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Complex Stimulus Control as a Function of Numerosity and Overlap

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Abstract

COMPLEX STIMULUS CONTROL

AS A FUNCTION OF NUMEROSITY AND OVERLAP

by

Linda Maree Davidson

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The effects of number and overlap of stimulus elements on the control of discriminative responding by complex stimuli were assessed. Complex stimuli were defined as those which can be partitioned into elements or components. Six White Carneau pigeons were exposed to each of ten 21-session discrimination tasks. Every 1 hour session consisted of quasi-random sequences of ten reinforcement and ten extinction intervals. The stimuli associated with reinforcement (S^+) and extinction (S^-) were composed of two or more vertical and/or horizontal lines produced by eight 7-segment light emitting diode displays. The number of lines in S^+ and S^-, either two, four, or eight, was equal for each task but varied across tasks. Throughout the experiment S^+ consisted of horizontal lines while S^-

was horizontal and/or vertical lines. Because numerosity was constant for S^+ and S^- in a given task, overlap of stimulus elements referred to the number of horizontal lines in S^- relative to the total number of lines in S^- or S^+. Three subjects were exposed to increasing values of overlap across discrimination tasks (i.e., 0%, 25%, 50%, and 75%, respectively) and three were exposed to decreasing values of overlap (i.e., 75%, 50%, 25%, and 0%, respectively).

Discrimination ratios (the number of responses during S^+ divided by the number of responses during S^+ and S^-) indicated that discrimination performance was excellent at low values of stimulus overlap but deteriorated as overlap increased. Excellent discrimination performance was indicated by large numbers of responses during S^+ intervals and low numbers of responses during S^- intervals which produced discrimination ratios approaching 1.00. The effects of increased overlap were consistent across the three values of numerosity. Response rates (the number of responses per minute) suggested that subjects searched the elements of each display for the distinctive features when the values of numerosity and overlap were small. As overlap of stimulus elements and number of elements increased, subjects were less likely to scan the entire display for the distinctive features as indicated by different rates of responding to specific patterns. Large differences in rates of responding to specific stimulus patterns suggested that subjects were under stimulus control more often by vertical lines occurring in the center of the display rather than the ends of the display.

The data were discussed in the context of information theory, stimulus selection models, and search strategies. Each of these approaches offered a framework for the discussion of the data which emphasized different aspects of complex stimulus control. It was suggested that the variables, numerosity and overlap of stimulus elements, provide convenient manipulations which are relevant to many experimental and theoretical issues in the area of complex stimulus control.

To those of you who were always there
when I needed you most

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The experiment reported here addresses the control of behavior by complex stimuli. For present purposes, a complex stimulus will be defined as one which can be partitioned into components or elements. For such stimuli it is possible to specify many variables, two of which are the number of elements in each stimulus and the degree of overlap of elements among sets of complex stimuli. The discussion which follows attempts to argue that these variables represent a useful and convenient way to characterize complex stimuli. Although this analysis of complex stimuli has been inferred in a few cases (e.g., Thorndike, 1910) it will be suggested that this characterization lends itself to particular manipulations which make contact with several experimental and theoretical issues in the area of complex stimulus control.

Of the many experimental procedures used to study complex stimulus control, discrimination learning tasks may serve to illustrate the use of numerosity and overlap of elements as variables. The discriminative stimuli, S+ and S-, may be chosen on the basis of specific values of numerosity and overlap in the following way. Given a complex stimulus comprised of two different elements denoted X and Y, numerosity refers to the total number of elements in the stimulus. If a second stimulus has the same total number of elements, it is possible to express the number of elements which are common to both first and second stimuli as a proportion of that total number. This proportion is the degree of overlap of identical elements between the two stimuli. For example, if one stimulus consisted of two X elements and the second consisted of an X and a Y element, then one of the two elements (X) is common to both stimuli and overlap would be one half (.50 or 50%). In the present study numerosity and overlap were varied across ten discrimination tasks. Within each task, the number of elements in S+ equaled the number of elements in S-. One stimulus, the S+ in each discrimination, was composed of one type of element, X. The second stimulus, S-, included Y elements as well as X elements. Because numerosity was constant for S+ and S- in a given task, overlap refers to the number of X elements in S- relative to the total number of elements in S- or S+.

Since numerosity and overlap of stimulus elements are variables which specify complex stimuli along quantifiable continua, discrimination learning tasks can utilize these properties in the selection of the discriminative stimuli. Within this framework, it is possible to discuss a variety of manipulations and data analyses which are relevant to discussions of perception and attention. In the context of the present experiment, one may refer to differential responding between an S+ and an S- in terms of perception or attention depending on the number of elements controlling responding. In its most rudimentary form, attention refers to control of responding by a single element of a complex stimulus (e.g., Reynolds, 1961). All other elements of the stimulus fail to control responding. Tests for control by elements following discrimination training which demonstrate control by one element of the stimulus rather than all elements serve to distinguish attention from perception. Perception refers to the case in which control of responding is shared to some degree by all elements. Thus, a test of individual elements which demonstrates control by all elements of the stimulus distinguishes perception from attention. The control may be shared equally across elements, or some elements may control responding more than others (e.g., Butter, 1964; Wilkie and Masson, 1976). One may think of a continuum of the number or proportion of elements in a complex stimulus which control responding varying from one to all elements. Attention and perception refer to the ends of that continuum.

Numerosity and overlap of stimulus elements are two variables which alter stimulus complexity. Given that a specific complex stimulus has produced differential responding which can be labeled perception or attention, altering the complex stimulus along the dimensions of numerosity and overlap may change the behavior. As stimulus complexity varies, responses controlled by all elements may subsequently be controlled by one element, or vice versa. Altering stimulus complexity by variations in numerosity and overlap allow for systematic explorations of results which influence the proportion of stimulus elements that control responding.

An illustrative example may serve to illustrate the possible effects of numerosity and overlap of elements. If the organism attends, or responds selectively to elements of stimuli which have a small number of elements and no overlap of elements, increases in numerosity and overlap would affect discrimination performance. If the organism attends to one element in a specific location to perform the discrimination, increasing the number of elements in the stimulus while holding overlap constant at 0% would not affect rates of responding to the stimuli. Each addition of an element to S+ and S- would be superfluous for the performance of the discrimination. As numerosity increases, other values of overlap may be selected. If the locations of the nonoverlapping elements vary from one stimulus presentation to the next, and if the organism continues to attend to a single element in the same location, discrimination performance will deteriorate; that is, rates of responding to S+ and S- will become similar. This deterioration would be the result of fewer nonoverlapping elements occurring, and the decreased reliability of the location of the nonoverlapping elements. If the organism shifted to a strategy which sampled more elements from the stimulus, likelihood of locating a nonoverlapping element would increase which might lead to approrpiate discrimination performance. This example serves to illustrate some possible outcomes resulting from manipulations of numerosity and overlap of elements.

As previously indicated, each element of the stimuli in this experiment can be either an X or a Y. These two alternatives may be represented as one bit of information in the terminology of information theory. (For a detailed definition of bit, refer to other sources; e.g., Shannon, 1958; Garner, 1962; Attneave, 1959). As numerosity of elements increases, bits of information increase. Overlap indicates the pattern of the elements in the stimuli. For a given value of numerosity, the information available to maintain differential responding is greater when overlap of S+ and S- is 0% than when it is larger than 0%. If the degree of differential responding is equivalent at 0% and 50% overlap, for example, then amount of information and the form of the stimulus pattern determined by overlap are not effective in controlling differential responding. If differential responding was not equivalent at 0% and 50% overlap, it would indicate that variations in information and element patterning did affect discrimination performance.

The data obtained during acquisition of discriminations at various values of numerosity and overlap may be used to evaluate specific hypotheses about the processing of the information in the complex stimuli. Examples of specific hypotheses are stimulus selection models (e.g., Mackintosh, 1965; Restle, 1959; Sutherland, 1964; Wagner, Logan, Haberlandt, & Price, 1968). In the present case, the element, X, which is present in S+ and S- when overlap is greater than 0%, does not provide information which distinguishes S+ from S-. The Y element is specific to S- and serves to distinguish S- from S+. Stimulus selection models would predict that X is an irrelevant cue for performing the discrimination while Y would be a relevant cue. Consequently, organisms would attend to the relevant cue of the complex stimulus and ignore the irrelevant cue. A searching process or mechanism selects the relevant cues despite their location in the stimulus. Increases in numerosity would provide more instances of relevant cues which would facilitate discrimination acquisition. Increases in overlap, conversely, would reduce the actual number of available relevant cues which would hinder discrimination acquisition.

