served by a meaningful stimulus does not account for the class enhancement effect produced by meaningful stimuli.

Method

Participants

The participants were 30 college students (20 women and 10 men) who varied in age from 19 to 45 years old, and averaged 26.4 years old. None had any experience with the current type of experiment or prior formal knowledge of stimulus equivalence. Nine additional participants who started the experiment either quit or were dismissed because they did not acquire the baseline relations after 1.5 to 3 hours. Failure/dismissal rates were uncorrelated with experimental group.

Apparatus

Setting. The experiment was conducted at Akershus University College in a suite that contained a greeting room, conference room, and experimental cubicle.

Hardware. The experiments were conducted on a Compaq nc6320 laptop computer that used an 1828 MHz Intel Centrino® processor, and had a screen with a 16.8-in diagonal length with a 16 × 9 horizontal-to-vertical ratio. An external mouse was used by participants to control the position of the cursor throughout the experiment.

Software. All aspects of the training and testing used to establish equivalence classes and to establish discriminative functions were controlled by a software program made by Psych Fusion Software in collaboration with the second author. The software recorded performance characteristics such as trial number, the stimulus relations that were trained or tested, the number of responses to the sample stimulus, the reaction time to sample and comparison stimuli, the correct/incorrect comparison choice, and the provision of feedback on each trial. Finally, the duration of the experiment, number of baseline and test trials, symmetry, and equivalence indices were also summed by the software.

Stimuli. The stimuli used as members of the equivalence classes were the abstract and familiar picture stimuli shown in the top two sections of Figure 1. The bottom section of Figure 1 shows the Arabic and Hebrew letter stimuli used during discrimination training, all of which were unfamiliar to the participants. The stimuli in the upper and lower sections of Figure 1 were displayed in black on a white background. The pictorial and familiar stimuli were displayed in color on the same white background. The sizes of the touch-sensitive areas in which each of these stimuli were presented were 9.4 cm (w) × 3.4 cm (h). In addition, each of the 15 abstract stimuli and the pictures were also printed on laminated cards that were 3.8 cm square. While baseline relations were being established, the selection of a correct comparison was followed by the word ''correct'' and synonyms like ''awesome'', ''very good'', etc. and the selection of an incorrect comparison was followed by the word ''wrong''. The same feedback stimuli were used for correct and incorrect responding during discrimination training.

Procedure

Experimental design. The participants were assigned on a block-randomized basis to one of three groups: (1) Abstract C Stimulus (ABS), (2) Meaningful C Stimulus (PIC), or (3) Acquired Discriminative Function (ACQ). Regardless of group assignment, the experiment began with a categorization task in which all participants sorted the stimuli that appeared on laminated cards into subject-defined categories. Thereafter, each participant attempted to form on the computer three 3-node 5-member equivalence classes, each of which had a Linear Series training structure represented as A→B→C→D→E. Participants in the ABS group attempted to form equivalence classes consisting of abstract stimuli only. Participants in the PIC attempted to form equivalence classes consisting of abstract A, B, D, and E stimuli, and a C stimulus that was a meaningful picture. Participants in the ACQ group attempted to form equivalence classes consisting of abstract stimuli only, after the C stimuli were established as S^Ds. At the

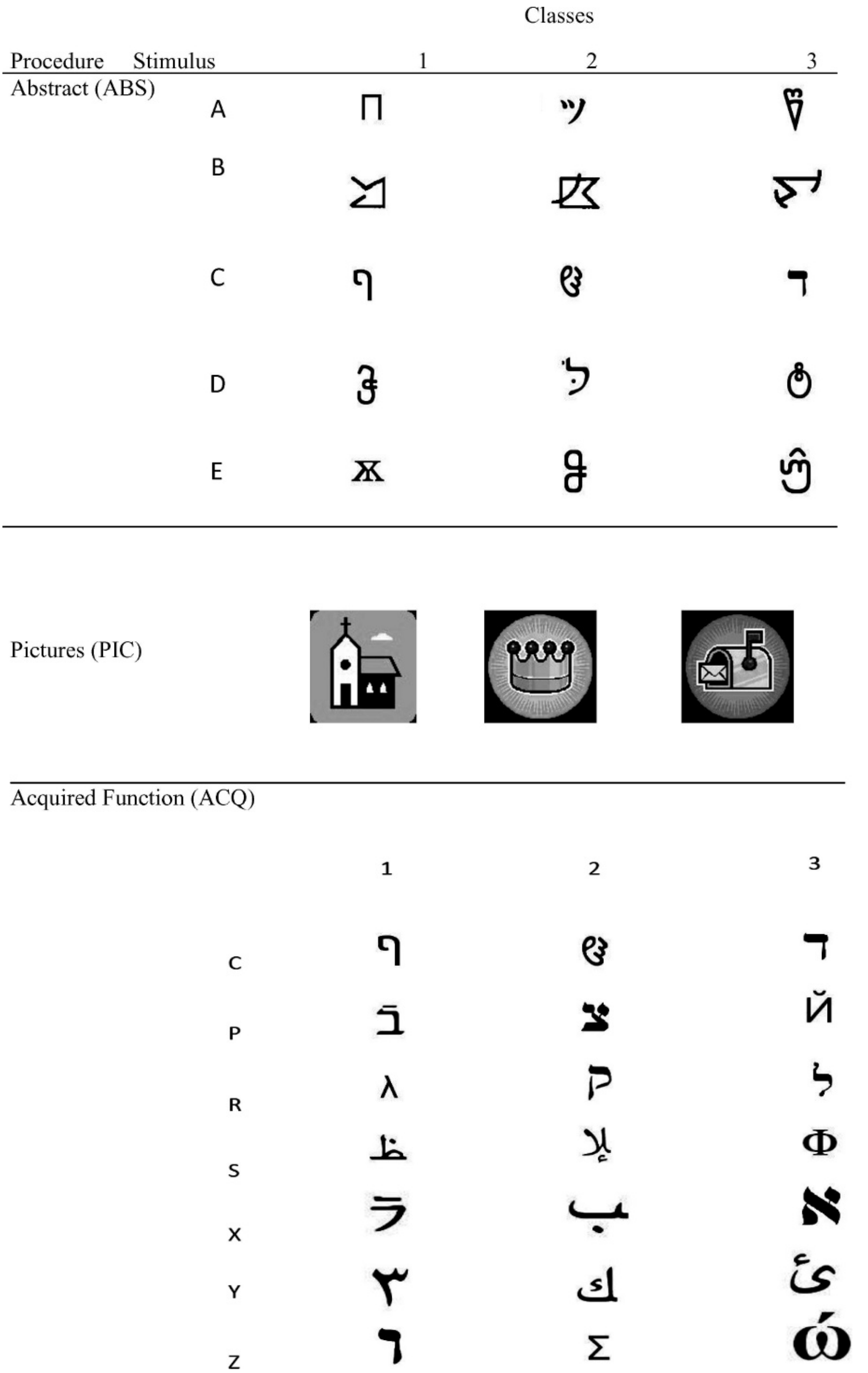

Fig. 1. The stimuli used as members of the equivalence classes were abstract and familiar picture-stimuli as shown in the two top sections. The bottom section shows the stimuli used during discrimination training. (See text for more details).

completion of equivalence class formation, the participants were reexposed to the categorization task.

