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STIMULUS GENERALIZATION AND EQUIVALENCE CLASSES: A MODEL FOR NATURAL CATEGORIES

LANNY FIELDS, KENNETH F. REEVE, BARBARA J. ADAMS, AND THOM VERHAVE

THE COLLEGE OF STATEN ISLAND/CUNY, QUEENS COLLEGE/CUNY, AND THE GRADUATE CENTER/CUNY

Two three-member classes were formed by training AB and BC using a conditional discrimination procedure. The A and B stimuli were nonsense syllables, and the C stimuli were sets of "short" or "long" lines. To test for equivalence, C1 or C2 was presented as a sample with A1 and A2 as comparisons. Once the class-related comparison was chosen consistently, different line lengths were substituted for the training lines in the CA tests. In general, the likelihood of choosing a given comparison was an inverse function of the difference in the length of the test line from the training line. Stimuli in an equivalence class became functionally related not only to each other but also to novel stimuli that resembled a member of the equivalence class. The combination of primary generalization and equivalence class formation, then, can serve as a model to account for the development of naturally occurring categories.

Key words: equivalence class, primary generalization, stimulus similarity, stimulus variant, natural categories, computer keyboard, human adult

Traditionally, an equivalence class as operationally defined contains a finite number of stimuli that become functionally substitutable for each other in conditional discrimination tests, even when the stimuli do not resemble each other (Fields & Verhave, 1987; Sidman, 1990; Sidman, Wynne, Maguire, & Barnes, 1989). For example, an equivalence class could be formed from three representations of "dog": Stimulus A being the Spanish word "perro," Stimulus B being the French word "chien," and Stimulus C being a picture of a golden retriever. Initially, AB and BC could be established by conditional discrimination training (Bush, Sidman, & de Rose, 1989; Fields & Verhave, 1987). The stimulus corresponding to the first letter in each trained pair is presented as the sample (Sa), and the stimulus corresponding to the second letter is presented as the positive comparison (Co+). The Sa and Co+ are presented with at least one negative comparison (Co−), which is a stimulus that is not a class member. To assess the formation of an equivalence class, all of the stimulus pairs not used in training (AA, BB, CC, BA, CB, AC, and CA) are presented as tests without informative feedback. For example, the CA test involves the presentation of the picture of the golden retriever as the sample, along with the words "perro" and "gato" as Co+ and Co−, respectively. Control by CA is demonstrated by the choice of "perro." Control exerted by all of these untrained stimulus pairs (called emergent relations) demonstrates the formation of the equivalence class (Bush et al., 1989; Fields & Verhave, 1987).

With two exceptions (Sidman, 1971; Sidman & Cresson, 1973), each member of an equivalence class has always been a singular stimulus. In natural settings, however, singular stimuli are rare or nonexistent (Catania, 1984; Herrnstein, 1984; Medin & Smith, 1984; Millenson & Leslie, 1979, pp. 319–340; Rosch & Mervis, 1975). Thus, in the above-mentioned class, although C was represented by a specific photograph of a particular golden retriever, C could also be represented by other photographs of the same golden retriever taken from different vantage points, by photographs of other golden retrievers, or by photographs

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of other breeds of dogs (Herrnstein, 1984; Herrnstein, Loveland, & Cable, 1976). All of these photographs, called "variants" of C, are generically represented by the symbol C′. If other pictures of the golden retriever or pictures of other breeds were substituted for the picture of the golden retriever in the CA test, what is the likelihood of choosing "perro" instead of "gato"? Loosely paraphrased, would the pictorial variants of C also control the choice of the textural member of the class that included the picture of the golden retriever? The likelihood of choosing "perro" should be a direct function of the resemblance of the variant pictures and the picture of the golden retriever used in training (Herrnstein, 1984; Honig & Stewart, 1988; Lea, 1984; Lea & Harrison, 1978; Medin & Smith, 1984; Rosch & Mervis, 1975). A similar argument can be made for variants that differ from a training stimulus along a quantitatively defined dimension such as wavelength or line length (Chase & Heinemann, 1972; Honig, Boneau, Burstein, & Pennypacker, 1963; Jenkins & Harrison, 1960; Wright, Cook, Rivera, Sands, & Delius, 1988). To date, however, there have been no demonstrations that one member of an equivalence class will also become functionally related to other stimuli that are physical variants of another class member. In the present experiment, an equivalence class was formed by training AB and BC. Once the CA equivalence relation emerged, quantitative variants of C were substituted for C in the CA tests, denoted by C′-A. Generalization of the equivalence relation was observed by measuring the choice responding occasioned by each variant of C in the C′-A tests.

