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LEARNING-SET OUTCOME IN SECOND-ORDER CONDITIONAL DISCRIMINATIONS

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This study was designed to determine whether the acquisition of second-order conditional discriminations becomes more rapid across new discriminations. Three normal grade-school children served as subjects. In general, performances improved across sets of second-order discriminations. Moreover, there was little disruption of performance when the second-order stimuli were changed from discrete forms to being compounded with the sample stimuli. Errors increased markedly when the second-order conditional discrimination shifted from one in which one second-order conditional stimulus indicated that the original contingencies were reversed to a condition in which one second-order conditional stimulus indicated that the subject should select the same comparison stimulus regardless of which sample form was present. Errors prior to mastery decreased, however, across problems of the new type—thus reproducing the learning—set outcome with new stimuli.

Harlow (1949) reported that monkeys' performances on two-choice simple discrimination problems improved markedly across new problems. In his classic study, food-deprived monkeys were trained to raise one of two objects to find a food item placed below one of the objects. After a number of training trials, the monkeys raised the object covering the food. When this occurred, another pair of objects was presented for discrimination. The procedure was repeated with several hundred different pairs of objects. After about 200 problems had been taught, the monkeys consistently selected the correct object after only one trial. In the

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final performance, when the selection of an object was reinforced, that same object was selected on the next trial. When an object selection was not reinforced, the other stimulus was selected on the next trial. This occurred regardless of the particular objects involved. Since Harlow's classic study, many studies have demonstrated a similar "learning set" outcome with human subjects and with a variety of stimuli (see Kaufman & Prehm, 1966).

Routh and Wischner (1970) demonstrated conditional discrimination learning-set with normal children between 7 and 11 years. of age. Each problem in their procedure involved presenting two objects on a black or white background. The color of the background determined which of the two objects was deemed correct. That is, black and white were the two conditional stimuli (sample stimuli) across all problems. Each problem was presented for only six trials and then two different comparison objects were presented. They continued to present new problems until the children were correct on at least five of the six trials for six new problems. Most of the children showed improved accuracy over successive new problems and met the criterion. Note that, in this procedure, the comparison stimuli changed across discrimination problems, but the conditional stimuli were always the same.

Saunders and Spradlin (1990, 1993) also reported a learning-set outcome in conditional discrimination training. In these studies, participants with mental retardation learned arbitrary matching-to-sample problems with a programmed instructional procedure. In this arbitrary matching procedure, two comparison (choice) stimuli were presented on each trial. The comparison stimulus that was correct depended on the sample stimulus that was presented on a given trial. With each new problem, both the samples (conditional stimuli) and the comparison stimuli changed with each new conditional discrimination. On successive new problems, fewer components of the teaching program were necessary for acquisition. Eventually, subjects who initially had been unable to learn through trial-and-error training were able to do so.

In the present study, we asked whether the learning-set outcome observed with first-order conditional discriminations could also occur with second-order conditional discriminations (see Sidman, 1986, for a detailed description of the first- and second-order conditional discrimination procedures). Our second-order conditional discrimination procedure included two contextual stimuli, two samples, and two comparisons. Comparison selection depended upon the contextual stimulus and the sample presented in a trial. With two contextual stimuli and two samples, there were four combinations of contextual stimuli and samples. A similar arrangement has been used in a number of studies on contextual control (e.g., Bush, Sidman, & de Rose, 1989; Lynch & Green, 1991).

Bush et al. (1989) presented a practical example of a second-order conditional discrimination. The two contextual stimuli are the words DISCIPLINE and NATIONALITY; the sample stimuli are the words CERVANTES and POLLOCK; and the comparisons are the words TWAIN

and PICASSO. For example, if the contextual stimulus DISCIPLINE is presented with the sample CERVANTES, then TWAIN is the correct choice. If the contextual stimulus NATIONALITY is presented with the sample CERVANTES then PICASSO is the correct choice. We will refer to this arrangement as a regular structure, in order to emphasize that the same type of arrangement can occur with different sets of stimuli.