Informed consent. Upon arriving at the laboratory each participant was brought to the conference room, was seated at a conference table, and was asked to read the consent form that was on the table. This text explained that they were about to take part in an experiment in the field of behavior analysis that involved doing tasks on a computer, that the experiment would last for approximately one and a half hours, that there were no known harmful effects of participating in the study, and that they were free to withdraw from the experiment at any time without any negative consequences. The experiment began immediately after participants signed the informed consent document.

Categorization of stimuli by card sorting. After signing the consent form, participants remained in the conference room and were given a set of the plastic-laminated cards that contained the stimuli to be used (15 abstract stimuli [A1-E3] for participants in the ABS and ACQ groups, or the 12 abstract stimuli and 3 pictures in the PIC group). The third coauthor then read the following instructions to the participant in English, regardless of a participant's first language: ''Please put them into groups and call me when you have completed the task.'' If a question was asked, the research assistant told the participant that he could not say anything. This sorting task was administered as a pretest before and as a posttest after a participant attempted to form the equivalence classes.

Preliminary training. After categorizing the stimuli, participants were escorted to and seated in the experimental cubicle (2 × 2 m) used to establish equivalence classes and the discriminative functions of the stimuli in the experiment. Once seated in front the computer, they were presented with the following instructions on the computer screen. The instructions were presented in English regardless of a participant's first language:

> ''A stimulus will appear in the middle of the screen. Click on this by using the computer mouse. Three other stimuli will then appear. Choose one of these by using the computer mouse. If you choose the stimulus we have defined as correct, words like very good, excellent, and so on will appear on the screen. If you press a wrong stimulus, the word ''wrong'' will appear on the screen. At the bottom of the screen, the number of correct responses you have made will be counted. During some stages of the experiment, the computer will not tell you if your choices are correct or wrong. However, based on what you have learned, you can get all the tasks correct. Please do your best to get everything right. Good Luck!''

No further instructions or cues were given during the experimental session.

Equivalence class formation under the simultaneous protocol. After discrimination training (see below), if used, all participants attempted to form equivalence classes using the simultaneous protocol. Under this protocol, all training and testing was conducted in blocks of trials. First, all baseline relations were trained in the serial order AB, BC, CD, and DE, after which all of them and all derived relations probes were presented in a randomized sequence in two test blocks.

Trial format and contingencies. Each trial started with the presentation of a sample stimulus in the middle of the screen. A mouse click to the sample stimulus was followed by the presentation of comparison stimuli with the sample still present. All stimuli remained on screen until a participant selected one of the comparisons. Comparison stimuli appeared in three of the four corners of the screen, which were randomized by the software program. A comparison was selected by moving the cursor to that comparison and pressing the left button on the mouse. If a feedback stimulus was presented after the selection of a comparison, it was displayed in the middle of the screen for 1,000 ms. The termination of the feedback messages was followed with a 500-ms intertrial interval. Between trials the mouse cursor was returned to the center of the screen.

Acquisition of baseline relations. The baseline relations were trained in five serialized phases. In all phases, feedback was provided for comparison selections on every trial. Phase 1 involved the training of AB relations in a block that contained nine trials, three for each of three classes. The block was repeated until nine of nine trials evoked the selections of the positive comparisons. Phases 2, 3 and 4 were the same except that BC, CD, and DE relations were trained.in each phase, respectively.

Phase 5 involved a mix of AB/BC/CD/DE trials. The trials used in the Phase 5 block included A1/B1-B2-B3, A2/B1-B2-B3, A3/B1-B2-B3, B1/C1-C2-C3, B2/C1-C2-C3, B3/C1-C2-C3, C1/D1-D2-D3, C2/D1-D2-D3, C3/D1-D2-D3, D1/E1-E2-E3, D2/E1-E2-E3, and D3-E1-E2-E3. In each trial representation, the first stimulus is the sample and the three stimuli after the slash (/) are the comparisons. The underlined comparison is the correct comparison. For a given trial, however, the three comparisons were presented in different locations on a randomized basis. Training was conducted using a block that contained 36 trials (3 presentations of each of the 12 trial types listed above). The block was repeated until correct comparisons were selected on at least 90% of the trials of each baseline relation in a block (the mastery criterion), which defined the acquisition of the baseline relations.

The number of presentations of each baseline relation was automatically equalized by the software for each participant by counting the number of trials needed to master the AB relations and then using the same number of presentations to train the remaining relations. In all cases, a participant acquired the latter relations in the assigned number of trials. For the remaining relations if the number of trials needed to reach the criterion was less than the number of trials used for AB training, the training for the respective relation continued until the same number of trials was reached.

Maintenance of baseline relations. Thereafter, the percentage of trials in a block that produced informative feedback was reduced to 75%, 50%, 25%, and 0% in that order, as long as the mastery level was achieved in two blocks at a given feedback level. If that did not occur, the level of feedback was increased to the previously used value in the next training block. The maintenance phase was completed with the occurrence of the first block with no feedback that occasioned the mastery level of responding. For each level of feedback, the trials that produced feedback were randomized in a block.

Emergent relations test blocks. The last block with no feedback was followed by two emergent relations test blocks, each of which contained 90 trials. Each test block contained all of the baseline and derived relations in the classes: 18 baseline trials, 18 symmetry trials, 27 one-node trials, 18 two-node trials and 9 three-node trials for a total of 90 trials. All of the trials in a test block were presented in a randomized sequence without replacement, and in the absence of informative feedback. Presenting two blocks permitted the measurement of the immediate or delayed emergence of the equivalence classes. The formation of equivalence classes was defined by the selection of class-consistent comparisons on at least 90% of the trials for each type of relation.

Discrimination training. Before attempting to form equivalence classes, the participants in the ACQ group were given two forms of discrimination training, called Discrimination training I and II, respectively. These are described below.

Discrimination training I was designed to insure that the C stimuli (see C1–C3 in the bottom panel of Figure 1) were discriminated from other concurrently presented stimuli (X–Z in Figure 1). Administered in four phases, the participants were taught to selecting C (as an S^D) instead of X, Y, or Z (all of which functioned as S^{Δ}s). The X–Z stimuli were not used in the equivalence class component of the experiment.

