SOURCES OF STIMULUS CONTROL DURING MULTIPLE DISCRIMINATIONS¹

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Pigeons learned to respond to the middle-sized member of six or seven sets of three stimuli differing in size. The sets were used successively, each serving as the discrimination problem from 10 to 16 times. After attaining criterion with one set, the birds received the others as probes. The number of responses in probes was related to the similarity of the probes to the prevailing discrimination problem. The birds responded either to the probe stimulus to which responding had most recently been reinforced, or to the probe stimulus closest in size to the positive member (S+) of the prevailing discrimination problem. Responses to a middle-sized probe-set stimulus occurred when it was the probe-set member most recently correlated with reinforcement, when it was one of two stimuli closest in size to S+, and when the stimulus closest in size to S+ was a negative member of the discrimination problem. All of the behavior could be explained in terms of control by the absolute sizes of the various stimuli.

When differential responding persists despite changes in environmental stimuli, the new and the old stimuli may be said to have functionally equivalent effects on behavior. An experimental procedure for analyzing functional equivalence is the transposition design, a version of the method of equivalent stimuli (Klüver, 1933). The subject is first exposed to several simultaneously presented stimuli under conditions designed to produce responding confined to one, and is then confronted with new combinations of stimuli. Distinct preferences for one stimulus of each new combination means that stimuli of the new and original combinations are equivalent. The basis of the equivalence is revealed by which stimuli are preferred. If responses with each combination are to the stimulus most similar to the one controlling responding originally, the equivalence is due to physical similarity. If responses are to the same relationally defined member of each combination equivalence is the product of identical relations between stimuli. Unsystematic responding, or the absence of responding, indicates

that the change from the original to the new stimuli produced functionally nonequivalent situations.

Most experiments involving the transposition design measured equivalence by observing the stimulus chosen on one test trial or the stimulus chosen most often in a fixed number of trials with each test set. Recent research also studied preferences with each test set but supplemented this information with quantitative data to indicate the degree of functional equivalence between the training and the test stimuli (Honig, 1962; Zeiler, 1965; Zeiler and Price, 1965). The experimental procedure enabling the acquisition of this additional information was a variation of the Guttman and Kalish (1956) technique for studying stimulus generalization. Intermittent reinforcement in training and the presentation of each test set for a fixed period of time allowed the rate of responding to different stimuli to vary. A higher rate of responding to one stimulus of each combination than to the others indicated differential responding; the preferred stimulus, the one responded to at the highest rate, was the test-set member equivalent to the positive stimulus (S+) of the original set. The additional information provided by this procedure was the rate of responding to the preferred member of each test set relative to the rate of responding to S+. These data indicated how equivalent the stimuli were to each other.

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Zeiler (1965) and Zeiler and Price (1965) used the above procedure to study equivalence when pigeons learned to respond to one of three stimuli differing in size. Differential responding persisted in the tests and was always to the stimulus closest in size to S+. The rate of responding to the preferred member of each set was related directly to how similar that stimulus was to S+. Since the similarity of the training to the test stimuli determined both preferences and response rate, the properties of individual stimuli completely controlled equivalence. Honig (1962) reported the same general findings in an experiment involving combinations of two stimuli differing in wavelength.

The present experiment further analyzed functional equivalence in pigeons. The joint implications of the research cited above were that absolute stimulus properties control the behavior of pigeons independent of the number of stimuli (two or three), the stimulus continuum (wavelength or size), the method of stimulus presentation (simultaneous or successive), the schedule of reinforcement in training (variable-interval or continuous reinforcement), and whether the procedure involves free-responding or discrete trials. Relational characteristics of stimuli seem to be ineffective. The experiments were identical, however, in using a single set of stimuli in training. When there is a single set and the same stimulus is always correct, reinforcement is correlated with both the particular absolute stimulus and the particular relation that the stimulus has to the others with which it appears. The data show, therefore, that confounding reinforcement for responding to one specific stimulus with responding to one specific relation produces control by absolute properties in pigeons. The present experiment was designed to determine whether the consistent correlation of a relation and inconsistent correlation of absolute stimuli with reinforcement would affect the basis of functional equivalence.