When overlap is greater than 0%, the positions of the relevant cues vary from one presentation to the next. Acquisition of a discrimination would depend upon strategies which allow the organism to search for the relevant cues. Several models of search strategies are applicable to this situation. The organism could examine each element of the stimulus individually and sequentially (serial search); or, all elements could be searched simultaneously (parallel search). If each element in the display required a constant amount of search time, then a serial search would require more time as numerosity increased (e.g., Sternberg, 1966; Blough, 1978). A parallel search might show greater invariance of search time as numerosity increased since all elements would be processed simultaneously (e.g., Neisser, 1963). When the number of elements in the stimulus reaches the limits of the organism's mechanisms for processing information, increases in numerosity would affect responding that was maintained by a parallel search strategy. Overlap would have a greater effect on a serial search strategy since a greater proportion of elements would be processed to find the distinctive cue. This would result in an increase of the amount of time to process the stimuli (e.g., Rabbit, 1964; 1967). Variations in overlap would be less likely to affect a parallel search strategy since all elements would be processed simultaneously (e.g., Egeth, 1966). The amount of time to process the stimuli would not be affected by changes in overlap.

In summary, the experiment which follows demonstrates the feasibility of using numerosity and overlap in the analysis of complex stimuli. These variables are relevant to the analyses of complex stimuli only if they can be shown to influence the acquisition and maintenance of discriminative responding. The series of discrimination learning tasks which follow, assess changes in behavior as a function of changes in numerosity and overlap of stimulus elements. Once these variables have been shown to affect discrimination performance, it may be possible to use numerosity and overlap of elements to examine a variety of experimental and theoretical aspects of complex stimulus control.

METHOD

Subjects

Eight female White Carneau pigeons, obtained from the Palmetto Pigeon Plant in Sumter, South Carolina, served as subjects. They were approximately nine years old and weighed between 510 and 690 grams prior to experimentation. The pigeons were individually housed in wire mesh cages and were given free access to water and grit in their home cages. Following determination of each pigeon's *ad libitum* body weight, the pigeons were maintained between 75% and 80% of their free-feeding weights.

Two of the eight pigeons became ill and died before the end of the experiment; the data for these birds are not included in the text but can be found in Appendix A.

Apparatus

A standard Lehigh Valley Electronics operant conditioning chamber, model 1519C, was used with a modified intelligence panel. The original operandum, a 1 inch (2.5 cm) disk, was covered by a 3 3/4 inch x 4 1/4 inch (9.5 cm x 10.8 cm) piece of black plexiglass. Directly above the occluded disk was a 8 1/8 inch x 1 3/8 inch (20.6 cm x 3.5 cm) clear Plexiglas response key held in place by three hinges connected to the intelligence panel along the top edge of the key. Switch contacts were mounted at the lower right corner of the key and were hidden from view by a black plexiglass frame which surrounded the entire key. The outer edge of the frame measured 9 inches x 2 3/8 inches (22.9 cm x 6 cm) while the window of the frame, which allowed the pigeon access to the key, measured 7 1/2 inches x 1 inch (19 cm x 2.5 cm). The key traveled a distance of 1/8 inch (.3 cm) along the bottom edge for the switch closure and required a static mass of 15 grams to close, measured at the center of the key. The visual stimuli used throughout the experiment were presented by 7-segment light emitting diode (LED) displays manufactured by Monsanto, model MAN-84. Each LED display was 3/4 inch x 3/8 inch (1.9 cm x .9 cm) with each segment of the display projecting a .3 inch (.8 cm) yellow light. Eight such LED displays were mounted side by side and centered directly behind the response key. Seven linear segments on each display were arranged to form the figure  . Following pretraining only two of the seven segments were used throughout the experiment; the upper left vertical segment and the bottom horizontal segment.

A ventilation fan provided masking noises during experimental sessions.

All experimental contingencies were programmed by BRS-LVE solid state logic circuitry and tape readers. Data were collected on Sodeco printers and counters.

Procedure

Preliminary Training. Following magazine training pigeons were trained to peck a disk illuminated by a white light on a standard intelligence panel by the method of successive approximations. Following shaping of the key peck response, pigeons earned 50 regular reinforcements, defined as 4 seconds' access to mixed grain, then 50 reinforcements on a random interval 30 second schedule (RI 30"), followed by 50 reinforcements on a random interval 60 second schedule (RI 60") spread across three successive daily sessions. All pigeons were exposed to preliminary discrimination tasks of various patterns of vertical and horizontal segments on the LED displays while key pecking on a response disk below the display. Subsequently, the response disk was occluded and the long key installed over the LED displays as described previously. During the first exposure to the long key, two adjacent horizontal segments in the center of the key were illuminated while keypecks were reinforced on a RI 60" schedule. All pigeons responded on the modified response key on the first exposure without further shaping.

Training. All experimental sessions lasted for 60 minutes. Each session was divided into 20 blocks of three minutes during which times specific configurations of vertical and horizontal segments were presented. During ten blocks, reinforcement for key pecking was available on a RI 60" schedule. The stimuli on the LED correlated with the reinforced components weredesignated S+. For the remaining ten intervals, reinforcement was not available for key pecking and any stimuli correlated with nonreinforcement weredesignated S-. The S+ and S- intervals were presented in quasi-random orders with the restrictions that first, neither an S+ or an S- interval could occur more than three times in succession and, second, that each component would occur ten times per session. For each experimental condition there were four different orders of S+/S- intervals. Each order was rotated from session to session in a quasi-random sequence.

The experiment consisted of ten discrimination tasks which differed in the number of segments presented in S+ and S-, and in the number of segments common to S- and S+. For each discrimination, the number of LED segments presented in S+ was equal to the number of segments presented in S-. The number of segments in S+ and S- were two, four, or eight. For all discriminations, S+ consisted of only horizontal segments whereas S- consisted of horizontal and/or vertical segments. Each LED display presented either a horizontal or a vertical segment at a time. It was never the case that a horizontal and a vertical segment were presented simultaneously on the same LED display. For each discrimination task, the same LED displays were used throughout. Table 1 indicates the specific combinations of vertical and horizontal segments used in S+ and S- as well as the sequence of presentation of the ten discriminations. The column labeled "percent overlap" indicates the number of horizontal segments in S- relative to the number of horizontal segments in S+. An S+-S- combination labeled "zero percent" represents a number of vertical segments in S- equal to the number of horizontal segments in S+; twenty-five percent overlap indicates

Table 1. Order of presentation of stimulus combinations

Task	Percent Overlap	Stimulus S+	Stimulus S-
	S33, S39, S40		
1	0	2H	2V
2	50	2H	1V1H
3	0	4H	4V
4	25	4H	3V1H
5	50	4H	2V2H
6	75	4H	1V3H
7	0	8H	8V
8	25	8H	6V2H
9	50	8H	4V4H
10	75	8H	2V6H
	S104, S108, S110		
1	50	2H	1V1H
2	0	2H	2V
3	75	4H	1V3H
4	50	4H	2V2H
5	25	4H	3V1H
6	0	4H	4V
7	75	8H	2V6H
8	50	8H	2V6H
9	25	8H	6V2H
10	0	8H	8V

that three-fourths of the segments in S- were vertical while one-fourth were horizontal; 50% overlap indicates that half of the segments in S- were vertical and half were horizontal; and so on.

When S- contained horizontal segments, the positions of the vertical segments were varied from one S- interval to the next. For tasks one through six, all possible positions of the vertical segments were used within sessions. Consequently, for some tasks, there were as many as six specific arrangements of vertical and horizontal segments in S-. When all eight LED displays were used for tasks seven through ten, six specific arrangements were selected from all possible combinations per task. (Specific patterns are presented in Appendix B.)