During Phase 1, a block of 30 trials was presented, each trial containing one of the following pairs of stimuli: C1 and X1, C2 and X2, or C3 and X3. Across trials, the stimuli appeared on the left and right of the screen an equal number of times and in a randomized sequence. The block was repeated until 100% of the trials occasioned the selection of the C stimulus. All trials provided informative feedback. Phases 2 and 3 were implemented using the same procedures but with the substitution of the Y1, Y2 and Y3 stimuli in Phase 2, and Z1, Z2 and Z3 stimuli in Phase 3 for the three X stimuli.

Phase 4 assessed the maintenance of the C–Other discriminations using trials that contained four stimuli each: C1 with X1, Y1, and Z1, C2 with X2, Y2, and Z2, as well as C3 with X3, Y3, and Z3. Training was conducted in blocks of 30 trials. For each trial, the locations of the stimuli were randomized. Picking the C stimuli was reinforced with the presentation of the word ''Correct'' or a synonym, while picking the other stimuli was followed by a blank screen. The block was repeated until participants selected the C stimuli on 100% of trials in a block.

Discrimination I testing. During this phase, pairs of stimuli were presented (C1 vs. P1, R1, or S1; C2 vs. P2, R2, or S2; C3 vs. P3, R3, or S3) in two-choice simultaneous discrimination trials in the absence of reinforcement. All of the stimulus pairs were presented in a block of 27 trials with 9 trials of each trial type. The block was repeated until 10 consecutive trials in a block occurred with the selection of the C stimuli instead of the P, R, or S stimuli.

Discrimination training II. A 3-ply multiple schedule was used to establish discriminations among the three C stimuli. When the C1 stimulus was presented on the screen, left-clicking it three times (FR-3) and pressing the END button on the keyboard was followed by ''correct'' on the screen. Completion of FR-6 and FR-9 before pressing the END button occasioned ''correct'' feedback in the presence of the C2 and C3 stimuli, respectively. Any other number of responses apart from the experimentally defined ones followed by the END button was followed with the presentation of the feedback word ''wrong'' on the screen. Ten consecutive correct trials finished this phase of discrimination training.

Results

C-stimulus Function and Class Formation: Emergent Relations Tests

Figure 2 shows the percentage of participants who formed equivalence classes in the first or second test block for each experimental group. Classes were formed by most of the participants when the classes contained a picture as the C stimulus (PIC), by none of the participants when the classes contained abstract images as the C stimuli (ABS) and by an intermediate number of the participants when the C stimuli were abstract images that had acquired discriminative functions prior to class formation (ACQ). Fisher's Exact Tests revealed that the difference in yields between the ABS and PIC groups was significant (p = .007) as was the difference between the ABS and ACQ groups (p = .033). Thus, equivalence class formation was enhanced when a class contained a middle node that had acquired a discriminative function prior to class formation. Although a smaller percentage of participants formed classes in the ACQ group than in the PIC group, the difference in yields was not significant (Fisher's Exact Test, p = .35). The trend, however, suggests that only part of the enhancement engendered by meaningful stimuli as nodes can be accounted for by the presumed discriminative functions served by meaningful stimuli.

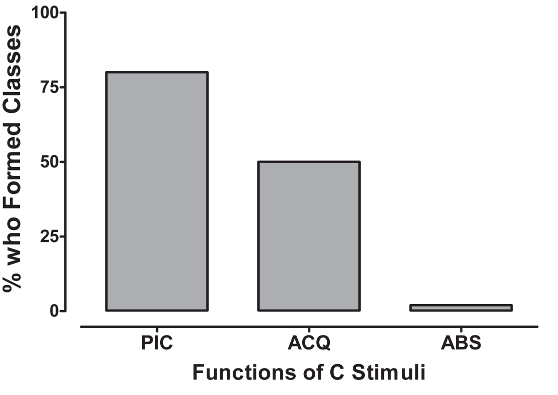

Fig. 2. The effect of the function served by the C stimulus on the percentage of participants who formed equivalence classes, in the Meaningful C Stimulus (PIC), Acquired Discriminative Function (ACQ) and Abstract Stimulus (ABS) conditions.

C-stimulus Function and Class Formation: Card Sorting Tests

Data obtained from the pre- and postclass formation sorting test are presented on the left and right sides of Table 1 with each row showing the sorting outcomes of a given participant. Rows are separated into participant groups, then by success or failure at equivalence-class formation. Each row is divided into boxes corresponding to the classes into which the participant sorted the cards at each assessment. All boxes have three cells, each of which shows the number of cards from the experimenter-defined classes (e.g., Class 1 contained stimuli A1-E1) that were sorted into participant-defined classes. Thus, the number 050 in the three cells in a box would indicate that the five stimuli in Class 2 were clustered into a subject-defined class, and an entry of 314 would indicate an 8-member subject-defined class that contained three stimuli from Class 1, one stimulus from Class 2, and four stimuli from Class 3. As no guidance was provided on how to sort the cards, the number of participant-defined categories varied across participants.

If participants spontaneously sorted the five cards into a participant-defined class that corresponded to one the three experimenter-

Table 1

Card sorting performances before (left side of the table) and after (right side) equivalence class formation. Rows correspond to individual participants and are separated by group. Within groups, data are separated into participants who did and did not form equivalence classes, based on emergent relations test performances. Within the pre- and post-class formation clusters, the boxes containing three numbers correspond to the classes into which participants sorted the 15 stimulus cards. Within each of these participant-defined classes the numbers correspond to the number of cards assigned to that class from the experimenter-defined Classes 1, 2, or 3. In three cases, the post class formation sorting tests were conducted but could not be analyzed due to an error in saving the information, and, thus, are listed as NOT AVAILABLE. See text for more details.

			Pre Class Formation Clusters																				
Group	ECF	ID	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3
ABS	NO	4113	4	0	2	0	3	3	1	2	0												
		4134	0	3	2	3	1	1	2	1	2												
		4141	1	0	2	2	1	0	0	2	1	1	0	2	1	2	0						
		4111	**3**	**0**	**0**	2	5	5															
		4139	**2**	**0**	**0**	**0**	**0**	**2**	2	1	0	0	3	2	1	1	1						
		4109	**3**	**0**	**0**	0	2	2	1	2	1	1	1	2									
		4142	1	1	0	1	1	0	0	2	2	2	1	1	1	1	2						
		4144	3	0	1	1	0	1	0	3	2	1	2	1									
		4101	**2**	**0**	**0**	0	0	1	0	2	2	2	1	0	0	1	1	1	1	1			
		4103	0	1	2	0	2	1	2	1	0	2	0	1	1	1	1						
PIC	YES	4104	1	1	3	2	2	1	2	2	1												
		4114	2	0	1	1	1	2	1	2	1	1	2	1									
		4133	**0**	**0**	**2**	1	0	1	1	1	0	1	1	0	0	1	0	1	1	1	1	1	1
		4137	1	3	1	2	1	2	2	1	2												
		4135	**0**	**0**	**2**	1	1	0	1	1	1	2	1	1	1	2	1						
		4105	2	2	1	2	2	1	1	1	3												
		4110	0	1	0	0	1	2	3	1	1	1	1	1	1	1	1						
		4102	3	1	0	0	1	2	0	1	2	1	1	0	1	1	1						
PIC	NO	4136	0	3	2	4	1	2	1	1	1												
		4132	2	2	0	1	1	1	1	1	2	1	1	2									
ACQ	YES	4131	3	1	0	0	3	3	2	1	2												
		4118	0	1	0	0	1	1	4	1	1	1	2	3									
		4125	3	2	0	1	0	2	0	2	1	1	1	2									
		4123	2	1	0	0	2	1	0	1	2	2	0	1	1	1	1						
		4120	3	1	0	1	2	2	1	2	3												
ACQ	NO	4127	0	2	2	2	1	1	1	1	1	2	1	1									
		4122	1	1	0	3	1	0	0	2	3	1	1	2									
		4117	**3**	**0**	**0**	1	3	3	1	2	2												
		4129	0	3	3	2	1	1	3	1	1												
		4128	3	1	0	2	4	5															

