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Matching to Complex Samples and Stimulus Class Formation in Adults with Autism and Young Children[1]

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Adults with autism and young children first learned to match one-element comparison stimuli to two-element sample stimuli. Test conditions then examined whether each of the individual sample elements (a) controlled selections of the comparison stimuli to which they were related during training, (b) were interchangeable with one another as either sample or comparison stimuli, and (c) were interchangeable with the original comparison stimuli. Test data were positive and suggested the formation of three-member stimulus classes. Subsequent experiments demonstrated the formation of four-member classes by (a) adding novel stimuli by training outside the original context; (b) adding novel stimulus elements to the two-element samples used during baseline training; and (c) training with three-element rather than two-element sample stimuli from the outset. Results suggest that acquisition of stimulus classes may be one of the benefits of broad rather than restricted attention to the components of complex stimuli.

A complex stimulus consists of multiple components or elements, each of which may exert stimulus control over the same behavior. The student

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whose learning encompasses each of the elements of a complex stimulus may, in turn, display a broad network of adaptive discriminative behavior. The acquisition of stimulus classes may be essential to such a network (cf. Stromer, Mackay, & Stoddard, 1992). For example, a student may learn to distinguish classes of fruits and vegetables by observing classroom materials and activities that simultaneously illustrate multiple relevant instances of each class (cf. MacDonald, Dixon, & LeBlanc, 1986; Varni, Lovaas, Koegel, & Everett, 1979). In further illustration, a student taught with total-communication methods may learn that both the sign and spoken-word elements of a teacher's instructions are in the same class as their object or picture referents (e.g., Clarke, Remington, & Light, 1986; Wulz & Hollis, 1979; but cf. Binkoff, Kologinsky, & Eddy, 1978; Carr, 1979; Carr & Dores, 1981).

Most research on stimulus classes has used matching-to-sample procedures in which each sample and each comparison is treated as a single stimulus rather than a stimulus complex. For example, the sample stimuli might be the dictated words "Dog" (A1) and "Cat" (A2); the comparison stimuli might be the pictures of a dog (B1) and a cat (B2), and the printed words *dog* (C1) and *cat* (C2). Subjects are taught directly A-B matching (e.g., A1-B1: if A1 is the sample, select B1; A2-B2: if A2 is the sample, select B2) and A-C matching (A1-C1 and A2-C2). Matching performances such as B-C and C-B are merely tested; their emergence demonstrates the mutual substitutability of the stimuli and permits an inference of stimulus class formation that helps explain how certain novel performances can come about indirectly (Sidman & Tailby, 1982; Spradlin & Saunders, 1984). The procedures have been used to establish and investigate stimulus classes in humans with capabilities that range from those of individuals with severe retardation to college students (Mackay, 1991; McIlvane, 1992; Stromer, 1991).

In extensions of the preceding methods with college students, Stromer and Stromer (1990a, 1990b, 1992) used matching tasks with multielement samples to establish stimulus classes. In AB-D matching, the samples were combinations of tones (A1 and A2) and colors (B1 and B2) and the comparisons were forms (D1 and D2); selections of D1 and D2 were conditional upon A1B1 and A2B2, respectively. In AC-E matching, selections of the forms E1 and E2 were conditional upon samples that consisted of the same tones but different colors, A1C1 and A2C2. Thus, the tone and color elements of the samples were perfectly correlated with comparison selection and the delivery of reinforcement. Moreover, because the tones were common to the AB-D and AC-E training trials, they provided the bases for two five-member stimulus classes (A1B1C1D1E1 and A2B2C2D2E2). Tests for these classes included all relations involving tones, colors, and forms as samples, and colors and forms as comparisons. Most subjects showed class-consistent performances on these tests, showing A-D, B-D, D-B, A-B, B-A, A-E, C-E, E-C, B-C, C-B, D-E, and E-D matching.