As with simple and conditional discriminations, a learning-set outcome in second-order conditional discriminations would be demonstrated if acquisition of second-order conditional discriminations became more rapid with successive new problems. Thus, we taught a number of problems to determine whether, in general, subjects began making fewer errors as more problems were learned. Two additional conditions were added to strengthen the demonstration. In one condition, we asked whether a learning-set outcome would occur when the contextual stimuli and sample were combined into a single compound stimulus (which we will call a contextual/sample stimulus compound). In a second condition, we asked whether a change in the structure, from the regular structure described above, to one in which the sample was irrelevant in the presence of one of the contextual stimuli (which we will call an irregular structure), would result in an increase in errors during acquisition. Such a change would be expected to increase errors because the rapid acquisition that defines learning set is presumably specific to a particular structure. In the example given above, in which the sample stimuli are CERVANTES and POLLOCK and the comparisons are TWAIN and PICASSO, when the contextual stimulus is DISCIPLINE, the correct response depends on the sample stimulus that is presented. When the contextual stimulus is SELECT WRITER, the sample stimulus is irrelevant—the correct comparison is TWAIN, regardless of the sample that is presented.

Method

Participants

Three normally capable children recruited from a day care center participated (Kay, girl, 9 years old; Eli, boy, 11 years old; and Mel, girl, 10 years old).

Apparatus

The experiment was carried out in a quiet room. A MS DOS computer presented the stimuli and recorded the responses. Participants responded on a standard IBM keyboard. The stimuli were light gray nonsense figures, approximately 2 cm on their longest side, presented on a black screen. Figure 1 shows the specific sets of stimuli used, their letter number designations, and whether they appeared as contextual stimuli (X1 or X2), samples (S1 or S2), or comparisons (C1 or C2).

Stimulus set	Contextual Stimuli		Samples		Comparisons	
1	 X1	 X2	 S1	 S2	 C1	 C2
2	 X1	 X2	 S1	 S2	 C1	 C2
3	 X1	 X2	 S1	 S2	 C1	 C2
4	 X1	 X2	 S1	 S2	 C1	 C2
5	 X1/S1  X1/S2	 X2/S1  X2/S2	 S1  S2		 C1  C2	
6	 X1/S1  X1/S2	 X2/S1  X2/S2	 S1  S2		 C1  C2	

Figure 1a. The contextual stimuli (X1 and X2), samples (S1 and S2), and comparisons (C1 and C2) for each of the 11 stimulus sets used. In stimulus sets with a contextual stimulus/sample compound (Sets 5 - 10), samples do not appear as separate stimuli in the second order conditional discrimination.

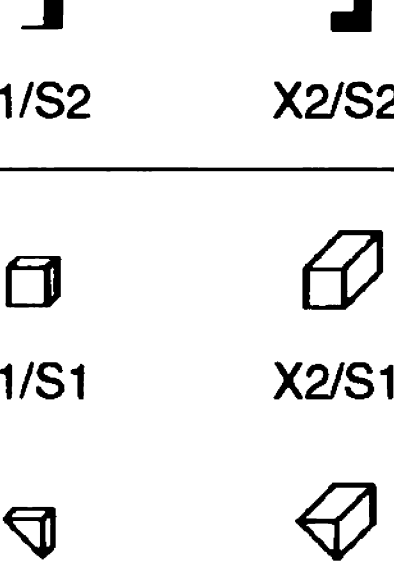
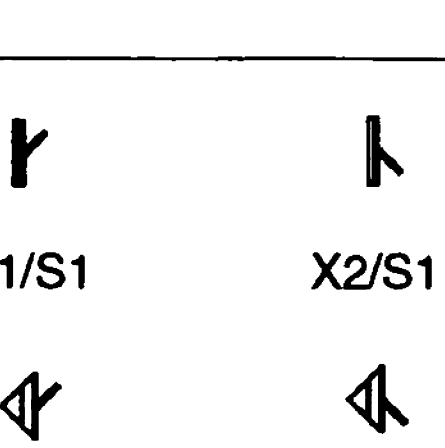
Relations	Contextual Stimuli	Samples	Comparisons
7	 X1/S1 X2/S1 X1/S2 X2/S2	S1 S2	C1 C2
8	 X1/S1 X2/S1 X1/S2 X2/S2	S1 S2	C1 C2
9	 X1/S1 X2/S1 X1/S2 X2/S2	S1 S2	C1 C2
10	 X1/S1 X2/S1 X1/S2 X2/S2	S1 S2	C1 C2
11	 X1 X2	S1 S2	C1 C2

Figure 1b. (See caption on preceding page).