METHOD

Subjects

Five undergraduate students at Queens College/CUNY were recruited from an introductory psychology class. No subject had any prior familiarity with the research area. The subjects received partial course credit upon completion of the experiment. Credit, however, did not depend on the subjects' performance during the experiment. Students participated in one or two experimental sessions lasting a total of about 3 h over the course of a week.

Apparatus and Stimuli

Experimental stimuli were presented to subjects using a microcomputer with a monochrome monitor. Subjects were seated in a cubicle at a table facing the computer. Their responses consisted of touching specific keys on the computer keyboard. These were automatically recorded by the computer. The experiment was conducted using software specifically developed for the training and testing of equivalence classes.

Each of the two classes was composed of two nonsense syllables and a group of lines. In Class 1, the nonsense syllables were LEQ (A1) and HUK (B1); in Class 2, the nonsense syllables were MEV (A2) and GUQ (B2). The lines were composed of contiguous horizontal strings of ASCII character 177 (▒) and were identified according to the number of ASCII characters in the line. Each ▒ was 3 mm wide and 5 mm high on the computer screen. Class 1 (C1) included lines two through seven characters long. Class 2 (C2) included lines 19 through 24 characters long. The remaining 13 line lengths were reserved for tests of the generalization of equivalence relations. Eleven of these lines, C(8) through C(17), were intermediate in length between Class 1 and Class 2. Two of these lines were supernormal; C(1) was shorter than the shortest line in Class 1, and C(25) was longer than the longest Class 2 line.

Procedure

General procedure. Each trial began when "Press ENTER" appeared on the screen. Pressing the ENTER key removed the message and displayed the sample. Pressing the space bar in the presence of a sample added two comparisons in an isoceles triangular array on the monitor with the sample at the vertex and the comparisons at the corners of the base. Subjects pressed the "1" key on the top row of the keyboard to choose the comparison on the left or the "2" key to choose the comparison on the right. Either choice cleared all stimuli from the screen and produced a feedback message. On each trial, the Sa and Co+ from one class were presented along with a Co− from the other class. If the Co+ was chosen, "RIGHT" appeared on the screen and remained there until the subject pressed the "R" key. If the Co− was chosen, the message "WRONG" appeared on the screen and remained there until the subject pressed the "W" key. When noninformative feedback was scheduled, the letter "E" appeared as soon as the subject emitted either of the choice responses and remained there until the subject pressed the "E" key. After the appropriate response (R, W, or E) the screen was cleared, and the next trial began (See Fields, Adams, Verhave, & Newman, 1990, for further details).

Each stage of training and testing was conducted in blocks with all trials in a block presented in a random order without replacement. In training, each block was repeated with informative feedback provided after each trial until all trials occasioned correct responding (100% mastery criterion). Thereafter, the percentage of trials that occasioned informative feedback was reduced to 75%, then to 25%, and finally to 0% over successive trial blocks as long as performance within a block was maintained at 100% accuracy. In the testing stages, test trials were presented along with training trials in a test/train ratio that varied from 1:1 to 2:1 in different test blocks (see Table 1). The blocks ranged in length from 32 to 48 trials, depending on the emergent relation(s) being tested. All choice responses were followed by noninformative feedback.

Pretraining. In Stage 1, subjects were trained to emit the appropriate keyboard responses in the presence of each cue used within each trial. This was accomplished by the serial deletion of instructional prompts (Fields, 1980). Stage 1 ended once the stimuli were presented with no prompts and performance exceeded 85% accuracy (14/16 correct trials) during a single block. For the remainder of the experiment, if a keyboard error was made, the instruction relevant to that error reappeared on the screen for that trial and the next two trials (see Fields, et al., 1990, for additional details).