Stromer and Stromer's (1990a, 1990b, 1992) studies have not been replicated in individuals with developmental delays. Although the complex sample feature of their training procedure has been used in some studies of attention in individuals with autism, only limited outcome tests have been conducted. For example, Touchette and Maguire (1986) taught conditional position discriminations to students with autism. These students learned to touch the left of two identical stimuli in the presence of one two-element sample (A1B1) and to touch the right stimulus in the presence of another sample (A2B2). Tests then examined whether each of the four individual elements of the complex stimuli would control the position discriminations in a manner consistent with the training history. Such control was clearly evident in the performances of three of eight participants: When presented individually, elements A1 and B1 each controlled touches to the left, A2 and B2 each controlled touches to the right. These results were replicated systematically by Dube, Kledaras, Iennaco, Stoddard, and McIlvane (1990) using a similar procedure and participants with mental retardation.

These findings demonstrate, in individuals with developmental delays, critical prerequisites for the development of stimulus classes like those shown by Stromer and Stromer's college students. The multiple, individual components of complex conditional stimuli must themselves control the conditional discrimination performances if these stimuli are to be functional in tests necessary to examine (a) whether classes of mutually substitutable stimuli may have resulted, and (b) whether the procedure may have established conditional relations among these stimuli. Notably, such class formation could not result or would be limited in individuals whose performances show stimulus overselectivity (Lovaas, Schreibman, Koegel, & Rhem, 1971) or restricted stimulus control (Litrownik, McInnis, Wetzel-Pritchard, & Filipelli, 1978). The present study included tests necessary to examine these stimulus control phenomena in individuals with autism and young, normally capable children who may be likely to evidence restricted stimulus control (cf. Burke, 1991).

In the present study we first established performance in a matching task in which the complex samples were made up of two different forms (e.g., A1B1 and A2B2) and the comparisons were single forms (e.g., D1 and D2). These stimuli then were used in other matching tasks that assessed the mutual substitutability of the stimuli. Experiments 1A and 1B examined performances in tasks where the sample and comparison stimuli for each trial were the individual forms (e.g., A1 and B1) that had appeared together as one sample during training. Would contiguity in sample presentation yield matching performance without direct training? Additional tasks examined whether the forms used as comparisons in training (e.g., D1) would serve as samples controlling selection of the individual elements (e.g., A1 and B1) of the samples to which they had been related by training. Performance that reflected such sample-comparison substitutability would support the inference that the relations among the training stimuli were symmetrical (Sidman & Tailby, 1982). Subsequent experiments examined methods for increasing the numbers of stimuli involved in the complex-sample performances under analysis. In Experiment 2A, new stimuli were introduced as samples in additional training with the original comparison stimuli. In Experiment 2B, additional stimuli were introduced by simply adding a new (third) form to each of the two-form samples used in original training. In Experiment 3, three-element samples were used during training.

EXPERIMENT 1A

In Experiment 1A, a student from Touchette and Maguire's (1986) study, whose performances had shown appropriate control by the elements of complex training stimuli, was taught a task denoted AB-D matching to sample. The training procedures differed from Touchette and Maguire's conditional position discrimination; the comparisons (D1 and D2) were forms whose position changed from trial to trial. This training enabled assessment of whether the A, B, and D stimuli were mutually interchangeable as samples and comparisons; if so, the training may have established two three-member stimulus classes (A1B1D1 and A2B2D2).

Method

Subject

Subject PNN (age 21 years) was diagnosed autistic and had an age-equivalent score of 3 years 10 months on the Peabody Picture Vocabulary Test. Subject PNN could perform most activities of daily living independently, follow two- and three-step directions, and use three- and four-word sentences, although PNN's speech was often unintelligible; PNN was unable to read and write.

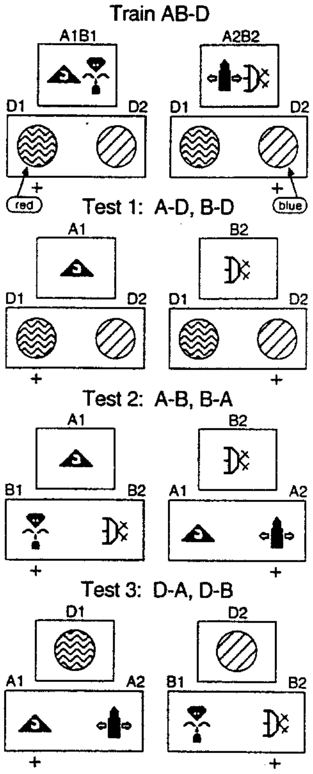

Fig. 1. Depictions of tabletop procedures used to train and test matching-to-sample performances in Experiment 1A (not drawn to scale). Panels in each row show representative trial types; sample stimuli appear at the top and comparison stimuli appear below. In AB-D training, for example, selections of one-element comparisons (D1 and D2) were conditional upon two-element samples (A1B1 and A2B2) (+ denotes the correct comparison). Tests 1–3 assessed performances expected if training established two three-member stimulus classes (A1B1D1 and A2B2D2).