METHOD

Subjects

Four experimentally naive adult Carneaux pigeons were maintained at 80% of their free-feeding weights.

Apparatus

The 16 by 10.75 by 12-in. experimental chamber was the same one used in Zeiler's (1965) study except that there was no house-light. Three translucent 2.5-in. diameter response keys, with their centers 8.5 in. above the floor, were mounted 3.25 in. apart, center-to-center. A window centered on the wall opposite the response keys provided access to grain during a 6-sec magazine cycle and was illuminated when grain was available. Relay circuitry, digital counters, and a cumulative response recorder located in an adjoining room controlled and recorded all experimental procedures. White noise in the chamber masked extraneous sounds.

A digital display unit behind each key projected a white disk, in 10 different diameters, on a black background. Each succeeding disk increased in area by a factor of 1.4:1; Stimulus 1 was 0.375-in. and Stimulus 10 was 1.71-in. in diameter. Tables 1 and 2 show the combinations of stimuli given each bird. The large and small stimulus of each combination given to Birds 4 and 6 differed in area from the middle-sized stimulus by a factor of 2.0:1; the large and small stimulus of each combination given to Birds 7 and 8 differed from the middle-sized stimulus by a factor of 1.4:1. Every combination was a discrimination problem and was also a probe with all other problems. The quantitative relation between problems and probes is specified by the area factor separating the relationally corresponding members of the combinations.

Procedure

Discrimination problems. Bird 4 had each set as the discrimination problem 12 times, Bird 6 had each 16 times, and Birds 7 and 8 had each 10 times. Tables 1 and 2 show the sequence of problems for each bird. Problems were changed on the session following the probes (see below).

The three stimuli appeared simultaneously with the positions of the stimuli changed after each reinforcement. The keys were dark during reinforcements. Responses to the middle-sized stimulus were reinforced irregularly according to either a variable-interval schedule with a mean of 1 min between reinforcements, or a variable-ratio schedule requiring an average of either 15, 30, or 60 responses to the

Table 1
Stimulus Combinations for Birds 4 and 6

<i>Problem Number</i>		<i>Stimuli^a</i>	<i>Probe Sets</i>				
<i>Bird 4</i>	<i>Bird 6</i>		<i>1.4:1</i>	<i>2.0:1</i>	<i>2.7:1</i>	<i>3.8:1</i>	<i>5.4:1</i>
5, 11, 17, 23, 29, 35, 41, 47, 53, 59, 65, 71	3, 7, 14, 19, 25, 34, 41, 44, 49, 59, 63, 67, 78, 84, 87, 93	1-3-5	2-4-6	3-5-7	4-6-8	5-7-9	6-8-10
1, 7, 13, 19, 25, 31, 37, 43, 49, 55, 61, 67	1, 8, 17, 22, 26, 35, 37, 46, 52, 55, 66, 69, 73, 79, 86, 92	2-4-6	1-3-5 3-5-7	4-6-8	5-7-9	6-8-10	
2, 8, 14, 20, 26, 32, 38, 44, 50, 56, 62, 68	6, 11, 16, 23, 28, 31, 42, 47, 53, 57, 61, 72, 74, 80, 88, 94	3-5-7	2-4-6 4-6-8	1-3-5 5-7-9	6-8-10		
4, 10, 16, 22, 28, 34, 40, 46, 52, 58, 64, 70	5, 9, 13, 20, 30, 32, 40, 48, 51, 60, 65, 68, 77, 83, 90, 96	4-6-8	3-5-7 5-7-9	2-4-6 6-8-10	1-3-5		
6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72	4, 12, 15, 24, 29, 36, 39, 45, 54, 56, 62, 70, 75, 81, 89, 95	5-7-9	4-6-8 6-8-10	3-5-7	2-4-6	1-3-5	
3, 9, 15, 21, 27, 33, 39, 45, 51, 57, 63, 69	2, 10, 18, 21, 27, 33, 38, 43, 50, 58, 64, 71, 76, 82, 85, 91	6-8-10	5-7-9	4-6-8	3-5-7	2-4-6	1-3-5

^aItalics indicates S+.

correct stimulus per reinforcement. All birds began with the variable-interval schedule. The schedules were changed whenever necessary to maintain a balance between a substantial rate of responding and the number of reinforcements per session (40 to 50 when responding was confined to the positive stimulus). To prevent reinforcing a correct response immediately after an incorrect response, no correct response was reinforced within 3.5 sec of an incorrect response. A similar procedure minimized switching in a variety of situations involving the concurrent presentation of several stimuli (Catania, 1966).