	Post Class Formation Clusters														
ID	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3
4113	**5**	**0**	**0**	0	4	1	0	1	4						
4134	**5**	**0**	**0**	0	2	3	0	3	2						
4141	**5**	**0**	**0**	0	2	3	0	3	2						
4111	**3**	**0**	**0**	**0**	**3**	**0**	**0**	**2**	**0**	**0**	**0**	**3**	2	0	2
4139	**0**	**2**	**0**	3	1	0	1	0	2	1	2	3			
4109	0	3	2	2	1	2	3	1	1						
4142	1	1	0	1	0	2	1	1	0	0	2	2	2	1	1
4144	2	1	0	0	2	2	2	1	1	1	1	2			
4101	NOT AVAILABLE														
4103	NOT AVAILABLE														
4104	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4114	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4133	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4137	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4135	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4105	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4110	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4102	NOT AVAILABLE														
4136	0	1	4	2	3	0	3	1	1						
4132	3	1	0	0	1	3	1	1	1	1	2	1			
4131	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4118	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4125	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4123	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4120	**5**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**						
4127	**4**	**0**	**0**	**0**	**4**	**0**	0	1	2	1	0	3			
4122	**0**	**3**	**0**	**0**	**0**	**2**	1	2	0	4	0	3			
4117	**0**	**0**	**2**	3	1	1	1	3	1	1	1	1			
4129	0	2	5	5	3	0									
4128	4	2	2	1	4	3									

defined classes, this would appear as 500, 050, or 005. The darker-shaded boxes correspond to the 8 of 119 subject-defined classes that consisted of two or three stimuli from a single experimenter-defined class. These data illustrate that participants did not spontaneously sort the stimuli into experimenter-defined five-member classes. No differences were apparent in the clusters formed by participants across groups or among participants who did and did not form equivalence classes.

After exposure to the class formation protocol, 12 of the participants sorted the stimulus cards into three clusters of five stimuli each, where each cluster contained the stimuli from only one of the experimenter-defined equivalence classes (see the lighter-shaded boxes in Table 1). The sorting into three 5-member subject-defined classes that corresponded to the experimenter-defined classes was produced by 0% of the participants in the ABS group, 50% of the participants in the ACQ group, and 80% of the participants in the PIC group. These were the same participants who formed all three of the equivalence classes as measured by the derived relations test performances (see Figure 1). Thus, the effects of the C stimulus functions on class formation were the same when measured by the sorting and the derived relations tests. Because the sorting test differed from the derived relations test, the sorting performances demonstrated the generalization and maintenance of the equivalence classes across different testing formats.

Dissociation of performances in card sorting and emergent relations tests. The participants who formed classes, as indexed by the derived relations test performances, also showed the intactness of the same classes on the post class formation card sorting tests. Thus, there was a perfect association of the performances produced by the two types of test.

Would similar correspondences also hold for the card-sorting performances of the participants who did not form all three experimenter-defined equivalence classes? That question was answered by a consideration of the data obtained from 3 of the participants (4113, 4134, and 4141; top three rows of Table 1) who did not show the formation of the three 5-member equivalence classes during the emergent relations tests but showed the

Table 2

Trial-by-trial analysis of emergent relations test performances. Matricies for 5 participants that display the frequencies of selecting each comparison (columns) in the presence of each sample (rows) stimulus in the last emergent relations test block. A maximum of three trials were presented for each relational probe. Thus, the formation of a 5-member experimenter-defined class involved the presence of 3s in each cell for a given class. The 4-STIMULI panel is a theoretical outcome. See text for more details.

PIC-4104

Samples		Comparisons														
		Class 1					Class 2					Class 3				
Class	Stimuli	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	A		3	3	3	3										
	B	3		3	3	3										
	C	3	3		3	3										
	D	3	3	3		3										
	E	3	3	3	3											
2	A							3	3	3	3					
	B						3		3	3	3					
	C						3	3		3	3					
	D						3	3	3		3					
	E						3	3	3	3						
3	A												3	3	3	3
	B											3		3	3	3
	C											3	3		3	3
	D											3	3	3		3
	E											3	3	3	3	

4-STIMULI

Samples		Comparisons														
		Class 1					Class 2					Class 3				
Class	Stimuli	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	A		3	3	3	3										
	B	3		3	3	3										
	C	3	3		3	3										
	D	3	3	3		3										
	E						2		1	1		3	1		3	
2	A							3	3	3	3					
	B						3		3	3	3					
	C						3	3		3	3					
	D	3	1			1						2	2	3		
	E						3	3	3	3						
3	A															
	B															
	C															
	D															
	E															

ABS-4113

Samples		Comparisons														
		Class 1					Class 2					Class 3				
Class	Stimuli	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	A		3	1	2	1			2		1	x			1	1
	B	3		2					1	1	2		x		2	1
	C	1	2		3	3	2						1	x		
	D		2	2		3	1		1			2	1		x	
	E		1	1	3			1	2			3	1			x
2	A				2	1		3	3	1		x				2
	B					1	3		3	2	1		x		1	1
	C					1	1	3		3	2	2		x		
	D					1	3	2	3		1		1		x	1
	E			2				2	1	3		3	1			x
3	A				2				2	1		x	3	1		3
	B				1	1				1		3	x	3	1	2
	C	1										2	3	x	3	3
	D						1	1	3		1	2	2		x	2
	E	2	1	1	1					2		1	2	2		x

ACQ-4127

Samples		Comparisons														
		Class 1					Class 2					Class 3				
Class	Stimuli	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	A		3	2	2	2			1	1	1					
	B	3		3	3	1					2					
	C	1	3		3						3	2				
	D	2	2	3		3	1	1								
	E	3	1	2	3				1				2			
2	A		1	1	1	1		2	2	2	2					
	B					1	3		3	3						2
	C						3	3		3	1					2
	D	1					2	3	3		1					2
	E	2	2	3	3		1	1								
3	A				2	1			1		1		3	2	1	1
	B	1								1	1	2		3	2	2
	C					2	1				1	2	3		3	
	D					1		1	1			3	2	2		2
	E						1	3	3	1		2			2	