Apparatus

The subject sat at a table facing an experimenter who presented stimuli, delivered consequences (e.g., soda and praise), and recorded data. Sample stimuli were placed upright in a wooden stand (25.3 cm × 45.7 cm); two comparison stimuli were displayed, one at each end of a panel that extended beyond both sides of the sample stand (15.2 cm × 40.6 cm). As depicted in Figure 1, the samples were two black forms displayed side by side on white paper (21.6 cm × 27.9 cm); the comparisons were red and blue circles (10.2 cm diam).

Procedure

Train AB-D Matching. Figure 1 depicts the AB-D matching task trained initially: In the presence of the two-element sample A1B1, a touch to the S+ (correct) comparison D1 (a red circle) was reinforced with a sip of coffee or soda; a touch to D2 (blue) was reinforced in the presence of the two-element sample A2B2. Touches to S– (incorrect) comparisons produced the intertrial interval of 3–5 seconds and the next trial. The sample (A1B1 or A2B2) and the left–right locations of the comparison stimuli varied from trial to trial unsystematically. A prompting/fading procedure was used to train the AB-D performance. Initially, the experimenter prompted comparison selection by placing a sample stimulus directly above its S+ comparison. After a correct trial, that sample then was placed 2.54 centimeters closer to the center of the display the next time it appeared. After an error, the sample was placed 2.54 centimeters further from center on its next appearance. Such prompting continued until each of the sample stimuli was displayed in the center and each of the positive comparisons was selected in 10 consecutive trails. Training then continued until an accuracy score of at least 90% occurred in one 50-trial session with no fading.

Test 1: A-D and B-D Matching. The A-D and B-D trials assessed whether PNN would select comparisons D1 and D2 when the elements of each respective complex sample were presented individually. Figure 1 illustrates trials to test D1 to A1 and D2 to B2 matching. The session involved 100 AB-D baseline trials and 40 test trials (20 A-D and 20 B-D trials). Trials were presented in 10 blocks of 14 trials each. The first 10 trials in each block were baseline trials and all correct responses were reinforced; then, in 4 test trials, both correct (class consistent) and incorrect (class inconsistent) responses were reinforced.

Test 2: A-B and B-A Matching. Test 2 assessed A-B and B-A matching in which the elements of the samples used in training served as comparison stimuli for the first time. For example, if the sample was A1, B1 was the correct selection; if the sample was B2, A2 was the correct selection (see Figure 1). Baseline and test trials were arranged as in Test 1.

Test 3: D-A and D-B Matching. Test 3 assessed D-A and D-B performances in the final 140-trial session. The D stimuli served as samples for the first time: For example, if D1 was the sample, A1 was the correct comparison; if D2 was the sample, B2 was the correct comparison (see Figure 1). Baseline and test trials were arranged as in Tests 1 and 2.

Reliability. An independent observer scored about 25% of the sessions. Trial-by-trial comparisons of these observations with those of the experimenter yielded complete agreement.

Results and Discussion

PNN's perfect performance during two AB-D training sessions satisfied acquisition criteria. Table I shows the percentage of test trial selections that were consistent with training. Positive A-D and B-D performances during Test 1 replicated prior results with PNN and others showing that each of four elements of complex sample stimuli came to exert control over comparison selection (e.g., Dube et al., 1990; Touchette & Maguire, 1986). Each comparison stimulus was conditionally related to two different sample stimuli (if A1 or B1, select D1; if A2 or B2, select D2); this provided the possible bases for stimulus class formation.

The outcomes of further testing confirm the emergence of other performances that were not directly trained. The A-B and B-A performances shown in Test 2 and the D-A and D-B performances in Test 3 reflect the mutual substitutability of the stimuli that may indicate the formation of two three-member stimulus classes. In particular, the sample-comparison reversibility reflected in these data suggests that the relations among the stimuli were symmetrical, demonstrating one of the defining properties of stimulus equivalence classes (cf. Sidman, 1986, 1990; Sidman & Tailby, 1982).