In Stages 2 through 9, different trial blocks were presented to establish two three-member equivalence classes. The symbolic representation of the stimuli used in each block and the number of trials in each block are listed in Table 1. In Stage 2, AB was trained. In Stage 3, the symmetrical property of A and B was assessed with B1-A1 and B2-A2 tests. In Stage 4, BC was trained with six variants of C1 and six variants of C2. Each variant of C is referred to as C1(x) or C2(x) where x represents the line length. In Stage 5, the symmetrical property of B and C was assessed with C1(x)-B1 and C2(x)-B2 tests. In Stage 6, maintenance of control by the symmetrical relations BA and CB was assessed with B1-A1, B2-A2, C1(x)-B1, and C2(x)-B2 tests. In Stage 7, the transitive property of A and C was assessed with A1-C1(x) and A2-C2(x) tests. In Stage 8, equivalence was assessed with C1(x)-A1 and C2(x)-A2 tests. In Stage 9, maintenance of control by the emergent relations and the training relations was assessed with AB, B-C(x), BA, C(x)-B, A-C(x), and C(x)-A tests for both classes of stimuli. The mastery criterion in Stages 2 through 9 was 100% correct for a block.

Generalization testing. After pretraining, the generalization of the equivalence relations was assessed in Stage 10 with the presentation of C(x)-A tests in the block of trials represented symbolically in Table 2. In each trial, A1 and A2 served as the comparisons. In eight trials, four from each class, the samples were a subset of the C stimuli used in training. In the remaining 28 trials, the samples were the intermediate lines, C(8) through C(18), and the supernormal lines, C(1) and C(25). Each line appeared twice as a sample, except C(13), which appeared four times. Three different types of test blocks were used; each contained a different subset of training lines. The configurations used in each block are listed in Table 2. Test Blocks 1 and 2 were each presented three times, and Block 3 was presented four times in the order 1, 2, 3, 1, 2, 3, 1, 2, 3, 3. In total, 10 blocks were presented, regardless of performance on any block.

RESULTS

All 5 subjects formed the two equivalence classes with a mean of 18.2 blocks. The total number of blocks required to form equivalence classes ranged from 15 to 20; the scheduled minimum was 14 blocks. The results of the generalization tests are presented for individual subjects in Figure 1. The vertical lines separate the values of C that were members of Class 1 or Class 2 from the values used for generalization testing. The solid line shows the proportion of trials in which the A1 comparison was chosen in the presence of each value of C and C′. The dotted line depicts the proportion of times that the A2 comparison was chosen in the presence of each value of C and

Table 1

Symbolic representation of stimulus triads in Stages 2 through 9. In each trial block, each Co+ appeared equally often on the left and right. The ratio of testing to training trials appears in the parentheses to the right of each stage description.