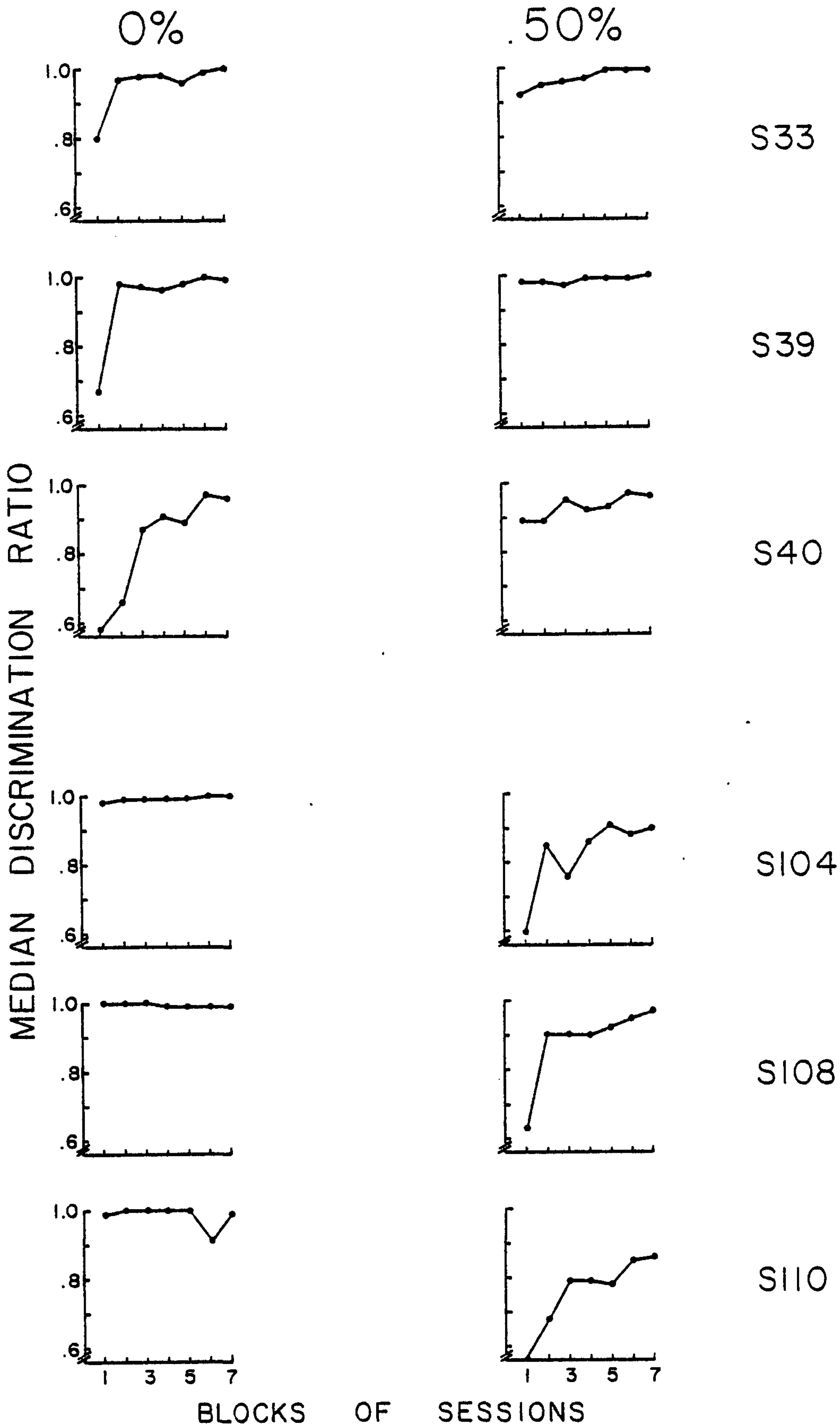
Each task was presented for 21 consecutive sessions. Data collection during each session included the following: number of responses during each of the 20 three-minute intervals, the latency of the first response in each three-minute interval, and the number of reinforcements per session.

Results and Discussion

Discrimination ratios, the number of responses made during S+ divided by the number of responses made during S+ and S- were calculated for all subjects across 210 sessions. A ratio of 1.0 would indicate that all responses were made to S+ while a ratio of .50 would indicate an equal number of responses to S+ and S-. The median discrimination ratios for blocks of three sessions are presented in Figures 1, 2, and 3. Since some subjects failed to respond during a few sessions and the equipment failed occasionally, some discrimination ratios for particular sessions were not consistent with the majority of ratios for each subject. Median ratios were selected to minimize the effects of those atypical discrimination ratios on the data summary.

The specific values of the variables, numerosity and overlap of stimulus elements, will be expressed in the following notation for the remainder of the discussion: N=2, 4, or 8; O=0%, 25%, 50%, or 75%, respectively. Figure 1 shows the median discrimination ratios for all subjects when N=2. The left and right columns of figures represent ratios when stimulus overlap was 0% and 50%, respectively. Each row of figures supplies data from a single subject. The top three rows of figures represent those subjects exposed first to O=0% discrimination then to O=50%, while the bottom three rows correspond to those subjects exposed first to O=50% then to O=0%.

Figure 1. Median discrimination ratio (responses in S+ divided by responses in S+ and S-) across blocks of three sessions for all subjects when N=2. Values of overlap were presented in an increasing series for S33, S39, and S40, and a decreasing series for S104, S108, and S110.

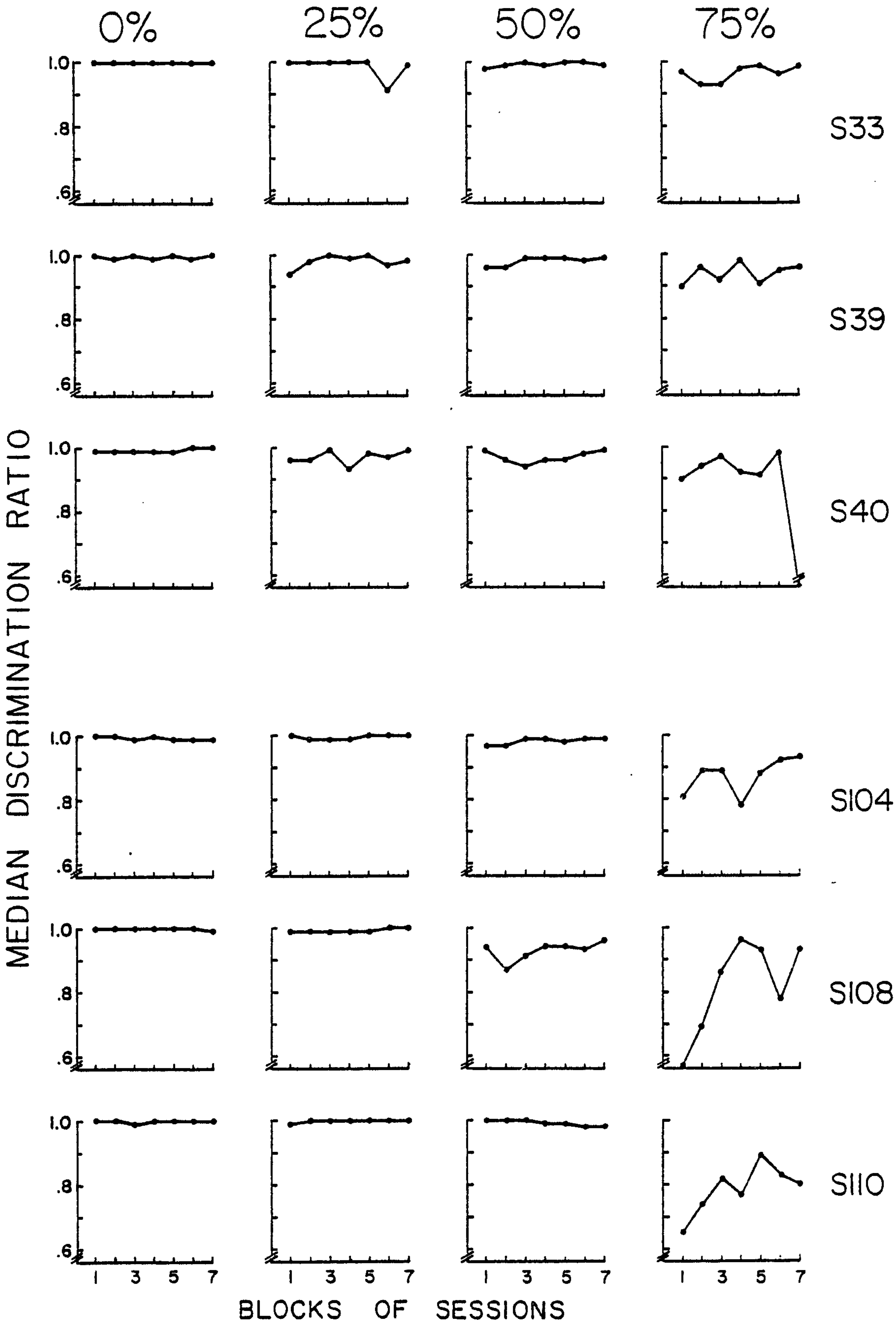

0%
.50%
1.0
.8
.6
S33
S39
S40
S104
S108
S110
MEDIAN DISCRIMINATION RATIO
1
3
5
7
BLOCKS OF SESSIONS

Both sets of figures indicate similar trends. Performance on the initial task was a gradual acquisition of the discrimination across the first few blocks of sessions. Terminal performance by all subjects but one produced discrimination ratios of .90 or better. All subjects demonstrated near perfect discrimination when shifted to the second task, with terminal performance at or near a ratio of 1.00.

It can be seen from these sets of figures that an initial discrimination task based on two stimulus elements results in lower ratios than a subsequent task based on the same number of elements. In addition, the difficulty of the initial discrimination affects the terminal level of performance on that discrimination. The subjects learning a difficult discrimination first (i.e., when overlap is 50%) performed better on a simple discrimination than those subjects who learned the simpler discrimination first. The subjects who learned a simple discrimination first demonstrated better performance on a more difficult task than those subjects who learned the difficult task first. However, performance on the second task is still influenced to a small degree by the difficulty of the first task. The type of discrimination as well as its ordinal position in a series of discriminations can affect performance on each specific task.