Procedure

Overview. For two participants, Kay and Eli, the first six second-order conditional discriminations were trained with the regular structure. The first four of these had an independent contextual stimulus, and the final two had a contextual/sample stimulus compound. The next five second-order conditional discriminations had the irregular structure. For the third participant, Mel, the first six second-order conditional discriminations had the irregular structure. After these six discriminations were trained, an attempt was made to train a second-order conditional discrimination with the regular structure. That attempt was unsuccessful, so Mel's participation was discontinued.

For each stimulus set, the first-order conditional discriminations were trained first, to a criterion of 24 consecutive correct responses. Then the first-order conditional discrimination became a part of a second-order conditional discrimination, which was presented until the participant achieved 24 consecutive correct responses. Upon meeting this criterion, the computer program advanced to the next stimulus set.

In the first-order conditional discrimination training, one sample and two comparisons were presented in each trial, as shown in the top panel of Figure 2. Selections of one comparison in the presence of one sample and selections of the other comparison in the presence of the other sample were reinforced. When criterion was met, a contextual stimulus was added (to form a second-order conditional discrimination), as shown for the regular structure in the second panel of Figure 2. For the second-order conditional discrimination, either separate shapes functioned as the contextual stimuli (Set 2, Figure 2) or two different values of a dimension of the sample functioned as the contextual stimuli (Set 5, Figure 2). The two comparisons (C1 and C2) were the same as in the previous first-order conditional discrimination. The comparison reinforced in the presence of each sample varied according to two contextual stimuli.

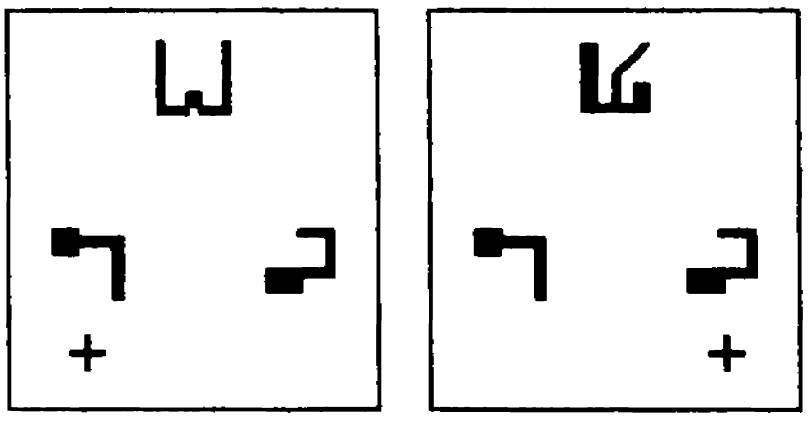
As noted, each of the two types of structures—regular and irregular—were presented in two variations (i.e., different types of contextual stimuli).

Regular structure. The regular structure with a separate shape as the contextual stimulus is shown for Set 2 in the first two panels of Figure 2. The samples (S1 and S2) and the comparisons (C1 and C2) were the same as in the first-order conditional discrimination. The contextual stimuli, X1 and X2, alternated randomly across trials. In the presence of one contextual stimulus (X1), the comparison selection reinforced in the presence of each sample was the same as in the first-order conditional discrimination (in the presence of X1 and S1, selection of C1 was reinforced, in the presence of X1 and S2, selection of C2 was reinforced). In the presence of the other contextual stimulus (X2), the correct comparison was the opposite (in the presence of X2 and S1, selection of C2 was reinforced, in the presence of X2 and S2, selection of C1 was reinforced).