A session consisted of 45, 1-min periods with stimuli on the keys separated by a 2-sec interval with the keys dark. The timer controlling the 1-min periods stopped during a reinforcement.

The criterion was two successive days of overall 95% correct responses to the middle-sized stimulus together with a minimum of 900 correct responses on each criterion day. The total number of responses on the two days had to differ by no more than 10%.

Discrimination problems plus probes. One day of exposure to all of the stimulus combinations followed the attainment of the criterion.

Table 2
Stimulus Combinations for Birds 7 and 8

Problem Number		Stimuli ^a	Probe Sets					
Bird 7	Bird 8		1.4:1	2.0:1	2.7:1	3.8:1	5.4:1	7.5:1
2, 14, 20, 24, 34, 38, 43, 52, 59, 66	6, 13, 20, 27, 34, 41, 48, 55, 62, 69	2-3-4	3-4-5	4-5-6	5-6-7	6-7-8	7-8-9	8-9-10
5, 11, 16, 27, 29, 36, 44, 54, 61, 68	7, 14, 21, 28, 35, 42, 49, 56, 63, 70	3-4-5	2-3-4 4-5-6	5-6-7	6-7-8	7-8-9	8-9-10	
4, 8, 19, 28, 32, 40, 47, 55, 62, 69	2, 9, 16, 23, 30, 37, 44, 51, 58, 65	4-5-6	3-4-5 5-6-7	2-3-4 6-7-8	7-8-9	8-9-10		
1, 12, 15, 22, 30, 39, 48, 51, 58, 65	1, 8, 15, 22, 29, 36, 43, 50, 57, 64	5-6-7	4-5-6 6-7-8	3-4-5 7-8-9	2-3-4 8-9-10			
7, 13, 18, 26, 35, 41, 45, 56, 63, 70	5, 12, 19, 26, 33, 40, 47, 54, 61, 68	6-7-8	5-6-7 7-8-9	4-5-6 8-9-10	3-4-5	2-3-4		
3, 9, 21, 25, 33, 37, 46, 50, 57, 64	4, 11, 18, 25, 32, 39, 46, 53, 60, 67	7-8-9	6-7-8 8-9-10	5-6-7	4-5-6	3-4-5	2-3-4	
6, 10, 17, 23, 31, 42, 49, 53, 60, 67	3, 10, 17, 24, 31, 38, 45, 52, 59, 66	8-9-10	7-8-9	6-7-8	5-6-7	4-5-6	3-4-5	2-3-4

^aItalics indicates S+.

The five or six stimulus combinations different from the current discrimination problem constituted the probes (Tables 1 and 2). A sequence of four 1-min intervals with the discrimination problem followed by a 1-min probe continued until each probe set appeared once. The spatial arrangements of the probe stimuli on the three keys varied from one probe to the next. In the discrimination intervals, reinforcements were programmed according to the schedule in force on the criterion days. No responses were reinforced during the probes.

RESULTS

Acquisition of Successive Problems

Figure 1 shows the number of days required to achieve two days of 95% responses to S+

in the successive discrimination problems. Except in a few instances the number of days shown in Fig. 1 was the same as that required to reach the criterion preceding the initiation of probes. The criterion for giving the probes required a substantial and stable response rate as well as accuracy. The reason for the rate specification was to ensure that the probes would be given while there was a high probability of responding to the discrimination problem. The relative distribution of responses to the various stimuli measured stimulus control independent of the rate of responding. The rates of responding varied considerably over the course of the experiment. The number of responses per session decreased after repeated exposures to the variable-interval schedule and increased with changes from variable-interval to variable-