Figure 2 presents the three-session median discrimination ratios for all subjects when N=4. From left to right, the columns of figures represent performance when 0=0%, 25%, 50%,

Figure 2. Median discrimination ratio (responses in S+ divided by responses in S+ and S-) across blocks of three sessions for all subjects when N=4. Values of overlap were presented in an increasing series for S33, S39, and S40, and a decreasing series for S104, S108, and S110.


0%
25%
50%
75%
1.0
.8
.6
S33
S39
S40
S104
S108
S110
MEDIAN DISCRIMINATION RATIO
1 3 5 7
BLOCKS OF SESSIONS

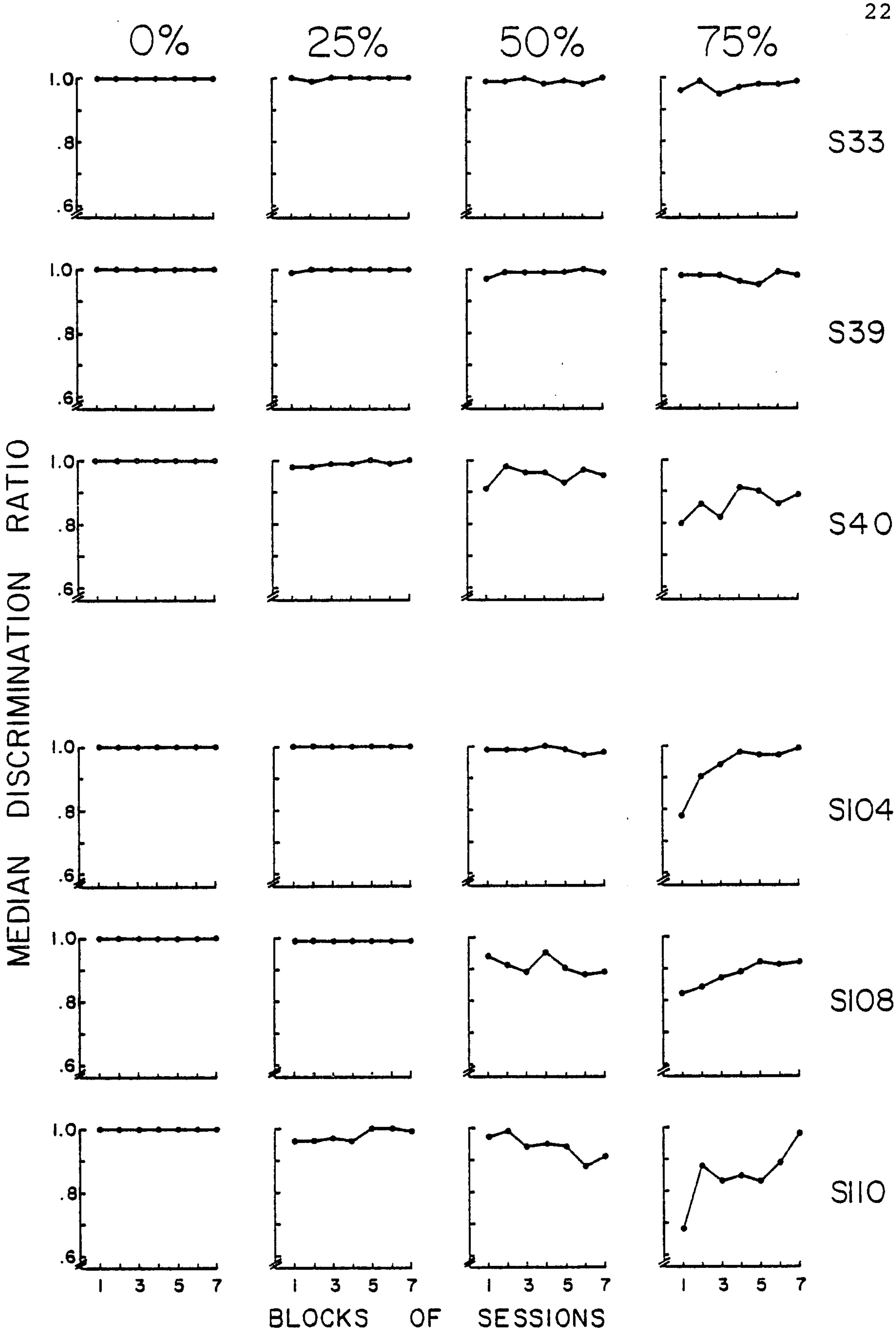
and 75%, respectively. The top three rows of figures correspond to those subjects exposed to increasing values of O (i.e., 0%, 25%, 50%, and 75%, respectively) across successive tasks whereas the bottom three rows correspond to those subjects exposed to decreasing values of O (i.e., 75%, 50%, 25%, and 0%, respectively).

All subjects demonstrated near perfect performance at low values of stimulus overlap. As overlap increased, there was a progressive decrement in discrimination performance, especially at O=75%. At this value of overlap, all six subjects showed greater variability across blocks of sessions as well as an overall decrement compared to performance on other values of overlap. Those subjects exposed to this condition initially (i.e., S104, S108, and S110) showed the greatest decrement in discrimination performance.

The median discrimination ratios for N=8 are presented in Figure 3. The trends in performance depicted by these figures are virtually identical to those in Figure 2. Subjects initially exposed to the largest percent overlap at a given value of N demonstrated slower acquisition and, in some instances, lower terminal discrimination ratios compared to those subjects learning those same discriminations following exposure to discriminations with less overlap.

Several points may be noted regarding the data presented in Figures 1, 2, and 3. Since S+ elements were always horizontal, overlap between S+ and S- was determined by the number of horizontal segments in S- relative to the

Figure 3. Median discrimination ratio (responses in S+ divided by responses in S+ and S-) across blocks of three sessions for all subjects when N=8. Values of overlap were presented in an increasing series for S33, S39, and S40, and a decreasing series for S104, S108, and S110.


0%
25%
50%
75%
1.0
.8
.6
S33
S39
S40
S104
S108
S110
MEDIAN DISCRIMINATION RATIO
1 3 5 7
BLOCKS OF SESSIONS

number in S+. When overlap was 0%, each element in S- was a vertical line, which was distinctly different from the elements in S+. As overlap increased, S- and S+ shared common elements. Thus, S- became more similar to S+ as overlap increased.

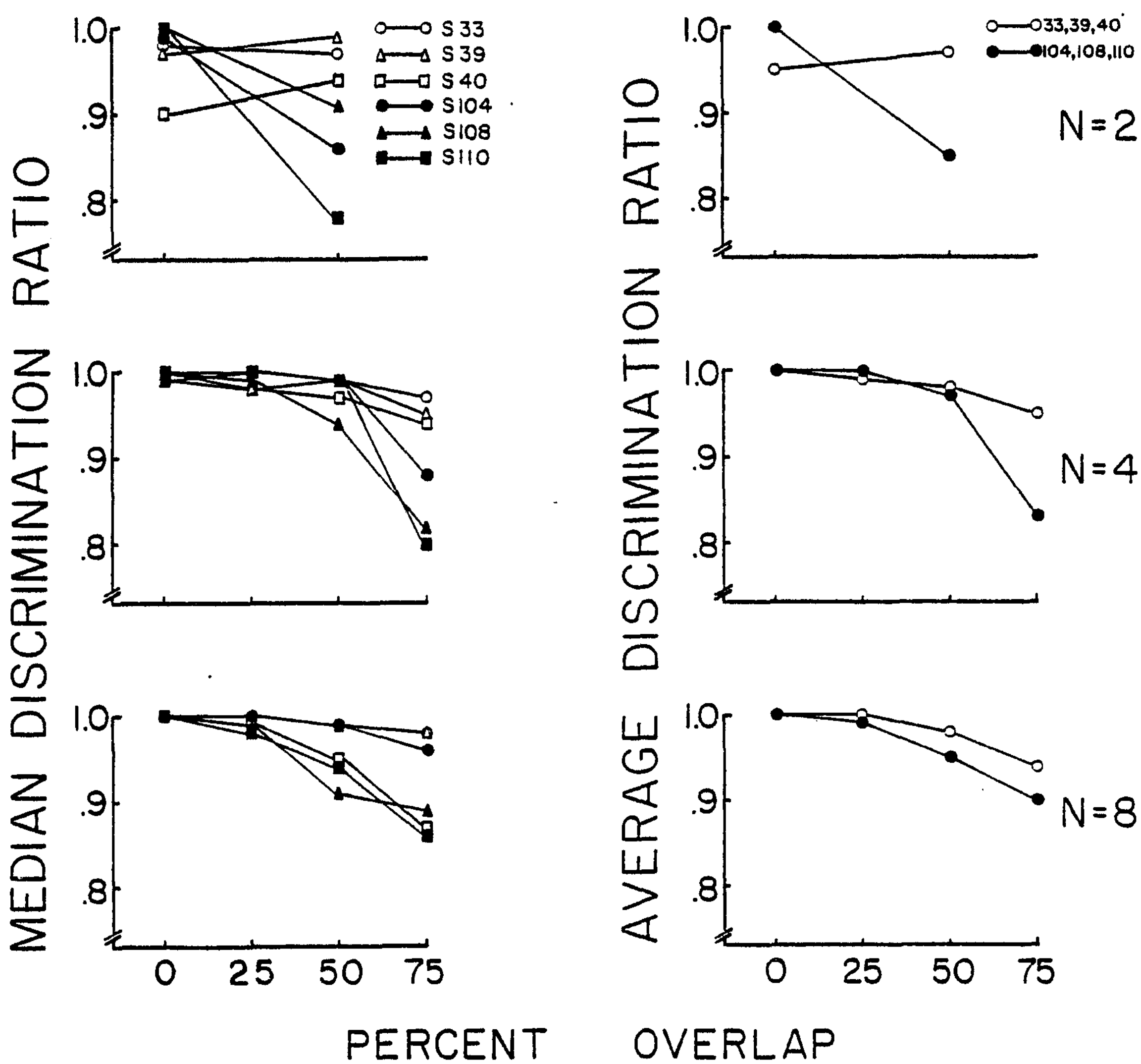
The data reported here indicate that stimulus similarity, defined by specific values of numerosity and overlap, affected the performance of a discrimination. Discriminative stimuli which shared many common elements, represented a more difficult task. The terminal performance of a discrimination was directly related to the amount of similarity between S+ and S-.