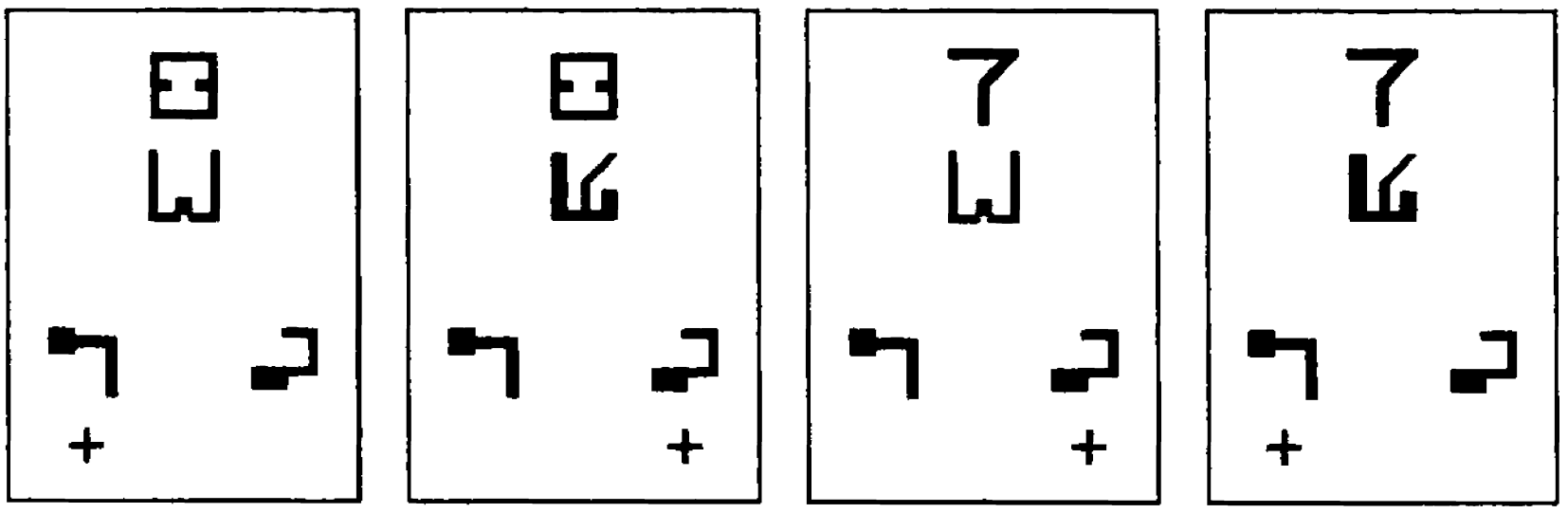
In the variation of the regular structure, with a "contextual/sample stimulus compound," dimensions of the sample served as contextual stimuli. The nature of the contextual control was the same as in the