Sa	Co+	Co−	Presented	Sa	Co+	Co−	Presented
Stage 2. Train AB							
A1	B1	B2	8[a]	A2	B2	B1	8[a]
Stage 3. BA symmetry test (1:1)							
A1	B1	B2	8	A2	B2	B1	8
B1	A1	A2	8	B2	A2	A1	8
Stage 4. Train BC							
A1	B1	B2	4	A2	B2	B1	4
B1	C1 (2)	C2 (24)	2	B2	C2 (19)	C1 (7)	2
B1	C1 (3)	C2 (20)	2	B2	C2 (20)	C1 (3)	2
B1	C1 (4)	C2 (22)	2	B2	C2 (21)	C1 (5)	2
B1	C1 (5)	C2 (21)	2	B2	C2 (22)	C1 (4)	2
B1	C1 (6)	C2 (23)	2	B2	C2 (23)	C1 (6)	2
B1	C1 (7)	C2 (19)	2	B2	C2 (24)	C1 (2)	2
Stage 5. CB symmetry test (1.5:1)							
A1	B1	B2	4	A2	B2	B1	4
B1	C1 (4)	C2 (22)	2	B2	C2 (19)	C1 (7)	2
B1	C1 (7)	C2 (19)	2	B2	C2 (22)	C1 (4)	2
C1 (2)	B1	B2	2	C2 (19)	B2	B1	2
C1 (3)	B1	B2	2	C2 (20)	B2	B1	2
C1 (4)	B1	B2	2	C2 (21)	B2	B1	2
C1 (5)	B1	B2	2	C2 (22)	B2	B1	2
C1 (6)	B1	B2	2	C2 (23)	B2	B1	2
C1 (7)	B1	B2	2	C2 (24)	B2	B1	2
Stage 6. BA and CB symmetry test (1.2:1)							
A1	B1	B2	4	A2	B2	B1	4
B1	C1 (3)	C2 (20)	2	B2	C2 (20)	C1 (3)	2
B1	C1 (6)	C2 (23)	2	B2	C2 (23)	C1 (6)	2
B1	A1	A2	4	B2	A2	A1	4
C1 (3)	B1	B2	2	C2 (22)	B2	B1	2
C1 (5)	B1	B2	2	C2 (23)	B2	B1	2
C1 (7)	B1	B2	2	C2 (24)	B2	B1	2
Stage 7. AC transitivity test (1.5:1)							
A1	B1	B2	4	A2	B2	B1	4
B1	C1 (2)	C2 (24)	2	B2	C2 (21)	C1 (5)	2
B1	C1 (5)	C2 (21)	2	B2	C2 (24)	C1 (2)	2
A1	C1 (2)	C2 (24)	2	A2	C1 (19)	C2 (7)	2
A1	C1 (3)	C2 (20)	2	A2	C1 (20)	C2 (3)	2
A1	C1 (4)	C2 (22)	2	A2	C1 (21)	C2 (5)	2
A1	C1 (5)	C2 (21)	2	A2	C1 (22)	C2 (4)	2
A1	C1 (6)	C2 (23)	2	A2	C1 (23)	C2 (6)	2
A1	C1 (7)	C2 (19)	2	A2	C1 (24)	C2 (2)	2
Stage 8. CA equivalence test (2:1)							
A1	B1	B2	4	A2	B2	B1	4
B1	C1 (4)	C2 (22)	2	B2	C2 (19)	C1 (7)	2
B1	C1 (7)	C2 (19)	2	B2	C2 (22)	C1 (4)	2
C1 (2)	A1	A2	2	C2 (19)	A2	A1	2
C1 (3)	A1	A2	2	C2 (20)	A2	A1	2
C1 (4)	A1	A2	2	C2 (21)	A2	A1	2
C1 (5)	A1	A2	2	C2 (22)	A2	A1	2
C1 (6)	A1	A2	2	C2 (23)	A2	A1	2
C1 (7)	A1	A2	2	C2 (24)	A2	A1	2
Stage 9. Symmmetry/transitivity/equivalence test (2:1)							
A1	B1	B2	4	A2	B2	B1	4
B1	C1 (3)	C2 (20)	2	B2	C2 (20)	C1 (3)	2

Table 1

(Continued)

Sa	Co+	Co−	Presented	Sa	Co+	Co−	Presented
B1	C1 (6)	C2 (23)	2	B2	C2 (23)	C1 (6)	2
B1	A1	A2	4	B2	A2	A1	4
C1 (4)	B1	B2	2	C2 (19)	B2	B1	2
C1 (7)	B1	B2	2	C2 (22)	B2	B1	2
A1	C1 (3)	C2 (20)	2	A2	C1 (20)	C2 (3)	2
A1	C1 (6)	C2 (23)	2	A2	C1 (23)	C2 (6)	2
C1 (2)	A1	A2	2	C2 (21)	A2	A1	2
C1 (5)	A1	A2	2	C2 (24)	A2	A1	2

[a] When less than 100% feedback was scheduled, each triad appeared four times.

C′. All subjects yielded similar results. When the training stimuli were presented as samples, the class-related comparison (A) was chosen almost exclusively. When the supernormal line C(1) was presented, the A1 comparison was chosen exclusively. When the supernormal line C(25) was presented, the A2 comparison was chosen exclusively. As the length of C′ increased from C(8) to C(18), the likelihood of choosing A1 declined systematically and eventually reached some value beyond which A1 was rarely chosen. Subjects' performances differed only in quantitative detail. The generalization functions differed in slope, in smoothness, and in the range of test variants that occasioned exclusive choice of A1 or A2.