The data presented in Figures 1, 2, and 3 are relevant to several stimulus selection models (e.g., Wagner, et al., 1968). When O=0%, every reinforcer was presented in the presence of horizontal lines while vertical lines were correlated with nonreinforcement. Stimulus selection models would characterize each line as a relevant cue for occurrence and nonoccurrence of reinforcement, since they were perfectly correlated. Subjects would be expected to perform the discrimination well since all elements were equally relevant. The present data confirm this prediction.

When O=75%, however, the status of the horizontal lines was not equivalent to the status of the vertical segments. The vertical lines remained perfectly correlated with the occurrence of nonreinforcement and, consequently, were reliable indicators of nonreinforcement. The horizontal lines, however, occurred with almost equal frequency during periods of reinforcement as well as nonreinforcement. They were not consistent indicators of reinforcement, and therefore, would be considered irrelevant cues, according to the models. If subjects initially learned that vertical lines were relevant whereas horizontal lines were irrelevant, reliance on vertical lines would allow adequate discrimination performance on the first and all subsequent tasks in which horizontal lines remained irrelevant. That is, stimulus selection models might predict good discrimination performance despite decreases in overlap from 75% to 0% because vertical lines remained relevant while horizontal lines would have to gain relevance as overlap decreased. Decreasing overlap would not affect subsequent performance since attention to vertical lines would result in appropriate discrimination between S+ and S-. However, the data do not support this interpretation. Regardless of the order of the tasks at each value of N, all subjects had lower discrimination ratios at larger values of overlap.

Comparisons among the six subjects for all conditions can be made on the basis of their median discrimination ratio. The median of all 21 session ratios for each task was determined and is presented for each subject in the left column of Figure 4. Twenty-one day median discrimination

Figure 4. Median discrimination ratios for 21 sessions as a function of percent overlap. The upper, middle and lower figures represent ratios for all subjects when N=2, 4, and 8, respectively. The left panel depicts ratios for individual subjects while the right panel shows means of the median ratios for S33, S39, and S40 (open circles) and S104, S108, and S110 (filled circles).


MEDIAN DISCRIMINATION RATIO
AVERAGE DISCRIMINATION RATIO
1.0
.9
.8
S 33
S 39
S 40
S104
S108
S110
33,39,40
104,108,110
N=2
N=4
N=8
0
25
50
75
PERCENT OVERLAP

ratios are plotted as a function of percent overlap. The upper, middle, and lower figures represent the ratios for all subjects when N=2,4, and 8, respectively. The right column of figures presents the means for the two sets of subjects exposed to like procedures. For example, the open circle function in the top right hand panel represents the mean for S33, S39, and S40 median discrimination ratios which were presented in the upper left panel. The left column of figures illustrates the differences between individual subjects and the right column of figures illustrates the overall relationship between performances on the various tasks.

Several trends are evident based on the data in Figure 4. In general, percent overlap between S+ and S- has an effect on learning as measured by discrimination ratios. This is true for all subjects and all values of N. The magnitude of the effect, however, is altered by the order of presentation of the specific tasks. Those subjects who were presented with stimuli which gradually became more similar had higher discrimination ratios than those subjects who were initially exposed to similar S+ and S-. The effects due to number of elements appeared to be less pronounced suggesting that the subjects' ability to discriminate was influenced more by percent overlap than by the number of elements in the display.

These findings indicate that the effects of overlap on discrimination performance were consistent across a range of values of numerosity. As overlap increases, the decrement in terminal discrimination performance was gradual, despite the number of elements in the complex stimulus. This suggests that the absolute number of distinctive elements in S+ and S- was less important to the control of discriminative behavior than the relative number of distinctive elements in S+ and S-. Given a specific proportion of distinctive elements between S+ and S-, discrimination acquisition and maintenance will remain constant for a range of stimuli with varying number of elements. The important characteristic of complex stimuli for discrimination learning in this context is the relative similarity between stimuli rather than the number of elements in the stimuli.

As indicated previously, the stimuli used in the present case can be expressed in terms of information theory. Every element represents one bit of information. Therefore, numerosity specifies the total number of bits of information. Table 2 summarizes the amount of information, expressed as bits, used in each of the ten discriminations. The number in parentheses indicates the number of stimulus patterns, both S+ and S-, presented per task. It should be remembered that the number of combinations of vertical and horizontal segments used in the tasks for a given value of overlap was not exhaustive. For example, when N=8 and O=25%, there are 28 different combinations of two horizontal segments and six vertical segments. Of those, only six specific patterns were

Table 2. Amount of information, expressed in bits, associated with each discrimination task. Numbers in parentheses represent the number of patterns presented during each task.

	Number of Elements (N)		
Percent Overlap	2	4	8
0%	1 (2)	1 (2)	1 (2)
25%		2.32 (5)	2.80 (7)*
50%	1.58 (3)	2.80 (7)	2.80 (7)**
75%		2.32 (5)	2.80 (7)***
TOTAL INFORMATION	2	4	8

When N=8 the number of patterns generated by the values of the percent overlap was not used exhaustively. Rather, subsets of patterns were selected thus reducing the amount of information. The total amount of information is listed below for each of the values of overlap in which subsets were actually used.

*4.85 (29)

**6.15 (71)

***4.85 (29)

selected (see Appendix B) in addition to the eight horizontal lines used as S+. (Total number of possible combinations and associated bits of information appear at the bottom of Table 2.)

Comparisons of performances represented in Figure 4 on the basis of bits of information listed in Table 2 indicate that discrimination performance did not vary systematically with changes in the amount of information expressed in bits. An example of this can be found when N=8. For O=25%, 50%, and 75%, there were 2.8 bits of information present in each discrimination task. Discrimination ratios across these values of overlap indicate a decrement in discrimination performance despite equal amounts of information. Other examples show that increases in bits of information were not related systematically to changes in discrimination ratios across values of numerosity and overlap. Although complex stimuli, defined by values of numerosity and overlap of stimulus elements, can be expressed in terms of bits, discriminative performance was not shown to be the result of changes in information.

The standard deviations of the mean rates of responding (responses per minute) to specific S- patterns were calculated for each subject across the ten discrimination tasks and are presented in Table 3. Relatively small measures of variability would indicate that a subject tended to respond at similar rates to each of the S- patterns per task whereas large measures of variability would indicate that a subject tended to respond with different rates to the various

Table 3. Standard deviations of the mean rates (responses per minute) of responding to each S- pattern for each subject.