ABS-4134

Samples		Comparisons														
		Class 1					Class 2					Class 3				
Class	Stimuli	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	A		3	3	3	3										
	B	3		3						3						3
	C		2				2			3		1	1			3
	D	2				3	1	2	3				1			
	E	2			3		1	3	3							
2	A		1			1		1	2	3			1	1		2
	B				2	2			3		1	3			1	
	C					2	3	3		3	1					
	D		3				3		3		2					1
	E															
3	A			2		2			1	1	1		3		2	
	B				1					2		3		3		3
	C					2	1					2	3		3	1
	D	3						3						3		3
	E	1	2	2					1			2	1		3	

ABS-4141

Samples		Comparisons														
		Class 1					Class 2					Class 3				
Class	Stimuli	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	A		2	2				1	1	1	2				2	1
	B	3		3	2	1				1	1					1
	C	1	2		3	2	1					1	1			1
	D		1	3		3	2	1				1	1			
	E	1		3	3		2	2					1			
2	A			2	2	1		1			1		2	1	1	1
	B			1			3		2	1	2				2	1
	C					1	3	3		1					2	2
	D	1							2		2	2	3	1		1
	E	1	3	2	1		1			2		1		1		
3	A					1				2	1		3	3	1	1
	B				1		1				1	2		3	2	2
	C						1				2	2	3		3	1
	D	1				1	2						3	3		2
	E	1					1		3	2		1	3		1	

presence of one 5-member equivalence class in the card sorting test. Specifically, each of them clustered together the A1, B1, C1, D1, and E1 cards in the sorting test, which documented the existence of equivalence class 1. Would the performances in the derived relations tests also show the presence of equivalence class 1 for these participants?

This possibility was evaluated by measuring the number of trials in the last block of the emergent relations test in which each comparison was selected in the presence of each sample for these 3 participants and for 1 who formed all three classes (Participant 4104). The left column in Table 2 contains matricies that show the results of such an analysis for all 4 of these participants. For Participant 4104, who showed the formation of all three equivalence classes, each sample stimulus in a class (represented in separate rows) occasioned the selection of comparisons from the same class and none from the comparisons in the other classes (represented in separate columns). Very different results were obtained for Participants 4113, 4134, and 4141. Specifically, the sample stimuli in Class 1 occasioned the selection of comparisons from all three classes, rather than the selection of comparison stimuli from Class 1 alone. Thus, while the performances occasioned by the card-sorting task documented the presence of Equivalence Class 1, the presence of that class was not documented by the performances produced by the emergent relations tests. The fact that Equivalence Class 1 was documented by performances seen in the card sorting tests but not in the emergent relations tests constituted a dissociation of class-indicative responding occasioned by the two different tests for class formation.

A similar analysis was conducted for Participant 4127. In Table 1, this participant responded in the card-sorting test in a manner that showed the existence of Classes 1 and 2, each of which contained four rather than five members. If these results indicated corresponding emergent relations test performances, the data would appear as shown in the upper theoretical panel in the right column of Table 2. In fact, the trial by trial analysis of the emergent relations data, which are shown in the bottom panel of the right hand column of Table 2, shows a different picture: The samples in Classes 1 and 2 occasioned the selection of comparison stimuli from all three classes. These results also show a dissociation between the results of the card sorting and the emergent relations tests.

The dissociations seen for the 4 participants mentioned above have two implications. First, the card sorting test may be a more sensitive measure of class formation than the emergent relations test. Second, the card sort was a second measure of class formation and may have tracked the first stages of the delayed emergence of all three classes. If true, this would further imply that the delayed emergence of equivalence class formation could be tracked by tests that are conducted in different formats. Further research will be needed to assess the validity of these inferences.

Other Effects of C-stimulus Function

While the data presented in Figure 2 and Table 2 documented the main effects of the functions of the C-stimuli on equivalence class formation, they did not indicate the effects of the grouping variable on the (a) speed of acquiring the baseline relations and the prediction of subsequent class formation from acquisition speed, (b) maintenance of the baseline relations, (c) frequency-based performances evoked by each type of relation during the delayed emergence of equivalence classes and the effects of nodal distance, and (d) the reaction times (RTs) evoked by each type of relation during the delayed emergence of equivalence classes and the effects of nodal distance.

Acquisition of baseline relations and predictability of class formation. Figure 3 depicts the median number of trials needed to acquire the baseline relations in each group, for participants who did and did not form equivalence classes. Medians were used to characterize acquisition because of extreme scores produced by a few participants. Overall, the individuals who formed classes acquired the baseline relations in 38% fewer trials than did those who did not form the classes, a statistically significant difference [$t(27) = 2.35$, $p = .026$]. This difference was obtained for the participants in the PIC and ACQ groups. When the relationship between class formation and acquisition speed was examined, an r^2 value of .36 indicated that the speed of acquiring the baseline relations was a

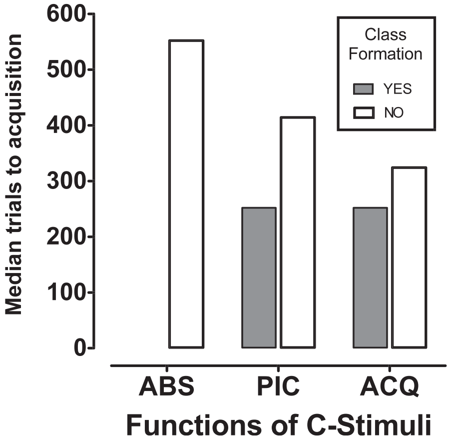

Fig. 3. The median number of trials needed to acquire the baseline relations in each condition, for two subgroups of participants: those who did and did not subsequently form equivalence classes.

modest predictor of class formation. This finding is consistent with that reported by Tyndall et al (2004), but differs in quantitative value.

For the participants who formed equivalence classes, similar numbers of trials were required to acquire the baselines in the PIC and the ACQ groups. Thus, the functions served by the C stimuli did not influence the speed of baseline acquisition for participants who went on to form the equivalence classes.

In contrast, among the participants who did not form equivalence classes, the baseline relations were acquired most slowly when the C stimuli were abstract with no prior training history (ABS), faster when the C stimuli were pictures (PIC), and fastest when the C stimuli were abstract and had previously acquired discriminative functions (ACQ). Thus, the functions served by the C stimuli influenced the speed of baseline acquisition for participants who did not form equivalence classes.

Maintenance of baseline relations. If there were no errors, feedback reduction would be completed in 144 trials. Across all groups, 24 of the 30 participants completed the maintenance phase in the minimum number of trials. The 6 remaining participants made a few errors and eventually showed the maintenance of the baseline relations in the absence of feedback. The function of the C stimuli across groups did not influence trials to maintenance of the baseline relations during feedback reduction.