EXPERIMENT 1B

This experiment systematically replicated the preceding study with additional subjects and automated, rather than tabletop, procedures.

Subjects

The five participants were experimentally naive. Subject DGJ (age 22 years) resided in a private school and was diagnosed autistic and mentally retarded (IQ score of 60 on the Wechsler Intelligence Scale for Children).

Subject DGJ was independent in all activities of daily living, spoke in full sentences, and followed multiple directions; DHJ could also sight read and write a few words. Subjects BHC, MRC, CTB (age 4), and CGM (age 9) were normally capable children.

Apparatus

A Macintosh computer presented the stimuli and consequences and stored data. Stimuli appeared on the screen in three white "keys" (4.5 cm × 5.0 cm) on a gray background (Figure 2). Responses to the stimuli were recorded by one of two methods: For four subjects (DGJ, BHC, MRC, and CGM), selections were entered into the computer by the experimenter through the keyboard. Subject CTB selected stimuli by using the computer's mouse to place the cursor (an arrow displayed on the screen) on a key, then pressing the button on the mouse. Subjects sat at a table facing the computer. An experimenter, who sat behind the subject, monitored sessions, and delivered reinforcers, tokens that were traded later for candy, soda, or a small toy. Sessions were held in a quiet area of the individual's school or home.

Procedure

Pretraining. This phase sought to verify that subjects could discriminate the A, B, and D stimuli from one another in matching to sample. Each trial began with a one-element (e.g., A1, B1) or a complex two-element sample (e.g., A1B1) on the center key of the three-key display (see Figure 2). A touch to the sample produced a pair of element comparisons (A1 and A2) or a pair of complex comparisons (A1B1 and A2B2). The S+ comparison was either wholly identical (e.g., in matching A1 to A1) or partially identical (e.g., in matching A1 to A1B1) to the sample and the S– comparison had no identical element. Only selection of the S+ comparison was reinforced; selection of the S– comparison produced the 3- to 5-second intertrial interval and the next trial. Each 60-trial session contained an equal number of element and complex trials presented in an unsystematic order.

Train AB-D Matching. The computerized AB-D task was like that in Experiment 1A but used forms as the D comparison stimuli (Figure 2, top). The training procedure also differed from Experiment 1A; we used a delayed cue procedure (Touchette, 1971) to establish AB-D matching with few errors. On the initial trials, a touch to the sample A1B1 or A2B2 produced the comparisons D1 and D2. The S– comparison then disappeared

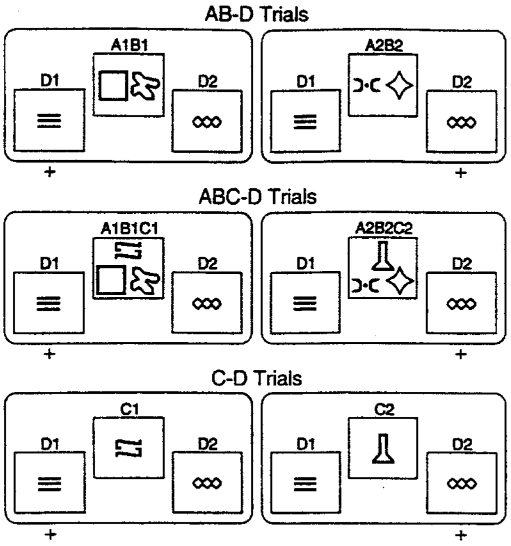

Fig. 2. Depictions of computer-generated training trials used in Experiment 1B (AB-D trials), Experiment 2A (AB-D and C-D trials), and Experiment 2B (AB-D and ABC-D trials). Each panel represents a matching-to-sample trial; sample stimuli appear in the center and comparison stimuli appear on the sides. During the AB-D trials, for example, selections of comparison stimuli D1 and D2 were conditional upon samples A1B1 and A2B2, respectively (+ denotes the correct comparison).