DISCUSSION

The formation of equivalence classes occurred rapidly for all subjects. Each training and emergent relation came to exert control with few presentations above the minimum number of testing blocks. Unpublished data from our laboratory suggest that the efficiency

Table 2

Symbolic representation of stimulus triads in Stage 10. In each trial block, each Co appeared equally often on the left and right. Each test block contained all of the generalization tests of equivalence relations plus Block 1, 2, or 3 of the training subsets indicated in the bottom half of the table.

Generalization tests of equivalence relations

Sa	Co?	Co?	Presented	Sa	Co?	Co?	Presented
C (1)	A1	A2	2	C (14)	A1	A2	2
C (8)	A1	A2	2	C (15)	A1	A2	2
C (9)	A1	A2	2	C (16)	A1	A2	2
C (10)	A1	A2	2	C (17)	A1	A2	2
C (11)	A1	A2	2	C (18)	A1	A2	2
C (12)	A1	A2	2	C (25)	A1	A2	2
C (13)	A1	A2	4				

Training subsets

Sa	Co+	Co−	Presented	Sa	Co+	Co−	Presented
Block 1							
C1 (4)	A1	A2	2	C2 (19)	A2	A1	2
C1 (7)	A1	A2	2	C2 (22)	A2	A1	2
Block 2							
C1 (3)	A1	A2	2	C2 (20)	A2	A1	2
C1 (6)	A1	A2	2	C2 (23)	A2	A1	2
Block 3							
C1 (2)	A1	A2	2	C2 (21)	A2	A1	2
C1 (5)	A1	A2	2	C2 (24)	A2	A1	2