Stimulus function and nodal distance effects. Some of the participants in the ACQ and the PIC groups showed the delayed emergence of equivalence classes. The effects of nodal distance have been seen during the delayed emergence of equivalence classes. Would the effect of nodal distance and delayed emergence be influenced by the functions served by the C stimuli in the classes? An answer to this question was obtained by the percentage of baseline, symmetrical, 1-, 2-, and 3-node probe trials that evoked class-indicative comparison selections for participants who showed the delayed emergence of the classes in the AQC and PIC groups, as seen in Figure 4. Data were averaged separately for participants in each group, and for the first and second test block.

As a reference condition, the leftmost data point in each panel presents the average performance occasioned by the baseline relations at the end of the maintenance phase of baseline acquisition. At that point, the baseline relations evoked nearly 100% class-consistent responding. The performances in the first emergent relations test block showed the maintenance of the mastery level of responding by the baseline relations and similar performances by the symmetrical relations probes, along with decreasing levels of class-consistent responding with increases in the number of nodes that separated the stimuli in the emergent relations probes. In the second test block, the performances occasioned by the latter probes all increased to the mastery level. This transition in pattern of responding from the first to the second test block demonstrated the rapid albeit delayed emergence of the equivalence classes.

The data obtained during the first test block in the two panels were similar to each other even though the pictorial stimuli served as the C stimuli in the PIC group and abstract stimuli that had acquired discriminative functions served as the C stimuli in the ACQ group. Thus, the functions served by the C stimuli did not influence the effects of nodal distance or the delayed emergence of the equivalence classes.

Chronometric measures of nodal distance. Figure 5 depicts median reaction times (RT) occasioned by the baseline relations at the end of the maintenance phase of training where responses did not produce any informative feedback (leftmost column), as well as each type of relation presented in the two emergent

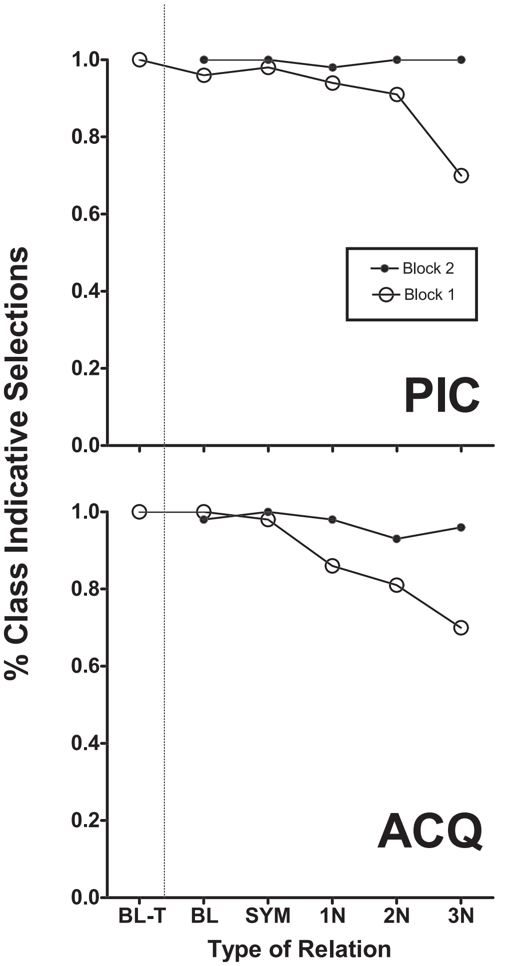

Fig. 4. The average percentage of trials that evoked class indicative comparison selections for the last block of feedback reduction during training (BL–T), and the baseline (BL), symmetrical (SYM), and 1-, 2- and 3-node probes (1N, 2N, 3N) for participants who showed the delayed emergence of the classes in the PIC and ACQ groups. For each group separate functions are plotted for test blocks 1 and 2.

relations test blocks. The top and bottom panels present the RT data for participants who did and did not form equivalence classes. In each panel, the RTs for each type of relation were further subdivided into trials that were terminated by correct and incorrect comparison selections. Data were aggregated across relevant participants across all experimental groups because we did not discern any systematic effect of group on RT.

Baseline relations. For all groups, the shortest RTs were produced by the baseline relations trials during maintenance. Reaction times remained at the same level when the baseline probes were presented in the first test block. This occurred for participants who did and did not form classes and for trials that were terminated by correct or incorrect responses.

Probes in test block 1. In the first test block, the RTs occasioned by correctly terminated trials increased systematically with nodal distance from the 0-node symmetry to the 1- and then 2-node probes. In contrast, the 3-node probes occasioned shorter RTs than the 2-node probes, an inversion that occurred regardless of equivalence class formation. When RTs obtained from the same type of relation were compared, they were much slower when trials were terminated by incorrect responses than correct responses. This difference was greater for probes presented to individuals who formed classes relative to those who did not form classes.

Probes in test block 2. In the second test block, when classes were formed (top panel of Figure 5), RT was a direct function of nodal distance. Indeed, RTs increased by about a factor of 2 from the symmetry probes to the three-node probes. Unlike the performances in the first test block, there was no inversion of RTs with the three-node probes relative to the two-node probes. All of these RTs were also shorter than those observed for matching probes during the initial test block. For the participants who did not form classes, however, RTs were essentially invariant with respect to correctness of responding or type of relation.

Discussion

Two measures of equivalence class formation showed that all three equivalence classes were formed by most participants when the middle node was a known picture and the other class members were abstract stimuli (group PIC), by about half of participants when the middle node was an abstract stimulus that had previously acquired a discriminative function (group ACQ), and by none of the participants when the middle node was also a simple abstract stimulus (group ABS). One of these measures was obtained using an emergent relations test and the other was obtained using a card sorting test. Thus, two convergent measures confirmed that the discriminative function acquired by a meaningless stimulus facilitated the formation of equivalence classes, but not as much as the use of a meaningful picture.

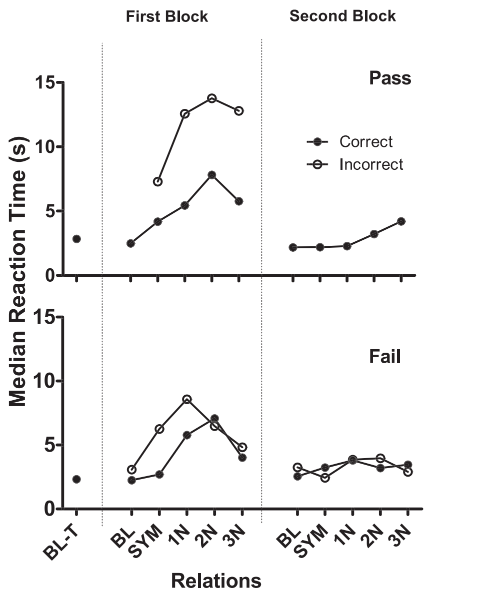

Fig. 5. Median reaction times of correct and incorrect responses plotted as functions of the type of relation (x-axis). Data within each panel are separated by the terminal baseline training trials and the first and second test blocks. The two panels separate reaction times of participants who did and did not form equivalence classes. Data are aggregated across groups.