Regular Structures

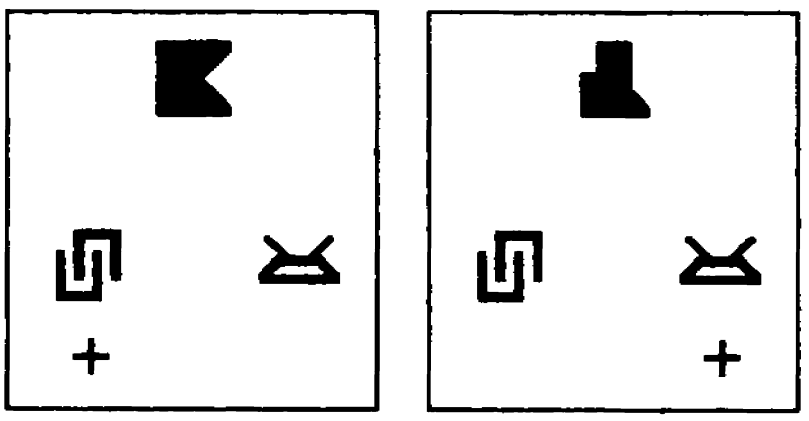
Set 2, First Order



Set 2, Second Order



Set 5, First Order



Set 5, Second order

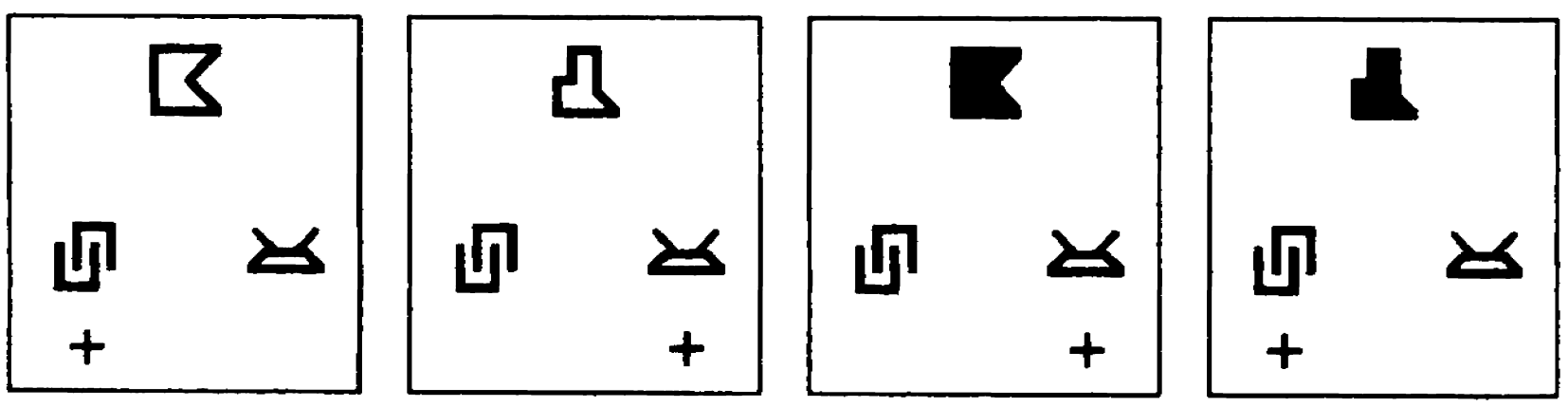


Figure 2. For the regular structure: example trial configurations for first- and second-order conditional discriminations. The top two panels show an example with a separate shape as the contextual stimulus, and the bottom two panels show an example with a contextual stimulus/sample compound.

regular structure with shapes as contextual stimuli. An example is shown in the bottom two panels of Figure 2 (Set 5). For the first-order conditional discrimination, two gray shapes (S1 and S2) were the samples; the comparisons were C1 and C2. In the second-order discrimination (Set 5) the same shapes were presented as samples, but they were filled either on white or black. If the sample was filled on black, the same contingencies were in effect as in the first-order conditional discrimination (i.e., when the samples were gray). That is, in the presence of a black X1S1, selections of C1 were reinforced; in the presence of a black X1S2, selections of C2 were reinforced. If the samples were figures filled on white (X2S1), the contingencies for comparison selection were reversed. That is, in the presence of a white X2S1, selection of C2 was reinforced; in the presence of a white X2S2, then selection of C1 was reinforced.

In addition to Set 5, Sets 6 through 10 had contextual/sample stimulus compounds. These stimuli are shown in Figure 1. For Set 6, the compound stimulus was either larger or smaller than the sample in the initial first-order discrimination. For Set 7, a thick line was added to either the top or the bottom of the sample. For Set 8, the compound was either larger or smaller than the initial sample. For Set 9, a dot was added to either the left or the right of the shape. For Set 10, a line of the shape was either +45 or -45 degrees from the horizontal.

Irregular structure. The first type of irregular structure had shapes as contextual stimuli (top two panels of Figure 3). In contrast to the regular structure, however, the subject had to learn that, when one of the two contextual stimuli was presented, the sample was irrelevant. That is, like in the regular structure, in the presence of one of the contextual stimuli (e.g., X1), the correct comparison was the same as in the first-order conditional discrimination (e.g., in the presence of X1 and S1, selections of C1 were reinforced, in the presence of X2 and S2, selections of C2 were reinforced). However, in the presence of the other contextual stimulus (X2), selections of the same comparison (C2) were reinforced, regardless of which shape occurred as the sample stimulus.

In the irregular structure with the contextual/sample stimulus compound, dimensions of the sample stimulus served as contextual stimuli (bottom two panels of Figure 3). As shown in the bottom panel of Figure 1, when the shapes were filled on black, selections of C1 in the presence of S1 were reinforced and selections of C2 in the presence of S2 were reinforced. When the shapes were filled on white, selections of C2 were reinforced regardless of which sample shape was presented.

Sessions. Sessions lasting 25 minutes were conducted 3 to 5 days per week. Usually only one session was conducted per day. After 25 minutes, the experimenter asked the child if he/she would like to continue. If he/she agreed, another 25-minute session was conducted. After the first session, sessions started at the point of interruption in the previous session. All criterion trials had to occur in a single session.