Fig. 1. Number of days to second day of 95% responses to S+. The first two problems are shown separately; subsequent points are the means for blocks of seven or eight problems. The scales on the abscissas differ because Birds 7 and 8 had 70 problems, Bird 6 had 96, and Bird 4 had 72.

ratio. The schedules had no influence on the number of days required to attain 95% S+ responses; the effects were on the absolute number of responses rather than on the relative frequencies of responding to the various stimuli. Accurate discrimination took many more days with the first problem than with the second, but there was no subsequent decrease in days after the second problem. Except for the marked difference between the first problem and all others, these data did not reveal the progressive improvement in the learning of discriminations considered to be evidence of a discrimination learning set (Miles, 1965).

Responses in the Probes

First discrimination problem. The probes given with the first discrimination differed from subsequent probes in that the birds had not yet received any probe as a prior discrimination problem. The results for the first probes are shown in detail in Fig. 2. Birds 7 and 8 never had a probe containing two stimuli equally similar in size to S+. Birds 4 and 6 had probes 1-3-5 and 3-5-7, each different

Fig. 2. First discrimination problem. The number of responses to the probe stimulus closest in size to S+ (S^{Sim}) and the middle-sized probe stimulus (S^M) are shown relative to the mean number to S+ during training. The vertical line crossing each abscissa separates probes containing stimuli larger than those of the discrimination problem from probes containing stimuli smaller than those of the discrimination problem.

from the discrimination problem by the factor 1.4:1. These sets contained two stimuli (3 and 5) equally similar in size to S+ (Stimulus 4). All four birds had one or two probes containing S+ as the largest or smallest stimulus and one S- as the middle-sized stimulus (Birds 4 and 6: the 2.0:1 probe, set 4-6-8; Birds 7 and 8: the 1.4:1 probes, sets 4-5-6 and 6-7-8), and one or two probes containing an S- and two other stimuli (Birds 4 and 6: the 3.8:1 probe, set 6-8-10; Birds 7 and 8: the 2.0:1 probes, sets 3-4-5 and 7-8-9). The other probes given each bird contained neither the stimuli used in the discrimination problem nor two stimuli equally similar to S+.

Both the number of responses in the probes and the stimuli to which these responses occurred depended on the similarity of stimuli to those of the discrimination problem. The absolute number of responses to a probe set decreased with increasing differences in size between the probes and the discrimination problem. Although changes in the number of responses showed that S+ and the preferred probe stimuli were not always totally equivalent, the responses that did occur were de-

terminated by the similarity of stimuli to S+. In every probe, the birds responded most to the stimulus closest in size to S+. These preferences were independent of the difference between S+ and the probe stimulus most like S+, and whether or not the discrimination problem contained the probe stimuli. With the 1.4:1 probes, Birds 4 and 6 preferred different stimuli but both responded most to the same one of the two stimuli in each of the two sets. These findings completely replicated earlier results (Zeiler, 1965; Zeiler and Price, 1965) in showing that the similarity of stimuli to S+ controlled the responses.

All discrimination problems. Response frequencies averaged over all probes for all discrimination problems appear in Fig. 3. The averages were representative of the relative response frequencies for the individual days of probes. The orderly decrease in the relative number of responses with probes less similar to the stimuli of the discrimination problem that was observed in the first discrimination occurred in subsequent discriminations. Since the responses made with a probe were usually to one stimulus, differential responding occurred in the probes and the stimuli controlling responding were functionally equivalent to S+. The degree of equivalence, as measured by the rate of responding to the preferred probe stimulus compared with the

Fig. 3. Mean number of responses to each probe relative to the mean number of responses to S+ in the discrimination problems.

rate of responding to S+, varied depending on the similarity of the two stimuli to each other.

The discussion of the basis of equivalence requires distinguishing between the middle-sized member of a set used as a probe and the same stimulus when the set was the discrimination problem. The symbols S+ and S- refer to the positive and negative members of discrimination problems only. The symbol S^M refers to the middle-sized member of the probe sets. The symbol S^{Sim} refers to the probe-set member closest in size to S+.