Quick Testing of Equivalence Class Formation

Equivalence class formation was assessed using an emergent relations test and a card sorting test. The sorting test was completed in less than 2 min while the emergent relations test required about 30 min. When the post-training sorting test resulted in performances that indicated the presence of all trained equivalence classes, the emergent relations test results also indicated the formation of these classes. Had the card sorting test been conducted prior to the emergent relations test it might have shown the same outcome. If so, a quick evaluation of class formation could be obtained with the sorting test instead of the emergent relations test, saving the difference in testing time: 2 min instead of 30 min. When the sorting test showed other patterns of responding, they were correlated with the absence of class-indicative responding during the emergent relations tests. Thus, the sorting test might also provide a quick evaluation of the absence of class formation. Additional research will be needed to (a) assess the potential and reliability of such an approach for the documentation of equivalence class formation, (b) identify the mechanisms that control performances in the card sorting test, and (c) determine whether equivalence classes defined by outcomes of card sorting will function in the same manner as those defined by the outcomes of emergent relation tests.

Factors Responsible for the Effects of Acquired Discriminative Function

For half of the participants in the ACQ group, establishing the abstract C stimuli as S^Ds enhanced the subsequent formation of equivalence classes containing those C stimuli. Two possible mechanisms might account for the facilitating effect of prior discrimination training on equivalence class formation: an operant discrimination account and a perceptual learning account.

Operant discrimination. According to this account, the establishment of equivalence classes involves the formation of conditional relations. The formation of conditional relations involves the establishment of a successive discrimination among sample stimuli, and the simultaneous discrimination of comparison stimuli (Saunders & Green, 1992). For the ACQ group, both of these repertoires (successive and simultaneous discriminations) were established for the C stimuli using the discrimination training procedures. Because both of these repertoires are prerequisites for the establishment of conditional relations, the initial discrimination training in this group could have enhanced equivalence class formation by facilitating the formation of the conditional relations that were the prerequisites of class formation. Enhancement of the formation of the conditional relations could have been induced by either or both of these discriminative repertoires. Additional research will be needed to determine the extent to which the enhancement effect was engendered by each of these procedures alone and/or in combination.

Perceptual learning. When discrimination training was conducted with the abstract C stimuli (ACQ group), of necessity, these stimuli were presented many times, occasioned either selection- or production-based responses, and were increasingly paired with contingent reinforcers. An extensive literature on perceptual learning (e.g., Hall, 1980) has shown that the sheer number of exposures to a stimulus can influence the formation of later discriminations with the same stimuli (our thanks to Reviewer B for providing this insight). Thus, it is possible that the enhanced formation of equivalence classes obtained in the ACQ group was due to perceptual learning that occurred with the abstract C stimulus prior to forming equivalence classes. This possibility could be evaluated by conducting a yoked control experiment in which the participants would be presented with the same stimuli, the same number of times as in preliminary training but in the absence of feedback stimuli and without the requirement of responding. The subsequent formation of equivalence classes with a yield like that obtained in the ACQ group of the present experiment would imply that the class-enhancement effect was driven by perceptual learning, A much lower yield like that obtained in the ABS group would imply that the class enhancement effect was attributable to the reinforcement contingencies used during preliminary discrimination training and not to perceptual learning.

Induction of a Class Enhancing Stimulus Control Repertoire during Preliminary Training

All of participants in the ACQ group acquired the successive and simultaneous discriminations during preliminary training. Thereafter, only 50% of these participants formed the equivalence classes. Thus, the acquisition of discriminative functions by the C stimuli was not a sufficient condition for equivalence class formation. While preliminary training resulted in the acquisition of C-based discriminative repertoires by all participants, 50% of the participants who subsequently formed the equivalence classes must have also learned or activated another class-enhancing stimulus control repertoire that played a critical role in class formation.

It might be argued that this ''other'' class-enhancing stimulus control repertoire was present preexperimentally in 50% of the participants in the ACQ group and they were the ones who formed the equivalence classes. If that assumption was valid, 50% of the participants in the ABS group would also be expected to have had that repertoire present prior to the experiment, and, those participants should have formed equivalence classes. In fact, only 10% of the participants in the ABS group formed equivalence classes. Therefore, the presence of a preexisting class enhancing repertoire could not account for the proportion of participants in the ACQ who formed equivalence classes. Rather, the discrimination training procedure must have adventitiously induced a class-enhancing stimulus control repertoire in most of the participants in the ACQ group who went on to form equivalence classes. Additional research will be needed to identify the adventitiously induced class enhancing stimulus control repertoire that was responsible for the formation of equivalence classes in the present experiment.

Formation or Expansion of Equivalence Classes?

The highest yields were obtained when the middle node in the class was a meaningful pictorial stimulus. This description, however, does not consider the mechanisms that might be responsible for the above-mentioned enhancement effect. No participants formed equivalence classes when the abstract C stimuli had not previously acquired discriminative functions. In contrast, 80% of participants formed equivalence classes when the C stimulus was a meaningful picture. How can this disparity be accounted for? It is likely that the known picture used as the C stimulus was conditionally related to many other stimuli with which it is functionally interchangeable (Tyndall et al., 2004, 2009); the picture and its associated stimuli were most likely members of a preexperimentally formed category akin to a generalized equivalence class (Barnes & Keenan, 1993; Fields, 2009; Fields, & Reeve, 2001; Galizio, Stewart, & Pilgrim, 2004; Lane, Clow, Innis, & Critchfield, 1998; Rehfeldt & Root, 2004). Thus, the ''formation'' of each five-member class that consisted of four abstract stimuli and a picture probably reflected the expansion of an already existing stimulus class by the addition of the four abstract stimuli rather than the de novo formation of a five-member equivalence class. Supportive evidence can be adduced from the reliable establishment of large equivalence classes through the merger of two already formed equivalence classes (Saunders, Saunders, Kirby, & Spradlin, 1988; Saunders, Wachter, & Spradlin, 1988; Sidman, Kirk, & Willson-Morris, 1985). The class-expansion interpretation mentioned above could be evaluated directly, however, by testing for the emergence of relations between the abstract stimuli and other stimuli that are associated with the pictures used as class members.