immediately, leaving only the S+. Across trials the duration of the S– increased by 0.5 second after every correct response. Responses to the S– decreased the duration of the S– on the next trial by 0.5 second. The delayed cue procedure continued until the subject responded to the S+ on 24 consecutive trials *before* the disappearance of the S–. Initially, each correct selection produced a flashing visual display, melodic tones, delivery of a token and praise, and the intertrial interval; errors darkened the computer screen for 5 seconds before the intertrial interval. Training continued until an accuracy score of 90% or better occurred for one 48-trial session without the delayed cue. The frequency of differential consequences following correct and incorrect selections was then reduced. For MRC and BHC, consequences were programmed every second trial, on average; for DGJ, consequences were programmed on 75% of the trials; CGM and CTB received no such consequences. All subjects also received instructions in each session in which consequences were not programmed for each trial

(Note: The initial sentence of the following was used only in the first of the sessions).

> This session will be different than the ones you have been doing. Not all of your answers will be followed by the computer music and flashing. Also, I will not say "good" or give you a token for each answer. Some of your answers will be followed only by the next problem. Do the best that you can and you will earn your (e.g., soda) at the end of the session.

The criterion for advancing to the test sessions was an accuracy score of at least 90% for two consecutive sessions under the reduced schedule of consequences.

Testing. As in Experiment 1A, Test 1 assessed A-D and B-D matching; Test 2 assessed A-B and B-A matching; and Test 3 assessed D-A and D-B matching. Subject DGJ's 48-trial sessions involved 44 AB-D trials and 4 test trials; differential consequences were unavailable on 8 baseline trials and all test trials. Sessions for BHC and MRC were 48 trials, each containing 32 AB-D baseline and 16 test trials (4 trials assessing each stimulus–stimulus relation). The consequences provided during training occurred on 24 of 32 baseline trials but never on test trials. Subjects CTB and CGM received the same tests but without differential consequences for correct selections and errors.

Reliability. Reliability of the experiment's keyboard recording was assessed in approximately 25% of the sessions. Recordings made by the experimenter and an independent observer were compared; their percentage of agreement averaged 99% across the four subjects.

Results and Discussion

All subjects performed identity matching to sample with few or no errors; they reached training criteria on AB-D matching in four (CTB) to seven (DGJ) sessions. Table I shows percentages of test trials consistent with the conditional relations defined experimentally. The subject with autism (DGJ) and two children (BHC and CTB) showed such performances immediately; accuracy scores for the other two children were either perfect or nearly so by the second test session. The results extend those of PNN in Experiment 1A and suggest that the present training also may establish the prerequisites for two three-member stimulus classes.

Experiment 2A attempted to confirm the formation of stimulus classes using a procedure that added novel C stimuli to the network of performances established previously by AB-D matching. These C stimuli were used as samples in separate training of C-D matching. The emergence of performances such as A-C, C-A, B-C, and C-B matching would confirm that training AB-D and C-D matching had established two four-member stimulus classes (A1B1C1D1 and A2B2C2D2).

Method

Subjects and Apparatus

Subjects MRC and CTB from Experiment 1B continued using the same apparatus.

Procedure

Train AB-D and C-D Matching. After reviewing AB-D matching (see Figure 2, top) in one session, C-D matching (see Figure 2, bottom) was trained. In the presence of sample C1, selections of comparison D1 were reinforced; in the presence of C2, selections of D2 were reinforced. Delayed-cue training followed the sequence described in Experiment 1B.

Testing. The test conditions were the same as these subjects received in Experiment 1B, but trial types were added to assess performances with the new C stimuli. Test 1 included trials retesting the A-D and B-D performances, and two C-D trial types that examined whether C1 and C2 would control selections of D1 and D2, respectively, under test conditions. Test 2 includes A-B and B-A retest trials and trials A-C, C-A, B-C, and C-B to assess matching performances involving the novel C elements and the A and B elements. Finally, Test 3 mixed D-C trials with those retesting the D-A and D-B performances to assess performances with the novel C elements as comparisons and the D stimuli as samples.