Although the preferred stimulus of each probe in the first discrimination was the one most similar to S+, the repeated use of each set as a discrimination problem could have generated different preferences. If the birds learned either to respond to a particular stimulus only when it appeared in a certain set of three stimuli, that is, to treat each set as unrelated to the others, or to respond on the basis of the middle-size relation, they would eventually respond most frequently to S^M. The

Fig. 4. Percentage of preferences for the probe member closest in size to S+ (S^{Sim}) and the middle-sized probe member (S^M) for blocks of seven or eight discrimination problems. The totals for each block for Birds 4 and 6 add to more than 100% because preferences for the middle-sized stimulus of 1.4:1 probes counted in both categories. The abscissa scales vary as in Fig. 1.

S^M curve of Fig. 4 shows the percentage of probes in which the middle-sized stimulus received the most responses over successive blocks of problems. Such preferences ranged from 27% to 42% for Bird 4, 30% to 55% for Bird 6, 16% to 37% for Bird 7, and 13% to 35% for Bird 8, with no evidence for increasing frequency as training continued. Throughout the experiment the birds preferred the stimuli closest in size to $S+$ (S^{Sim} curves of Fig. 4) more frequently than the middle-sized stimuli.

Fig. 5. Frequency of preferences for the middle-sized probe stimulus (S^M) and the probe member closest in size to $S+$ (S^{Sim}). With 1.4:1 probes for Birds 4 and 6, two stimuli were equally similar to $S+$. Only preferences for the non-middle-sized stimulus are classified as S^{Sim} .

Preferences for S^M and S^{Sim} depended on the relation of the probes to the discrimination problem. Figure 5 plots the percentage of preferences for S^{Sim} and S^M as a function of the similarity of the probe stimuli to the current discrimination problem. When $S+$ was contained in the probe, it was always preferred (1.4:1 probes for Birds 7 and 8, 2.0:1 probes for Birds 4 and 6). All of the other probes produced preferences for both S^{Sim} and S^M . Two relations of probe sets resulted in the most

frequent preferences for the middle-sized stimulus. The first was the probe having two stimuli equally similar to $S+$ with one being the middle-sized stimulus (1.4:1 probes for Birds 4 and 6). The birds almost always responded to the same absolute stimulus in both whenever there were two such sets. This stimulus was the middle-sized member of one probe and the largest or smallest member of the other. When there was one 1.4:1 probe, the birds usually responded to the middle-sized stimulus. The second condition producing frequent preferences for the middle-sized stimulus was that of probes containing an $S-$ of the discrimination problem as the member closest in size to $S+$ (3.8:1 probes for Birds 4 and 6, 2.0:1 probes for Birds 7 and 8).

Fig. 6. Frequency of preferences for the probe stimulus to which responding was most recently reinforced.

Another way of analyzing preferences was by reference to the most recent history of reinforcement. After the first several problems, one stimulus of each probe was always the member of the set to which responses had most recently been reinforced. Figure 6 shows the frequency of preferences for that stimulus. Recency of reinforcement accounted for as many or more preferences than did either responses to S^{Sim} or S^M (Fig. 5); it included most of the preferences for the middle-sized stimuli, most of the preferences for the stimuli

closest in size to S+, and the 5% to 10% of the preferences for the non-middle-sized stimuli which were also the members of the probes least similar to S+.

Bird 4 had 44 probes and Bird 6 had 50 probes containing two stimuli equally similar to S+ in which responses were to a stimulus other than the one most recently correlated with reinforcement. Both birds almost always preferred the middle-sized stimulus whenever there was only one probe of this type, that is, when the discrimination problem was either 1-3-5 or 6-8-10. Under those conditions the two stimuli of the probes equally similar to S+, Stimuli 2 and 4 of probe 2-4-6 and Stimuli 7 and 9 of probe 5-7-9, had different histories of correlation with reinforcement. Responding to one (Stimulus 2 or 9) was never reinforced in any discrimination problem, whereas responding to the other (Stimulus 4 or 7) was reinforced (when set 2-4-6 or set 5-7-9 were the discrimination problem). If those probes are omitted from the tabulation, Bird 4 had 29 probes and Bird 6 had 42 probes containing two stimuli equally similar to S+ in which reinforcement recency did not account for the behavior. Bird 4 preferred S^M in 15 probes and the other equally similar stimulus in 14; Bird 6 preferred S^M in 22 probes and the other stimulus in 20. These data suggest an interaction of the history of reinforcement with the similarity of the probe stimuli to S+. If there were two stimuli equally similar to S+, and responding to only one was ever reinforced, that one was preferred. If responses to two stimuli equally similar to S+ were both correlated with reinforcement in the past, the birds divided their preferences almost evenly between the two.