Trial operation. All of the stimuli were presented simultaneously (the participants did not have to respond to the samples to produce the

Irregular Structures

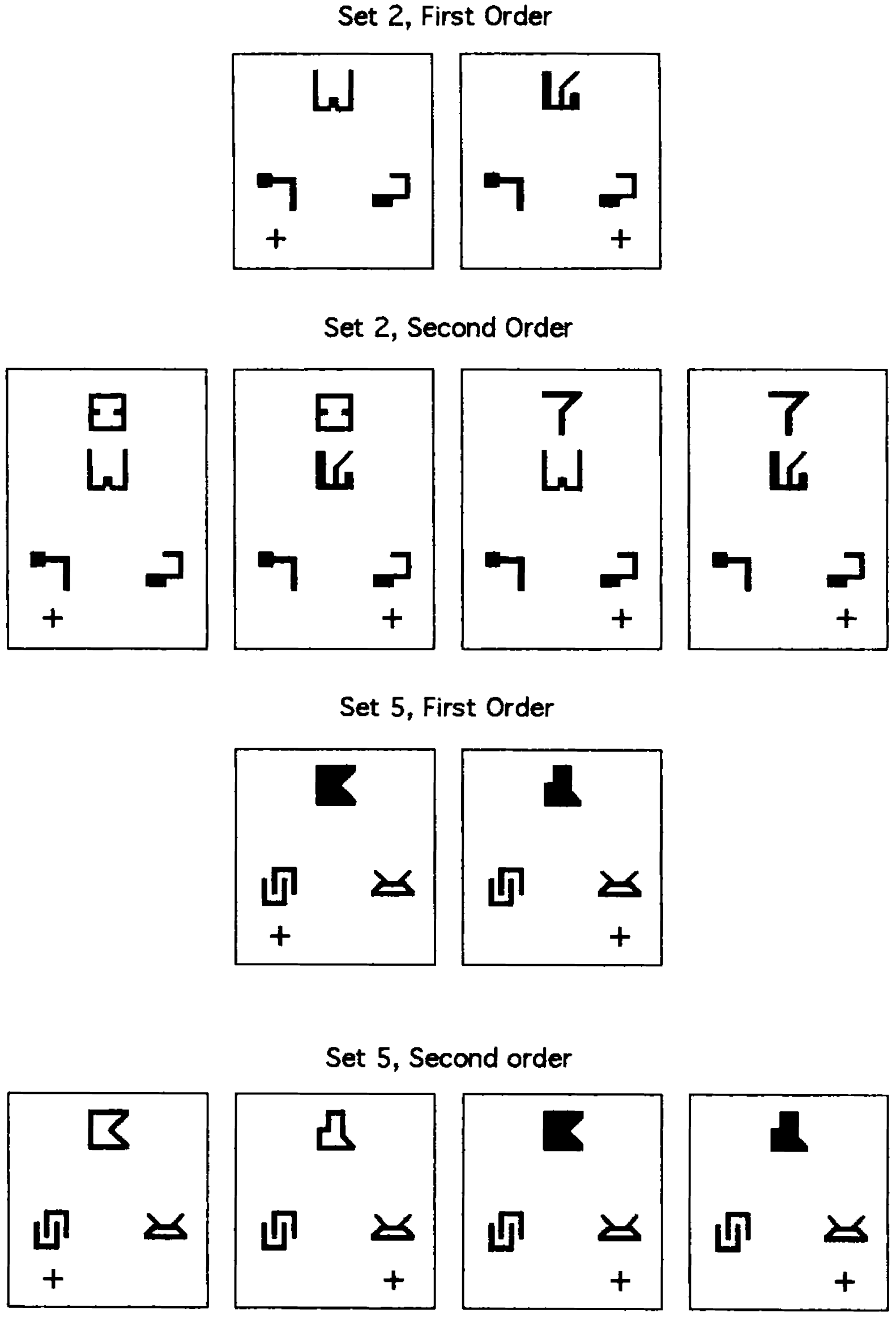


Figure 3. For the irregular structure: example trial configurations for first- and second-order conditional discriminations. The top two panels show an example with a separate shape as the contextual stimulus, and the bottom two panels show an example with a contextual stimulus/sample compound.

comparison stimuli). As shown in Figure 2, the sample shape appeared above the two comparison stimuli. When there was an independent contextual stimulus (second panel), it was displayed above the sample. The two comparisons appeared below the sample, from left to right. The position of each comparison varied randomly over trials. Each of the four possible combinations of contextual stimuli and samples was presented, in random order, in each block of four trials.