		Overlap		
Subject	N	25%	50%	75%
S33	2		.205	
	4	.320	.148	1.125
	8	.176	.242	1.018
S39	2		.440	
	4	2.001	1.367	1.034
	8	.156	.529	.853
S40	2		1.340	
	4	3.166	2.605	3.910
	8	.353	2.603	8.014
S104	2		9.051	
	4	.140	.423	1.661
	8	.098	1.051	4.911
S108	2		.205	
	4	.240	1.604	.605
	8	.388	1.501	3.773
S110	2		6.463	
	4	.082	.673	4.763
	8	2.268	5.401	7.154

S- patterns. The results show that the largest standard deviation for a given value of N occurred at the highest value of overlap. When N=4 and 8, in eight out of twelve cases the standard deviations increased as percent of overlap increased. These data indicate that the rate of responding to various S- stimuli became more variable as overlap increased, suggesting that certain patterns controlled responding differently from other patterns.

Tables 4 through 9 show the mean rate of responding for 21 sessions for each subject as a function of the specific stimulus combinations of vertical and horizontal elements. At each value of N and O, the number(s) on the left of the dash correspond(s) to the position of the vertical elements in the display and the number(s) to the right of the dash correspond(s) to the mean rate of responding. If a low rate of responding was associated with a specific stimulus pattern, it might be assumed that the subject was performing the discrimination based on the location of the vertical segments. If, however, rates were high for a specific pattern, it is suggested that the subject was not using that specific pattern for discrimination performance. Comparisons of patterns across conditions which are associated with low rates provide some indication of the portions of the display which control responding, while comparisons of patterns associated with high rates suggest those portions of the display which do not control responding. For example, if a

Table 4. Mean rates of responding to S+ and each S- for S33.

	Percent Overlap			
Numerosity	0%	25%	50%	75%
2	S+-34.00 45-2.10		S+-24.9 4- .95 5- 1.24	
4	S+-26.40 3456-0.00	S+-21.62 345- .33 346- .19 356- .29 456- .90	S+-19.38 34- .10 35- .00 36- .05 45- .00 56- .38	S+23.24 3- .10 4- .14 5- .57 6- 2.48
8	S+-18.38 2345678-.00	S+-23.62 234567-.00 123678-.00 124578-.00 134568-.00 345678-.00 123456-.43	S+-18.14 1278-.05 1458-.00 1357-.00 3456-.05 5678-.05 1234-.62	S+-14.05 18-.14 27-.05 36-.10 45-.05 12-2.57 78-.05

Table 5. Mean rates of responding to S+ and each S- for S39.

	Percent Overlap			
Numerosity	0%	25%	50%	75%
2	S+-31.48 45- 2.48		S+-39.95 4- .76 5- 1.38	
4	S+-34.24 3456-.19	S+-33.62 345-5.24 346-2.29 356-1.10 56- .90	S+-36.81 34- 1.48 35- 3.33 36- 3.57 45- 4.53 46- 5.48 56- 4.38	S+-38.33 3- 4.48 4- 2.14 5- 2.90 6- 2.48
8	S+-49.05 12345678-0.00	S+-59.20 234567-.10 124578-.10 134568-.05 345678-.43 123456-.33	S+-42.71 1458- .05 1357- .05 3456- .48 5678- .57 1234- 1.48	S+-34.19 27- .76 36- .67 45- .81 12- 2.76 78- 2.10

Table 6. Mean rates of responding to S+ and each S- for S40.

	Percent Overlap			
	0%	25%	50%	75%
Numerosity				
2	S+-120.7		S+-141.67	
	45- 28.00		4- 10.00	
			5- 11.90	
4	S+-138.14	S+-145.95	S+-105.38	S+-68.10
	3456-1.43	345- 6.33	34- 8.10	3- 13.89
		346- 8.38	35- 4.19	4- 4.89
		356- 1.71	36- 2.48	5- 6.67
		456- 2.48	45- 2.53	6- 7.72
			46- 4.14	
			56- 8.24	
8	S+-70.90	S+-55.43	S+-55.86	S+-52.29
	12345678-.05	234567-.67	1278-2.52	18-13.33
		123678-.14	1458- .62	27- 5.52
		124578-.24	1357- .38	36- 4.62
		134568-.24	3456-1.52	45- 3.43
		345678-.95	5678-5.05	12-24.29
		123456-.86	1234-6.86	78-14.33

Table 7. Mean rates of responding to S+ and each S- for S104.

	Percent Overlap			
	0%	25%	50%	75%
Numerosity				
2	S+-107.05		S+-107.57	
	45- .95		4- 17.00	
			5- 29.8	
4	S+-77.71	S+-66.29	S+-67.52	S+-51.24
	3456-.48	345- .33	34- 1.71	3- 10.05
		346- .43	35- .90	4- 6.48
		356- .10	36- .95	5- 9.43
		456- .24	45- .57	6- 9.81
			46- .57	
8	S+-60.71	S+-44.76	S+-52.00	S+-42.67
	12345678-.00	234567-.00	1278- .38	18- 4.05
		123678-.00	1458- .10	27- 2.90
		124578-.00	1357- .00	36- 4.62
		134568-.00	3456- .38	45- 4.24
		345678-.24	5678-2.81	12- 6.05
		123456-.00	1234- .57	78-16.14

Table 8. Mean rates of responding to S+ and each S- for S108.

Numerosity	Percent Overlap 0%	25%	50%	75%
2	S+-9.48 45-.00		S+-19.95 4- 3.43 5- 3.14	
4	S+-35.90 3456-.00	S+-26.81 345- .48 346- .00 356- .00 456- .00	S+-23.90 34- 4.48 35- 2.24 36- .76 45- 2.80 46- .33 56- .67	S+-7.95 3- 3.71 4- 2.57 5- 3.90 6- 3.10
8	S+=28.90 12345678-.00	S+-20.52 234567-.71 123678-.00 124578-1.00 134568- .10 345678- .19 123456- .33	S+-34.81 1278-2.29 1458- .67 1357- .38 3456-1.57 5678-1.95 1234-4.58	S+-27.81 18- 2.90 27- 3.00 36- 3.38 45- 2.48 12-12.33 78- 4.29

Table 9. Mean rates of responding to S+ and each S- for S110

Numerosity	Percent Overlap 0%	25%	50%	75%
2	S+-49.38 45-.14		S+-74.71 4- 19.24 5- 28.38	
4	S+-95.76 3456-.14	S+-75.57 345- .24 346- .10 356- .24 456- .29	S+-44.29 34- 1.90 35- .33 36- .52 45- .40 46- .24 56- 1.33	S+-30.38 3- 6.43 4- 5.57 5- 10.05 6- 16.05
8	S+-58.62 12345678-.00	S+-52.48 234567-1.81 123678- .71 124578- .48 134568- .48 345678- .86 123456-6.29	S+-72.38 1278- 3.24 1458- 1.95 1357- 1.71 3456- 3.76 5678- 3.90 1234-15.95	S+-47.86 18-12.14 27- 7.05 36-10.71 45-10.29 12-27.00 78-17.19

subject had high rates of responding for those S- which had vertical elements in positions 1 and 8, but low rates for those with vertical elements in positions 4 and 5, the subject demonstrated better stimulus control by elements in the center of the display than elements at the ends of the display.

Even though there are differences between rates of responding on specific tasks, the trends are difficult to characterize across all subjects. Since trends across conditions were idiosyncratic for each subject, only a few conclusions can be drawn. Subjects did not show strong biases for specific portions of the display, which were consistent throughout all ten conditions. However, some biases within a given condition were evident. In those instances in which subjects showed biases to specific patterns, the patterns can be described as follows: patterns with large values of overlap in which the vertical segments were located at the end positions of the display. For example, S108 demonstrated a bias for the right end of the display, especially when N=8 and O=75%. That is, low rates of responding occurred when vertical segments were in positions 7 and 8 and high rates occurred when vertical segments were in positions 1 and 2.

Since the positions of the vertical elements changed from one S- presentation to the next, the subject would have to scan the display for the vertical elements to perform the discrimination. There are two indices which suggest subjects scanned the display. One index is derived from the rates of responding to specific S- which failed to demonstrate pronounced preferences for specific patterns. A second index is based on the discrimination ratios which indicated that subjects were under good stimulus control for a range of values of numerosity and overlap of elements. If subjects failed to use many of the elements in the display to perform the discrimination, ratios would be lower, especially as overlap increased. Failure to scan all elements would also produce larger differences in the rates of responding to specific S- patterns.

If one S- was selected for each discrimination task, the performances on the tasks might have been very different. In such a case, subjects could learn the position of the distinctive feature and learn to recognize if a vertical or horizontal segment occurred in that position. If such a strategy had been used, subjects could disregard the remainder of the display, given that the position of the vertical elements remained constant across conditions. B.K. Cole (personal communication) has observed a similar performance by pigeons discriminating sets of five digit numbers in which only two of the five numbers were varied across S+ and S-. Testing of the discrimination included, among other variations, removal of the constant elements of the display with no disruption in the performance of the discrimination. His findings suggested that subjects were under stimulus control by those positions of the stimulus which covaried with the presence or absence of reinforcement. The data of the present experiment indicate that subjects were not selecting specific locations of elements, but utilized most of the elements to perform the discrimination.