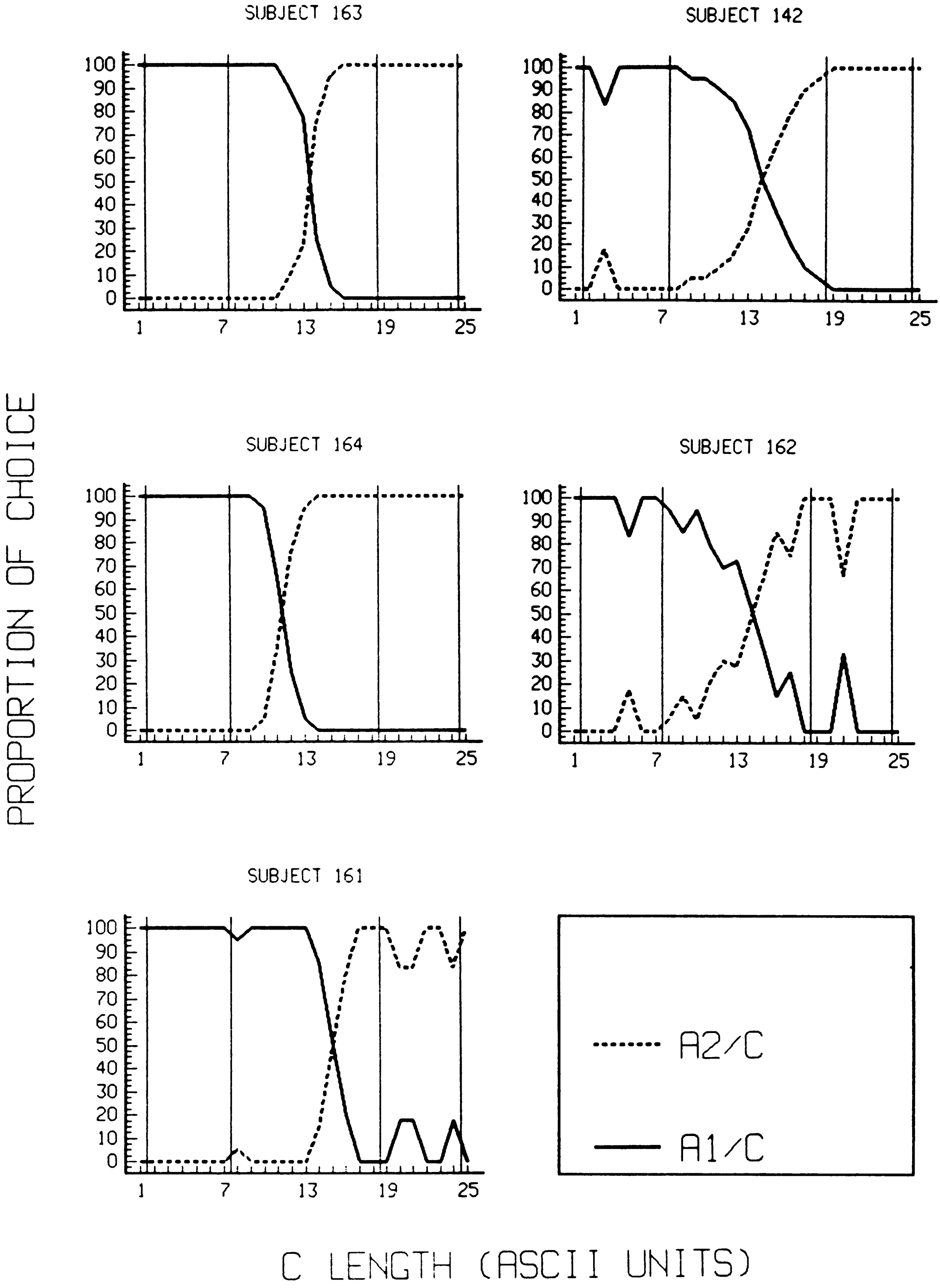

Fig. 1. Likelihood of choosing A1/C and A2/C as a function of the length of C. Each graph is for a different subject. Vertical lines separate line lengths used in training and in testing.

of the training procedure can be attributed to the induction of symmetry and transitivity before equivalence.

In this study, a host of novel stimuli (C′), which were dimensional variants of one member of an equivalence class (C), were substituted for the class members in the equivalence tests (C′-A). The control exerted by each variant was an inverse function of the disparity between the length of each variant and the lengths of the lines that were class members by training. Thus, the stimuli that constituted the equivalence class as trained were not only related to each other but were also functionally related in varying degree to a broad range of other stimuli. This spread of effect is similar to the generalization that occurs to novel stimuli that resemble the discriminanda in classical, relational, probabilistic, polymorphous, or fuzzy categories (Herrnstein, 1984; Medin & Smith, 1984; Millenson & Leslie, 1979; Rosch & Mervis, 1975).

The generalization functions differed quantitatively from subject to subject. Indeed, they need not be invariant for the same subject; rather, the degree of generalization may well be influenced by parameters such as the number of variants used as class members and the availability of a response option that permits a subject to label a test stimulus as not being a class member. These parameters and others may influence the slope and smoothness of the generalization gradients or the range of stimuli that function in the same manner as the class member in an equivalence test.

The generalization of equivalence relations reported in this experiment can be used to model the complex categories observed in real-world settings. In terms of physical characteristics, all of the stimuli in a naturally occurring complex category are not perceptually similar. Some stimuli in the category do not bear any physical resemblance to each other; neither do the stimuli in an equivalence class. Other stimuli in such a naturally occurring category do resemble each other; so do the stimuli in classical or fuzzy categories (Chase & Heinemann, 1972; Herrnstein, 1984; Honig & Stewart, 1988; Hrycenko & Harwood, 1980; Hull, 1920; Neisser & Weene, 1962; Rosch & Mervis, 1975; Medin & Smith, 1984; Smoke, 1932). An example of a naturally occurring category of "dog" could be the written words "dog," "perro," and "chien," as well as pictures of dogs from many different breeds in which many pictures of each breed are taken from different vantage points. The stimuli within the written-word equivalence subset become interrelated through a history of conditional discrimination training. The stimuli in the fuzzy/classical pictorial subset are interrelated through a history of differential reinforcement of similar responding to each exemplar. The stimuli in the two subsets must also become related to one another. To do this, the equivalence subset of textual names must be expanded through conditional discrimination training to include at least one stimulus from the fuzzy/classical subset. At minimum, this can be done by pairing one written word for dog with one picture of a dog. Once this has occurred, the stimuli that resemble each other in the fuzzy/classical subset should also become related to the remaining members of the equivalence subset (Lea, 1984). Thus, the development of complex naturally occurring categories may be accounted for by the combined effects of equivalence class formation and stimulus generalization.