When the stimuli were displayed, the symbol "L" appeared in the bottom left-hand corner of the screen. Participants selected a comparison stimulus by pressing either the "b" key, which moved "L" to a position below the left comparison, or the "n" key, which moved "L" to a position below the right comparison. Additional presses to the "b" or "n" keys moved "L" below the other comparison. The participant recorded his/her comparison selection by pressing the "h" key, which resulted in "L" moving upward towards the comparison, the delivery of the consequence programmed for that trial, and a 2-s intertrial interval which was followed by the next trial. Correct responses produced a sequence of four musical notes. Incorrect responses produced a low tone.

Instructions. At the beginning of the first session, the participant was seated in front of the computer, and the following instructions appeared on the screen:

> Welcome! Some shapes are going to appear on the screen. One or two will be in the center, and others will be on the bottom. You have to pick from the shapes displayed on the bottom. To pick a shape, first move L by pressing the "b" and "n" keys. Then press the "h" key to pick a shape. When you are correct, some music will play. When you are wrong, a tone will sound. You will earn a penny for each two times you are correct. (Press the space bar when you want to start.)

If the participant asked which picture to select, he/she was told that he/she would learn this very easily. Only questions strictly related to the instructions were answered. During the first session, the experimenter was seated beside the participant. After every correct response, he said "Good!" After two correct responses, he put a penny in a box close to the participant. Before the second session, the participant was told that the computer was going to keep track of the number of correct responses and how much money he/she earned. Then, the experimenter left the room for the remainder of the experiment. After each session, the participant received the money, which could be used to buy snack items in the "store."

Results

Table 1 shows the number of errors made prior to meeting the criterion of 24 consecutive correct trials for each first- and second-order conditional discrimination.

Participant Kay

Across all first-order conditional discriminations, the number of errors made by Participant Kay ranged from zero to four. In the second-order conditional discriminations, she made six errors in the first discrimination; then the errors reduced to three or fewer for the next five stimulus sets. Changing to a different type of contextual stimulus (Sets 5 and 6, with contextual/sample stimulus compounds) did not change performance. Kay made few errors in the fifth and sixth second-order discriminations.

When the condition was changed to the irregular structure (beginning with Set 7), the number of errors made on the second-order discriminations increased to 19, then decreased to 4, 10, 6, and 8 on subsequent discriminations.

Participant Eli

In the regular structure condition, Participant Eli made eight errors in the first first-order conditional discrimination, and three or fewer errors in the next five conditional discriminations. In the second-order conditional discriminations, he made 11 and 15 errors respectively in the first two conditional discriminations. Errors stabilized at four or fewer for the remaining second-order discriminations with the regular structure. In the irregular structure condition, his errors on the first-order conditional discrimination remained low for the next two discriminations and then increased to 11 and 5 respectively for the Set 9 and Set 10 discriminations (perhaps because of the irregular structure, which included an irrelevant sample stimulus, in Sets 7 and 8). In the first second-order conditional discrimination with the irregular structure, errors increased to 20 then decreased to 0, 8, 4, and 8 errors.

Participant Mel

Mel started with the irregular structure condition. She made 60 errors during the first first-order discrimination, and 80 in the second (although

Table 1

Number of Errors to Reach Criterion for First- and Second-Order Discriminations

	Regular Structure				Irregular Structure	
	Kay		Eli		Mel	
Stimulus Sets	1st order	2nd order	1st order	2nd order	1st order	2nd order
1	0	6	8	11	60	126
2	1	3	3	15	80	26
3	0	3	0	1	3	10
4	1	3	0	4	1	3
5	1	3	0	2	2	8
6	3	2	0	1	5	4
	Irregular Structure				Regular Structure	
7	4	19	2	20	25	112
8	4	4	2	0		
9	2	10	11	8		
10	0	6	5	4		
11	0	8	2	8		

the first order training was the same regardless of the type of second-order structure). No more than five errors were made on the next four first-order discriminations. Mel made 126 errors in the first second-order conditional discrimination, and errors decreased markedly across stimulus sets.

When Mel began the regular structure condition, however, errors increased dramatically. She made 112 errors in two sessions and her participation was discontinued at that point.

Discussion

All 3 subjects showed a learning-set outcome in the acquisition of second-order conditional discriminations. The number of errors made across successive discriminations decreased regardless of which type of structure the participant learned first (regular or irregular). Moreover, the number of errors remained low even when the form of the contextual stimulus was changed from an independent stimulus to a compound stimulus. For all 3 participants, errors increased markedly when the structure type was changed (either from the regular structure to the irregular structure or vice versa).