Data collection included latencies which were measured in tenths of a second, from the onset of each three minute interval to the first response in that interval. The median latencies to S+ and S- were determined for each subject across sessions. The median of the median latencies to S+ and S- for the 21 sessions per discrimination task are presented in Table 10 for each subject. The numbers on the left and right of the slash represent the median S+ and S- latencies, respectively. In the majority of cases, the median S+ and S- latencies were less than three seconds. In nearly half of the cases, median S+ latency was longer than the corresponding S- latency. Although a few subjects had latencies which varied directly with the value of O, trends were not consistent across subjects.

The failure to show variation in the latency measures as a function of N and O should be viewed in the context of the other measures previously mentioned. It was shown that differential responding was a function of percent overlap and sequence of the task. Given that rates of responding were high during S+ and low during S- (see Tables 4 through 9), the differences between S+ and S- latencies can be explained in the following way. Once the subject was

Table 10. 21 day median latency in seconds

S+/S-

		0%	25%	50%	75%
	N=2	2.00/14.4		3.95/21.9	
33	N=4	2.15/.25	3.25/.55	2.80/3.20	2.40/2.60
	N=8	2.40/.10	2.55/.50	3.20/3.70	5.95/3.05
	N=2	1.95/15.70		1.65/1.50	
39	N=4	1.80/18.35	1.55/4.10	1.55/7.10	1.65/2.00
	N=8	1.75/.30	2.55/.60	2.95/1.00	3.50/3.70
	N=2	1.35/1.05		1.45/.80	
40	N=4	1.45/.65	1.45/.60	1.65/.80	2.65/1.52
	N=8	2.20/.50	2.95/1.20	2.15/2.20	2.25/1.85
	N=2	1.00/.90		.95/1.05	
104	N=4	1.60/8.80	1.60/1.40	1.35/1.70	1.30/1.30
	N=8	2.65/.60	2.50/.50	1.95/2.00	1.65/3.00
	N=2	3.6/91.3		3.05/9.95	
108	N=4	1.30/23.00	1.50/37.35	1.40/11.35	8.10/20.45
	N=8	2.25/48.15	2.40/27.05	1.20/3.70	1.85/3.35
	N=2	2.15/5.00		1.95/2.10	
110	N=4	1.65/.20	2.15/2.10	2.75/2.90	3.30/2.65
	N=8	2.20/.20	1.75/3.42	1.90/1.95	2.00/1.25

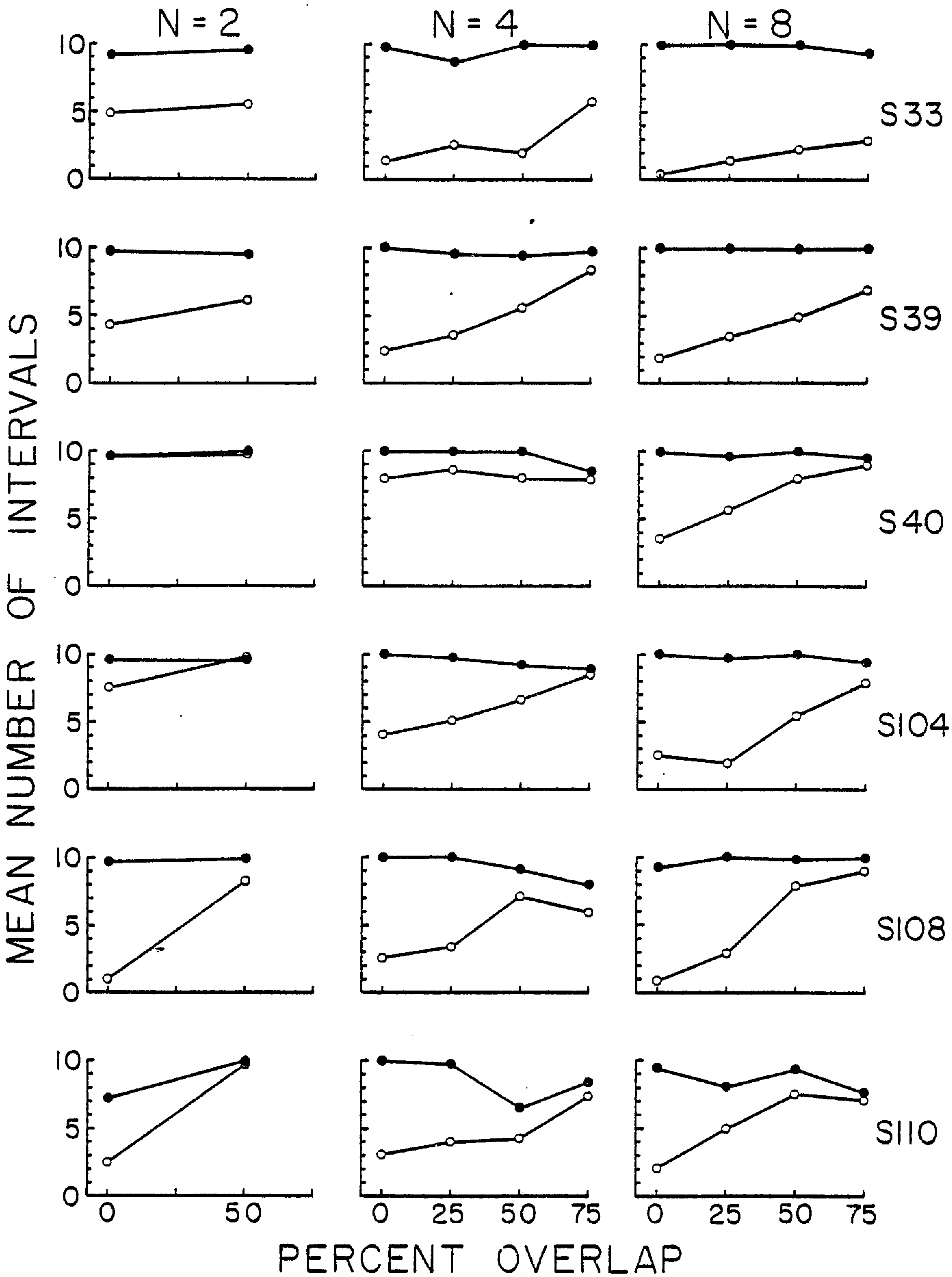
responding during S+, the tendency to continue responding might cause the subject's responses to run over from one S+ interval to a subsequent S- interval. This spilling over of responses might account for those latencies of one second or less, since the S+ rate of responding for many subjects was approximately 60 responses per minute. Conversely, given that the subject was not responding during a given S-, the tendency to not respond would carry over to a subsequent S+ which would partially account for those relatively long S+ latencies. These tendencies would not be affected by variations in numerosity and overlap which accounts for the present finding. (See Appendix C for changeover latencies.)

It was suggested previously that latencies to various stimuli may reflect the strategy for processing of the stimuli. If subjects used a serial strategy to process the stimuli, such processing would be reflected in latencies which varied as a function of N. If there were more items to process then more time would be necessary to process the entire display given that each item was processed prior to the next item. The present data do not support this hypothesis since the latencies did not vary as a function of N. A parallel search strategy would be reflected in latencies that did not vary as a function of N since all N items would be processed simultaneously. The S+ latencies suggest parallel processing because they were relatively similar across values of N and O. The S- latencies varied unsystematically across values of N and O which precludes conclusion about search strategies.

Figure 5 presents the mean for 21 sessions of the number of S+ and S- intervals per session which at least one response was made. A value of 10 would indicate that at least one response was made in each of the intervals (S+ or S-) while a value of zero would indicate no responses were made in any interval. In all but nine cases, the mean number of S+ intervals was between 9 and 10. Any variation in the mean number of S+ intervals was not associated with increasing values of N or O. However, the mean number of S- intervals increased as a function of O for a given value of N. Subjects tended to respond in more S- intervals as S+ and S- became more similar.

These data represent another measure of the relative difficulty of the discrimination tasks. When overlap was low, subjects did not respond in many S- intervals. As overlap increased there was an increase in the number of S- intervals with one or more responses. If this measure is considered in the context of the latency measures, the following explanation might account for an increase in the number of S- intervals sampled. The short latencies to S- suggest a spill over response from S+ intervals while long S- latencies may be the result of an incorrect decision to respond to the S-. In both cases, a single response in S- can account for the latency measure. These two measures should be considered in the context of the discrimination ratios. All three measures suggest that subjects responded

Figure 5. Mean number of S+ and S- intervals per session in which at least one response was made as a function of numerosity and overlap of elements. Filled circles correspond to mean S+ intervals and open circles correspond to mean S- intervals.