Most preferences that were not for the stimulus to which responses were last reinforced were for the stimulus most similar to S+. This combination of recency of reinforcement and similarity to the prevailing S+ accounted for between 95% and 98% of the preferences. The few failures of the combination of history and similarity to explain the behavior (11 for Bird 4, 10 for Bird 6, 17 for Bird 7, 7 for Bird 8) occurred because of responses to the middle-sized stimuli. From 70% to 82% of these instances involved probes in which the stimulus that was closest in size to the S+ was an S- of the discrimination problem.

DISCUSSION

The differential responding established with the discrimination problems persisted in the probes. Since the probability of responding in the probes varied with their similarity to the discrimination problem, similarity determined the degree of functional equivalence between S+ and the preferred probe stimuli. The basis of equivalence appeared complex, since the stimuli preferred in the probes were often the middle-sized stimuli, often the stimuli closest in size to S+, and sometimes the third member of the probes. Further analysis indicated that control by absolute stimulus properties could account for all of the preferences, and, therefore, could best explain the graded equivalence of stimuli.

To attribute all of the behavior to absolute stimulus properties requires accounting for the frequent responses to middle-sized stimuli and the occasional responses to the probe stimulus least similar to S+. Responses to the middle-sized probe stimulus, the stimulus correct when the probe was the discrimination problem, occurred under four conditions: (1) almost always when that stimulus was the one of the three probe-set members to which responses were most recently reinforced; (2) almost always when that stimulus was one of two stimuli closest in size to S+ and was the only one of the two ever correlated with reinforcement; (3) on about half of the probes when that stimulus was one of two stimuli closest in size to S+ and responses to both had equivalent histories of reinforcement; (4) frequently when the probe-set member closest in size to S+ was an S- of the discrimination problem. Although these four cases may illustrate the conditions under which control by the middle-size relation prevailed, all are subject to alternative explanations. Since recency of reinforcement typically controlled behavior independent of the relation of the stimuli to each other, the first condition indicated that choices of the middle-sized stimulus occurred because of the history of reinforcement of responses to specific stimuli. The second condition revealed that when two stimuli were equally similar to S+ the history of reinforcement biased the choices in favor of one. The third condition showed that when responses to two stimuli were reinforced in the past and when the two were equally similar

to the current S+, preferences were divided between the two. Weak control by the middle-size relation might have been manifested since absolute learning was equalized. Yet the birds revealed no tendency toward uniform middle-size choices but responded equally to the two stimuli. The fourth condition indicated that responses to the middle-sized stimulus occurred because the birds may have learned not to respond to an S- and chose the stimulus closest in size to S+ that was not an S-.

Spence (1942) presented a theory to explain responses following a single discrimination between three stimuli. This theory asserts that the subject is controlled by the absolute sizes of the positive and negative stimuli. The tendencies to respond to S+ and not to respond to each S- generalize to other stimuli on the basis of similarity of sizes. The response strengths obtained by subtracting the inhibitory from the excitatory tendency dictates the choices: in each set the stimulus having the most net excitatory potential will be chosen. Since the theory predicts consistent choices of the stimuli closest in size to S+, it accounted for Spence's data, those reported by Zeiler (1965) and Zeiler and Price (1965), and those following the first discriminations of the present experiment. Although Spence presented the theory in the same paper (Spence, 1942) in which he reported the effects of two training sets on subsequent responding, he did not extend the theory to those data because he considered the situation too complex. The complexity is multiplied in the present experiment since there were from 70 to 96 training conditions. It should be noted, however, that Spence's theory predicts the following: (a) Subjects should always prefer S+ when it appears in combination with S-. (b) Subjects should divide their preferences between two stimuli equally similar to S+ if both are also equally similar to an S-. (c) If the generalization gradient generated by nonreinforcement is considerably steeper in slope than that generated by reinforcement, subjects should choose the middle-sized stimulus in probes in which the stimulus closest in size to S+ is an S- of the discrimination problem. (d) In all probes other than those referred to in a, b, and c, subjects should either prefer the stimulus closest in size to S+ or should have no consistent preferences. The preferences for the stimulus closest in size to S+, for the