Results and Discussion

Table I shows that subjects' performances were class-consistent, either immediately (CTB) or after repeated testing (MRC). The results suggest the formation of four-member stimulus classes. Moreover, the positive performances involving A-C, C-A, B-C, and C-B matching (Test 2) were *derived*, and not merely an outcome of broad element control and stimulus substitutability. Such emergent performance not only suggests symmetry of the relations among the stimuli but also permits an inference of transitivity, another of the defining properties of stimulus equivalence classes (see Sid-

Table I. Summary of Test Data[a]

Tests	Subject					
	PNN	DGJ	BHC	MRC	CTB	CGM
Experiments 1A & 1B (AB-D trained)						
A-D, B-D	100	94/100	100	69/100	100	75/94/100
A-B, B-A	100	81/94	100	94/100	100	100/94
D-A, D-B	98	100	100	94	96	88/100
			MRC		CTB	
Experiment 2A (AB-D, C-D trained)						
A-D, B-D, C-D			96/92		100	
A-B, B-A, A-C, C-A, B-C, C-B			83/88/92		100	
D-A, D-B, D-C			75/96		100	
			BHC		CGM	
Experiment 2B (AB-D, ABC-D trained)						
A-D, B-D, C-D			100		92/92/100	
A-B, B-A, A-C, C-A, B-C, C-B			92/100		100/100	
D-A, D-B, D-C			100[b]		79/96	
			DGJ		CTB	
Experiment 3 (EFG-H trained)						
E-H, F-H, G-H			71/96/100		000/100/88/100	
E-F, F-E, E-G, G-E, F-G, G-F			71/88		100/100	
H-E, H-F, H-G			92		100	

[a] Numbers represent percentages of test trials consistent with the stimulus classes defined experimentally. Percentages are based on 40 (PNN) or 16 trials that were accumulated across four sessions (DGJ) or within one session (BHC, MRC, CTB, and CGM). A solidus separates percentages for repetitions of particular tests. All scores are percentages based on 24 trials except where otherwise indicated.

[b] Based on 12 trials.

man, 1986, 1990; Sidman & Tailby, 1982 for detailed discussions of the properties of equivalence classes; cf. Stromer, McIlvane, & Serna, 1993).

EXPERIMENT 2B

Experiment 2B examined the effects of another method of adding new stimuli to the network. Novel C elements were added to the familiar AB samples. Would training with ABC-D trials add the new C elements to the previously established classes? Positive results would replicate prior data with normally capable adults (cf. Stromer & Stromer, 1990a, 1990b). However, negative outcomes might be predicted on the basis of studies examining "associative competition" between stimuli (e.g., Williams, 1984). For example, it is possible that the stimulus control already exerted by the A and B elements might "block" the development of control by the C stimuli (e.g., Kamin, 1969; Koegel & Schreibman, 1974; Mackintosh, 1974).

Method

Subjects and Apparatus

Subjects BHC and CGM from Experiment 1B continued using the same apparatus.

Procedure

Train AB-D and ABC-D Matching. First, the AB-D trials (Figure 2, top) were reviewed in one session to ensure accuracy was 90% or better. Subjects were then taught ABC-D matching (Figure 2, middle) by trial and error: Selections of D1 and D2 were reinforced in the presence of A1B1C1 and A2B2C2, respectively.

Testing. Test conditions were as in Experiment 2A. Test 1 included trials retesting the A-D and B-D performances, and two C-D trials that examined whether C1 and C2, appearing alone for the first time, would control selections of D1 and D2, respectively. Test 2 assessed A-B, B-A, A-C, C-A, B-C, and C-B matching; and Test 3 assessed D-A, D-B, and D-C matching.

Results and Discussion

Table I shows the percentages of selections that were consistent with classes defined experimentally. The table shows that BHC's selections were usually consistent with the defined classes. For CGM the same performances developed more gradually. These results suggest that the network of performances established with AB-D matching could be expanded by adding novel C elements to the original AB samples (ABC-D matching). The high accuracy of the test results suggest that the C elements exercised control just like the A, B, and D stimuli in prior Experiments 1A and 1B. Subjects' data suggest that the three-member classes established in Experiment 1B now had four members each (A1B1C1D1 and A2B2C2D2).

Prior training and testing histories of the A and B stimuli in Experiment 1B apparently had no negative effect on the development of stimulus control by the novel C elements; this finding contrasts from what might be predicted from the literature on blocking. For example, the performances of both subjects showed that the new stimuli immediately functioned in accordance with the experimenter-defined stimulus class membership; each was effective as a sample and as a comparison stimulus.