Class Formation Under the Simultaneous Protocol

Prior research showed low likelihoods of equivalence class formation when training and testing were conducted under the simultaneous protocol (Buffington, Fields, & Adams, 1997; Fields et al., 1999; Fields, Landon-Jimenez, Buffington, & Adams, 1995; Fields, Reeve, Rosen, Varelas, Adams, Belanich, & Hobbie, 1997; Fields, Varelas, Reeve, Belanich, Wadhwa, DeRosse, & Rosen, 2000; Fields & Watanabe-Rose, 2008). Thus, we opined that such a behavioral preparation would be sensitive to the effects of different types of stimuli on equivalence class formation. The substantial differences in yields across experimental groups documented the utility of using the simultaneous protocol to identify variables that enhance the formation of equivalence classes (see also Fields et al., 1999).

When the simultaneous protocol was used to form *two* equivalence classes using nonsense syllables as class members, about 20% of college students formed two 3-node 5-member classes (Fields et al., 1997; Fields et al., 2000). In the present experiment, none of the participants in the ABS group formed three equivalence classes of the same size and nodal structure, also under the simultaneous protocol. The decrement in yield from 20% to 0% was correlated with, and was probably driven by, the requirement to form three rather than two equivalence classes. Thus, the results of the present experiment provide a consistent extension of the findings of prior research.

Although systematic, these outcomes also might have been influenced by the content of the stimuli used as the members of the equivalence classes in the present and prior experiments. Class members in the present and prior experiments were abstract stimuli and nonsense syllables, respectively. Thus, the difference in yield could have been driven by this stimulus factor, or the number of classes being formed, alone or in combination. Additional research is needed to isolate the effects of these variables.

Nodal Distance Effects

During the delayed emergence of the equivalence classes, the accuracy of selecting the class-based comparisons was an inverse function of the nodal distance that separated the stimuli in the derived relations. These differences disappeared once the classes were fully formed. In contrast, once the classes were fully formed, RT was a direct function of the nodal distance that separated the stimuli in the derived relations. This latter measure indicated that the nodal structure of the equivalence classes influenced the relatedness of the stimuli in the class even in the steady state defined by fully formed equivalence classes (Moss-Lourenco & Fields, 2011). This finding extends related observations reported by others (Spencer & Chase, 1996; Tomanari, Sidman, Rubio, & Dube, 2006). On the other hand, the functions served by the C stimuli did not influence the relation between RT and nodal distance in fully formed equivalence classes just as they did not influence the frequency-based measures of nodal distance during the delayed emergence of the equivalence classes. To summarize, the functions served by the C stimuli influenced likelihood of class formation but not the relatedness of the stimuli in the equivalence classes.

Discrimination Training as Facilitator of Class Formation and Function Transfer

The present experiment showed that inclusion of a stimulus that had acquired a discriminative function before class formation increased substantially the likelihood of equivalence class formation. The experiment did not however measure the generalization of the response trained to the C stimuli to the other members of the class once the class had been formed.

Many other experiments have shown that after the formation of an equivalence class, a response trained to one class member results in the evocation of that response by the other members of the class (Augustson & Dougher, 1997; Barnes, Browne, Smeets, & Roche, 1995; Belanich & Fields, 2003; Fields, Adams, Buffington, Yang, & Verhave, 1996; Fields & Watanabe-Rose, 2008; Rehfeldt & Hayes, 1998; Sidman, 1971; Sidman & Tailby, 1982; Wirth & Chase. 2002). That is, once one class member acquires a discriminative function, the response generalizes to the other members of the class. Such a preparation, however, cannot be used to enhance class formation because the classes have been formed before the establishment of the discriminative function.

In one experiment, discriminative functions were established prior to class formation and then generalized to the other class members once the classes had been formed (de Rose, McIlvane, Dube, Galpin, & Stoddard (1988). The design of this experiment, however, precluded determining whether the establishment of the discriminative functions enhanced subsequent class formation. Such a demonstration would document the added value of establishing a discriminative function prior to class formation. Not only would it lead to the generalization of responding among class members; it would also enhance the likelihood of forming the class that would then act as a function transfer network, a result that should have interesting practical application.

Functional Properties of Meaningful Stimuli

A meaningful stimulus can serve a number of behavioral functions. It can function as a CS and elicit physiological responses that are the correlates of emotional reactivity. It can function as a discriminative stimulus and evoke responses that produce appetitive stimuli or avoid aversive stimuli. It can function as a member of an isolated conditional discrimination and be related to one other stimulus. Finally, it can function as a member of another equivalence class, a perceptual class or a complex category such as a generalized equivalence class. The present experiment demonstrated that the acquisition of a discriminative function by one meaningless stimulus increased the percentage of participants who formed classes that contained that stimulus, but not as much as the inclusion of a meaningful stimulus. Thus, the enhancement of equivalence class formation by the inclusion of a meaningful stimulus can be partially accounted for by the discriminative function served by that stimulus. Additional research will be needed to evaluate how the likelihood of class formation will be influenced by the other above- mentioned behavioral functions that are served by meaningful stimuli. Indeed, changes in the likelihood of equivalence class formation then can provide a measure of some of the properties of meaningful stimuli.

As noted in the Introduction, in addition to discriminative functions that are served by meaningful stimuli, meaningful stimuli frequently have acquired emotive functions which also influence the likelihood of equivalence class formation. For instance, equivalence classes that contain words or images which have valences that are incompatible with each other are less likely to be formed by individuals with clinical anxieties, phobias or depression than by matched individuals who are not diagnosed as such (Grehan,1998; Leslie, Tierney, Robinson, Keenan, Watt, & Barnes, 1993; Plaud, 1995). Similarly, the formation of equivalence classes that contain stimuli which represent opposing political positions are less likely to be formed by individuals with correlated political prejudices than by individuals with little political prejudice (Moxon, Keenan, & Hine, 1993; Watt, Keenan, Barnes, & Cairns, 1991).

In these experiments, the valences of the stimuli were established preexperimentally by personal experience. In other studies, explicit training was used to induce emotional valences in stimuli that were subsequently used as members of to-be-formed equivalence classes (Peoples, Tierney, Bracken, & McKay, 1998; Tyndall et al., 2004; Tyndall et al., 2009). Thus, the likelihood of equivalence class formation is influenced by the preexperimentally induced or experimentally established emotional valences of stimuli included in the to-be-established classes, as well as the discriminative functions acquired by these stimuli.

Conclusions

The presence of meaningful stimuli in a set of meaningless stimuli influences the conversion of the set into an equivalence class. A meaningful stimulus has preexisting denotative, connotative, and behavior analytic properties. In a growing number of experiments, some of these properties have been experimentally established for initially meaningless stimuli. When these stimuli are included in a set of other meaningless stimuli, their inclusion also influences the conversion of the set into an equivalence class, in ways that are similar to the effects of meaningful stimuli. The results of these experiments as well as the present experiment then identify some of the properties of meaningful stimuli that influence the formation of equivalence classes. Conversely, studying the formation of equivalence classes clarifies the factors that make meaningful stimuli meaningful.

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