REFERENCES

Bush, K. M., Sidman, M., & de Rose, T. (1989). Contextual control of emergent equivalence relations. *Journal of the Experimental Analysis of Behavior*, **51**, 29–45.

Catania, A. C. (1984). *Learning* (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall.

Chase, S., & Heinemann, E. G. (1972). Choice based on redundant information: An analysis of two-dimensional stimulus control. *Journal of Experimental Psychology*, **92**, 161–175.

Fields, L. (1980). Enhanced learning of new discriminations after stimulus fading. *Bulletin of the Psychonomic Society*, **15**, 327–330.

Fields, L., Adams, B. J., Verhave, T., & Newman, S. (1990). The effects of nodality on the formation of equivalence classes. *Journal of the Experimental Analysis of Behavior*, **53**, 345–358.

Fields, L., & Verhave, T. (1987). The structure of equivalence classes. *Journal of the Experimental Analysis of Behavior*, **48**, 317–332.

Herrnstein, R. J. (1984). Objects, categories, and discriminative stimuli. In H. L. Roitblatt, T. G. Bever, & H. S. Terrace (Eds.), *Animal cognition* (pp. 233–261). Hillsdale, NJ: Erlbaum.

Herrnstein, R. J., Loveland, D. H., & Cable, C. (1976). Natural concepts in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, **4**, 285–302.

Honig, W. K., Boneau, C. A., Burstein, K. R., & Pennypacker, H. S. (1963). Positive and negative generalization gradients obtained after equivalent training conditions. *Journal of Comparative and Physiological Psychology*, **56**, 111–116.

Honig, W. K., & Stewart, K. E. (1988). Pigeons can discriminate locations presented in pictures. *Journal of the Experimental Analysis of Behavior,* **50,** 541–551.

Hrycenko, O., & Harwood, D. W. (1980). Judgments of shape similarity in the Barbary dove (*Streptopelia risoria*). *Animal Behaviour,* **28,** 586–592.

Hull, C. L. (1920). Quantitative aspects of the evolution of concepts. *Psychological Monographs,* **28**(1, Whole No. 132).

Jenkins, H. M., & Harrison, R. H. (1960). Effect of discrimination training on auditory generalization. *Journal of Experimental Psychology,* **59,** 246–253.

Lea, S. E. G. (1984). In what sense do pigeons learn concepts? In H. L. Roitblatt, T. G. Bever, & H. S. Terrace (Eds.), *Animal cognition* (pp. 263–276). Hillsdale, NJ: Erlbaum.

Lea, S. E. G., & Harrison, S. N. (1978). Discrimination of polymorphous stimulus sets by pigeons. *Quarterly Journal of Experimental Psychology,* **30,** 521–537.

Medin, D. L., & Smith, E. E. (1984). Concepts and concept formation. *Annual Reviews of Psychology,* **35,** 113–138.

Millenson, J. R., & Leslie, J. C. (1979). *Principles of behavioral analysis* (2nd ed.). New York: Macmillan.

Neisser, U., & Weene, P. (1962). Hierarchies in concept attainment. *Journal of Experimental Psychology,* **64,** 640–645.

Rosch, E., & Mervis, C. B. (1975). Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology,* **7,** 573–605.

Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research,* **14,** 5–13.

Sidman, M. (1990). Equivalence relations: Where do they come from? In D. Blackman & H. Lejeune (Eds.), *Behavior analysis in theory and practice: Contributions and controversies* (pp. 93–114). Hillsdale, NJ: Erlbaum.

Sidman, M., & Cresson, O., Jr. (1973). Reading and crossmodal transfer of stimulus equivalences in severe retardation. *American Journal of Mental Deficiency,* **77,** 515–523.

Sidman, M., Wynne, C. K., Maguire, R. W., & Barnes, T. (1989). Functional classes and equivalence relations. *Journal of the Experimental Analysis of Behavior,* **52,** 261–274.

Smoke, K. L. (1932). An objective study of concept formation. *Psychological Monographs,* **42**(4, Whole No. 191).

Wright, A. A., Cook, R. G., Rivera, J. J., Sands, S. F., & Delius, J. D. (1988). Concept learning by pigeons: Matching-to-sample with trial-unique video picture stimuli. *Animal Learning & Behavior,* **16,** 436–444.

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