EXPERIMENT 3

Experiment 3 assessed whether the kinds of performances shown in Experiment 2A would occur if the sample complexes used at the start of training were made up of three elements rather than two. Previous work with PNN had shown that each of three elements of two complex stimuli may come to exert discriminative control consistent with training (Touchette & Maguire, 1986; and see Dube et al., 1990, for an example with two four-element stimuli). Experiment 3 asked whether training with such sample complexes sufficed to establish stimulus classes comprised of the elements and their respective comparison stimuli (E1F1G1H1 and E2F2G2H2).

Subjects and Apparatus

Subjects DGJ and CTB from Experiment 1B continued using the same apparatus.

Procedure

Train EFG-H Matching. The baseline task was like that in Experiment 2A (ABC-D matching; Figure 2, middle), except that all new stimuli were used from the beginning of training. The task is denoted EFG-H matching: If E1F1G1, selections of comparison H1 were reinforced; if E2F2G2, selections of H2 were reinforced. Delayed-cue training was conducted as in Experiment 1B.

Testing. Test conditions were the same as Experiment 2A. Test 1 assessed E-H, F-H, and G-H matching performances; Test 2 assessed E-F, F-E, E-G, G-E, F-G, and G-F matching; and Test 3 assessed H-E, H-F, and H-G matching.

Results and Discussion

Table I shows that test performances were eventually class consistent for both subjects. These data suggest that training established two four-member stimulus classes.

GENERAL DISCUSSION

The arbitrary matching-to-sample performances of young adults with autism and young children without intellectual handicaps were examined using complex sample stimuli. Results for all individuals showed that each of two redundant relevant sample elements, and their respective comparison stimuli, were substitutable for one another in matching to sample (Experiments 1A and 1B). These data suggest the formation of stimulus classes; further training and testing then verified and expanded the classes (a) by establishing relations among novel sample stimuli and familiar comparison stimuli in a separate training phase (Experiment 2A); and (b) by adding a third stimulus element to each of the two-element samples used during the original training (Experiment 2B). Another training method that yielded classes of four stimuli directly used original baselines of three-element rather than two-element sample stimuli (Experiment 3).

The results extend prior analyses of the matching of redundant relevant stimulus elements with college students (Stromer & Stromer, 1990a, 1990b, 1992) and children (Schenk, 1993). Besides using different subjects, the present study also differed from those by Stromer and Stromer because the complex samples were entirely visual. Stromer and Stromer used tone and color elements to form complex samples. The data for some college students suggested that control by colors overshadowed control by tones thus preventing the formation of stimulus classes. The class formation shown by the present subjects may be attributable, in part, to the use of visual forms as elements. Although there was no evidence of "associative competition" (Williams, 1984) in the present study, a profitable area of future research would be to explore the effects of such stimulus variables on attentional processes in matching to sample (cf. Koegel & Schreibman, 1974; Singh & Solman, 1990).

Further research should explore the effects of using complex stimuli in different procedural arrangements. For example, Schenk (1993) asked whether children would learn to match different colors and Greek letters that were elements of complex stimuli used in identity-matching tasks. Each sample and its corresponding comparison were two-element stimuli, the letters lambda and pi on red and green backgrounds, respectively. After learning to match these complexes to one another, tests showed that the children matched the colors and letters to one another (if red, select lambda; if green, select pi; if lambda, select red; and if pi, select green). In view of these data, it seems possible that the identity matching given as pretraining in Experiment 1B may have sufficed to produce the desired outcome performances in some of our subjects, perhaps the young children. Nevertheless, for individuals with developmental limitations there may be advantages favoring the use of an arbitrary matching baseline for studying stimulus classes. Such a baseline would ensure that the tasks used in training and testing have the same stimulus control basis. This consistency may circumvent the potential difficulties that occur if, during assessment, arbitrary matching test trials are mixed among identity matching baseline trials.