middle-sized stimulus with probes containing an S- as the stimulus most similar to S+, and for the middle-sized stimulus on half the probes having two stimuli equally similar to S+ all fit this theory. Counter to theoretical expectations were the preferences for stimuli least similar in size to S+ and the consistent choices of the middle-sized stimulus when only one probe contained two stimuli equally similar to S+.

A complete account of the behavior needs to provide for the modulation of the effects of stimulus similarity by the history of reinforcement. Given equal similarity of two stimuli to S+, the birds responded only to the one correlated with reinforcement in the past. When all of the stimuli differed considerably from S+, the birds responded to the one last correlated with reinforcement whether it was the one closest in size to S+, the middle-sized stimulus, or the member of the set least similar to S+. It appears, therefore, as if the recency of reinforcement determined preferences when similarity favored two stimuli equally and when all of the stimuli differed considerably from S+. In most other cases the two factors complemented each other; when they were opposed, either was likely to prevail. These factors always interacted to the extent that the similarity of the probe stimuli to S+ controlled the rate of responding even when the preferred stimulus was the one last correlated with reinforcement and not the one closest in size to S+.

Preferences for either the stimulus most recently correlated with reinforcement or the stimulus closest in size to S+ show control by absolute stimulus properties. The first reveals the importance of the history of reinforcement of responding to specific stimuli. The second indicates that the absolute sizes of the stimuli of the last discrimination problem determine responding with other sets. These two forms of absolute stimulus control explain the functional equivalence of different stimuli without requiring assumptions about the effectiveness of stimulus relations.

Other experiments involving training subjects to respond to the middle-sized stimulus of more than one set indicated somewhat different results. Spence (1942) trained chimpanzees to respond to the middle-sized member of one set and found that they chose S+ when it was either the largest or smallest member of

a probe set that contained an S— of the first set as the middle-sized stimulus. Next, Spence trained the animals to respond to the middle-sized member of the probe set and gave the original set as the probe. Four of the six animals chose the stimulus positive in the last training set, and two chose the middle-sized stimulus. An additional probe with a new set produced responses to the stimulus closest in size to the last S+. Zeiler and Paalberg (1964) found that two sets distinctly different from each other caused adult humans to respond to the middle-sized member of a new set. Humans generalized control by the middle-size relation to new situations, whereas chimpanzees either learned to respond to the middle-sized member only of sets in which such responses had been reinforced, or, like pigeons, were controlled by absolute stimuli. Information is not presently available as to whether species or procedural differences produced the various results.

Cumming and Berryman (1965) reported a series of experiments showing that pigeons developed a high probability of responding to the stimulus that matched a sample when several combinations of stimuli were presented frequently according to an unpredictable sequence. They obtained similar results when the correct stimulus was the one that differed from the sample. Since control by absolute stimuli would produce 50% correct responses at best, the data showed that pigeons could respond to stimuli in relation to certain contexts. I investigated the possibility that a procedure similar to Cumming and Berryman's, in terms of the frequency of changes in stimulus sets and the absence of test probes, might result in consistent responses to middle-sized stimuli. Two birds received extended exposure (several months of each procedure) to from two to eight sets of three stimuli. The set changed after each reinforcement but responding to the middle-sized stimulus was al-

ways reinforced. With two sets the birds responded correctly to both only if the stimulus positive in one was not negative in the other; with more sets the birds never had more than about 65% correct responses in a session. The difference between the results of the present experiments and those reported by Cumming and Berryman may be due to the type of relational discrimination (middle-size *vs.* matching or oddity), to the stimulus continuum used (size *vs.* wavelength), or to other, currently obscure, procedural variables.

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