Additional evidence of a learning-set outcome comes from data suggesting that training on one structure did not transfer to the other structure. That is, errors increased with the change in structure, regardless of whether the change was from regular to irregular (Kay and Eli), or vice versa (Mel). This finding is consistent with the notion that the rapid acquisition that defines learning set is specific to a particular structure. That is, put loosely, the participant learns that a particular pattern applies to many different sets of stimuli. Once the general pattern (i.e., structure) is learned, it needn't be relearned with each new stimulus set, and thus errors decrease with experience.

Finally, the 2 participants who were exposed to a number of stimulus sets after the structure was changed allowed a within-subject replication of the learning-set outcome (with the new type of structure). Errors were much higher in the first set with the irregular structure (Set 7), than in subsequent sets. Thus, a learning-set outcome has been shown across more than one set of stimuli and more than one type of structure.

The learning-set outcome in second-order conditional discriminations requires an analysis parallel to the analysis of the learning set in first-order conditional discriminations (see Saunders & Spradlin, 1993). For a child to respond correctly to a new second-order discrimination, he/she would have to be exposed to the contingencies in the presence of one of the contextual stimuli for at least one trial. Given previous experience with a particular structure, exposure to one of the four trial types with a new set of stimuli could ultimately result in performance like that shown by Harlow (1949) with simple discrimination. That is, performance could be error free after as few as one trial of exposure to these relatively complicated second-order conditional discriminations. This is because some trials could be responded to by exclusion (McIlvane et al., 1987).

For example, given X1 and S2 as contextual stimulus and sample, respectively, the subject would select from C1 and C2. Selecting C1 and receiving feedback that this is an error might enable a subject with experience on the problem type to correctly select C1 on a subsequent trial with X1 and S1 as contextual stimulus and sample, respectively.

An implication of these findings is that brief assessments of specific learning abilities may be quite misleading. This is because relatively small differences in experience might make large differences in performance. For the present participants, more rapid acquisition was sometimes seen after mastery of only a few problems. In previous studies (e.g., Saunders & Spradlin, 1993), individuals with mental retardation who were initially unable to learn first-order conditional discriminations with trial-and-error teaching eventually learned these problems in a few trials. On this particular task, then, these individuals' terminal performance was indistinguishable from that of normal adults.

The findings also have implications for research that assesses the effects of drugs and other variables on learning. For example, matching-to-sample procedures are often used in studies of the cognitive effects of psychoactive drugs. Along with previous demonstrations of learning set in conditional discrimination, the present studies show that drug manipulations should not begin until a stable number of errors is being made. Otherwise, improvements in performance that result from experience might mask the effects of drugs.

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.

HARLOW, H. F. (1949). The formation of learning sets. *Psychological Review*, 56, 51-65.

KAUFMAN, M. E, & PREHM, H. J. (1966). A review of research on learning sets and transfer of training in mental defectives. In N. R. Ellis (Ed.), *International review of research in mental retardation* (Vol. 2, pp. 123-149). New York: Academic Press.

LYNCH, D. C., & GREEN, G. (1991). Development and crossmodal transfer of contextual control of emergent stimulus relations. *Journal of the Experimental Analysis of Behavior*, 56, 139-154.

MCILVANE, W. J., KLEDARAS, J. B., MUNSON, L. C., KING, K. A. J., DE ROSE, J. C., & STODDARD, L. T. (1987). Controlling relations in conditional discrimination and matching by exclusion. *Journal of the Experimental Analysis of Behavior*, 48, 187-208.

ROUTH, D. K., & WISCHNER, G. T. (1970). Effects of verbal pretraining and single-problem mastery on Weigl learning-set formation in children. *Developmental Psychology*, 2, 176-180.

SAUNDERS, K. J., & SPRADLIN, J. E. (1990). Conditional discrimination in mentally retarded adults: The development of generalized skills. *Journal of the Experimental Analysis of Behavior*, 54, 239-250.

SAUNDERS, K. J., & SPRADLIN, J. E. (1993). Conditional discrimination in mentally retarded adults: Programming acquisition and learning set. *Journal of the Experimental Analysis of Behavior*, 60, 571-585.

SIDMAN, M. (1986). Functional analysis of emergent verbal classes. In T. Thompson & M. D. Zeiler (Eds.), *Analysis and integration of behavioral units* (pp. 213-245). Hillsdale, NJ: Lawrence Erlbaum.