The results also contribute to the comparatively little research using matching-to-sample methods to examine restricted stimulus control and other attentional processes in individuals with developmental delays (Litrownik et al., 1978; Mackie & Mackay, 1982; Schneider & Salzberg, 1982; Stromer, McIlvane, Dube, & Mackay, 1993; Ullman, 1974; Whiteley, Zaparniuk, & Asmundson, 1987). Further study of matching procedures is justified because of their parallels to classroom teaching methods. As one example, we note the similarities between total communication methods (e.g., Clarke et al., 1986; Wulz & Hollis, 1979) and the two-element sample procedure used here and elsewhere (Stromer & Stromer, 1990a, 1990b, 1992). As a recipient of total communication training, the student who has learned to attend to multiple elements of complex stimuli may have a distinct advantage: Broad attending skills seem to permit more efficient expansion of existing repertoires than is likely if each performance must be taught directly (cf. Etzel & LeBlanc, 1979; Stromer, 1991).

The studies described here used arbitrary stimuli with which the subjects had no experience because the emphasis was on experimental control and basic discriminative processes rather than on direct functional usefulness. However, the outcomes obtained in related studies of the formation of stimulus classes suggest that the same results would be obtained using functional stimuli like pictures, printed words, Bliss symbols, manual signs, quantities and numerals (e.g., see reviews by Mackay, 1991; McIlvane, 1992; Stromer, 1991).

Other interesting possibilities for research and application are suggested by studies involving the kinds of social stimuli with which autistic individuals may have special difficulty. For example, Schreibman and Lovaas (1973) analyzed the restricted, idiosyncratic stimulus control shown by children with autism in identifying male and female dolls. Their methods resembled the two-choice conditional discrimination procedure of the present study. Perhaps training programs based on the present methods would help to remediate the children's deficits by encouraging broader control by multiple elements from the same classes of social stimuli (e.g., male/female features).

Stimulus class concepts and methods might be relevant to other aspects of the development and analysis of social behavior in persons with developmental limitations. For example, Silverman, Anderson, Mashall, and Baer's (1986) study suggests an important role for social stimuli and class formation in the development and generalization of language behavior. Another set of social variables is implicated in the research reported by MacDonald et al. (1986); these investigators demonstrated the potential of observational learning methods in establishing classes of equivalent stimuli in individuals with mental retardation.

The potential for expanding existing repertoires is readily apparent when teaching methods that use complex stimuli are analyzed in the context of a stimulus class network (Mackay, 1991; Stromer, 1991). As discussed more thoroughly elsewhere, advances in our understanding of stimulus class phenomena have begun to contribute to the development of technologies for teaching generative behaviors (e.g., Mackay, 1991; McIlvane, 1992; Sidman, 1990; Spradlin & Saunders, 1984; Stromer, 1991; Stromer et al., 1992). The point to be reinforced here is that broad attending skills may enable the emergence of large networks of adaptive behaviors, only a few of which require direct training. Studies thus far suggest that explicit use of the methods involved in establishing stimulus class networks translates into highly cost-effective teaching.

The present study suggests that some students with developmental limitations may be immediate candidates for such teaching. We should mention, however, that the two participants with autism in this study did not show the persistent problems of restricted stimulus control that others probably would under the present experimental conditions. This may simply reflect the typical variability among such individuals. For example, recall that in an assessment prior to this study, PNN was among a minority of students whose performance suggested broad rather than restricted stimulus control (Touchette & Maguire, 1986). That training may have contributed to the positive outcomes shown by PNN in the present study.

Students who lack such broad attending skills should be candidates for direct teaching of these skills. Attention is at least as much a learnable skill as it is an inherent capacity of the individual (cf. Allen & Fuqua, 1985; Bickel, Stella, & Etzel, 1984; Burke, 1991; Burke & Cerniglia, 190; Ray, 1969; Schreibman, Charlop, & Koegel, 1982). The development of programs for improving observing skills thus is a crucial endeavor and the outcomes demonstrated in the present study only highlight critical instructional needs. Without training, restricted stimulus control that is evident in the performances of many students will only continue. This limitation can only prevent the formation of stimulus classes that could derive from exposure to contingencies involving complex stimuli. The present study strengthens the argument for treating narrow or restricted attention as an important intervention target (cf. Burke, 1991). A benefit of developing methods that ensure the development of control by redundant but relevant aspects of complex stimuli may be the formation of stimulus classes that engender flexible repertoires of adaptive behavior.

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