N = 2
N = 4
N = 8
S33
S39
S40
S104
S108
S110
MEAN NUMBER OF INTERVALS
PERCENT OVERLAP
0
5
10
0
50
0
25
50
75

at least once in more S- intervals and continued to respond during S- intervals as overlap of elements increased. Compared to the discrimination ratios, there was more variation in the number of S- intervals having at least a single response at the lower range of values of overlap. Both measures demonstrated effects of the variables despite the absence of systematic variation in latencies to S-.

Based on the data which have been presented, several conclusions can be made. The effects of overlap of stimulus elements are consistent across a range of values of numerosity. This suggests that the number of elements which distinguish two complex stimuli is less critical to the control of responding than the proportional relationship of the element between the two stimuli. In this context, behavior was affected by the relationships between discriminative stimuli rather than the individual attributes of each stimulus.

The data also suggest that the subjects relied on most of the elements of the complex stimuli. The high discrimination ratios reflect good stimulus control and the S- rates of responding suggest that control was shared by most elements. These data are consistent with a perceptual strategy which was discussed previously. The data obtained when numerosity and overlap were largest indicate that further increases in numerosity and overlap may force organisms to attend to fewer elements of the stimuli. Depending on the values selected, numerosity and overlap of elements could require organisms to rely on all elements or a few elements to perform a discrimination. In the present experiment the subjects were beginning to shift from control by all elements to control by a few elements at the extreme values of numerosity and overlap. Numerosity and overlap can change the complexity of stimuli and this can affect the ways in which organisms utilize the elements of the complex stimuli.

The data presented here demonstrate that numerosity and overlap of stimulus elements can alter discrimination acquisition and performance. These are two variables which can be manipulated parametrically and can produce changes in behavior. Selection of specific procedures and values of each variable provide opportunities to examine other experimental and theoretical issues in complex stimulus control.

Appendix A

Table 1. Rate of responding (responses per minute) across 210 sessions for S204, who was exposed to increasing values of overlap.

	Discrimination Tasks																	
	I		II		III		IV		V		VI		VII		VIII		IX	
Sessions	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-
1	36	7	64	7	58	2	59	4	66	5	61	16	56	0	59	1	60	6
2	59	20	68	9	74	1	73	4	98	4	57	20	59	0	55	2	65	7
3	66	7	80	8	61	1	70	1	80	3	65	8	65	0	78	1	69	3
4	60	1	57	10	64	0	69	3	74	5	68	11	64	0	73	1	72	6
5	52	1	46	2	75	1	62	2	78	4	51	17	62	0	69	1	65	7
6	80	2	50	1	78	1	62	2	80	2	46	9	51	0	81	2	59	5
7	63	3	52	5	68	2	45	6	89	4	50	9	50	0	73	1	59	6
8	58	8	42	2	77	0	78	4	75	1	45	8	56	0	71	1	52	8
9	53	1	41	2	74	0	91	2	71	2	40	11	43	0	67	1	47	6
10	26	1	47	3	67	0	88	4	64	1	59	16	44	0	69	1	39	3
11	31	30	45	10	65	0	84	1	63	1	58	13	47	0	80	1		
12	56	1	53	6	69	1	75	3	65	2	53	10	55	0	73	1		
13	57	1	49	4	72	1	73	1	64	2	52	17	52	0	61	1		
14	62	1	22	1	62	1	75	5	62	2	53	8	56	0	75	1		
15	34	1	46	3	62	0	77	1	69	4	60	4	65	0	77	2		
16	56	0	49	3	69	0	77	2	72	1	66	6	66	0	72	1		
17	58	1	51	9	71	0	68	1	55	1	68	9	62	0	76	1		
18	71	3	44	6	64	0	66	3	63	2	135	7	56	0	64	1		
19	65	2	62	8	71	1	74	1	66	3	41	2	68	0	68	1		
20	55	0	56	8	68	1	146	2	71	7	46	6	62	0	70	1		
21	69	1	41	6	69	0	91	1	68	3	54	8	63	0	62	1		

Appendix A

Table 2. Rate of responding (responses per minute) across 210 sessions for S105, who was exposed to decreasing values of overlap.

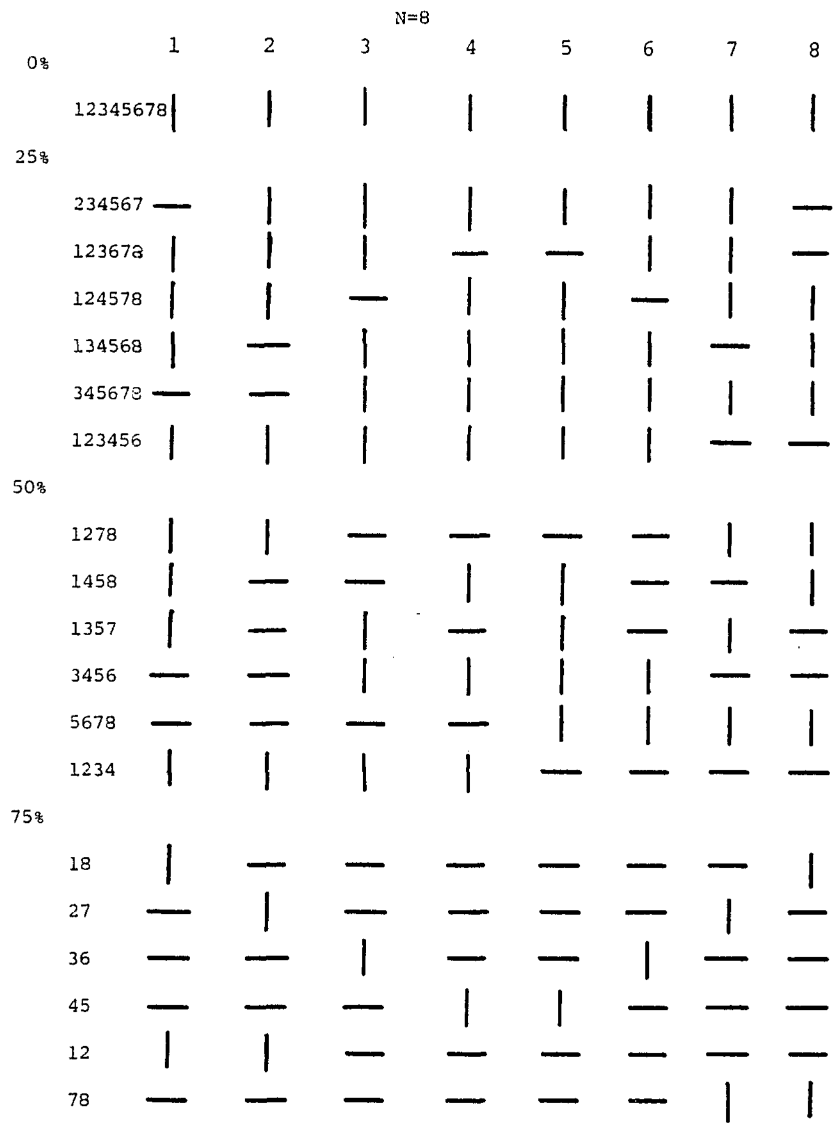
Discrimination Tosks

SESSIONS	I		II		III		IV		V		VI		VII		VIII		IX	
	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-
1	44	47	186	16	120	77	49	1	113	11	115	9	62	48	118	12	66	4
2	56	43	190	37	142	91	160	13	119	7	124	7	52	30	103	11	61	9
3	73	32	190	21	152	52	134	7	112	15	126	3	61	31	82	12	67	12
4	88	39	192	22	136	46	128	5	121	4	119	2	63	24	84	13	81	9
5	89	46	186	15	110	49	127	28	127	9	123	9	74	24	86	15	77	8
6	77	17	187	16	131	15	92	5	121	4	129	11	71	17	98	10	69	9
7	70	42	138	8	89	23	139	9	136	10	144	7	68	24	92	8	66	11
8	96	62	151	4	25	18	141	5	115	10	147	2	67	14	78	7	73	7
9	73	53	157	11	101	19	133	23	114	8	155	8	66	15	83	10	60	7
10	58	41	112	5	103	22	119	9	140	3	129	10	55	17	85	11	54	5
11	67	31	113	9	110	37	131	9	146	11	174	3	47	41	77	11	55	6
12	76	17	119	4	90	33	121	7	135	6	125	4	63	15	84	9	53	6
13	95	55	158	6	127	43	136	19	130	22	141	8	51	22	79	15	37	1
14	89	48	176	28	125	42	115	17	110	4	144	16	69	18	94	21	34	2
15	91	50	167	19	115	29	103	16	101	6	129	22	73	7	79	16	23	5
16	92	45	150	12	57	27	120	17	107	3	130	23	65	7	101	12	16	3
17	93	42	162	6	181	62	121	29	106	7	124	19	75	10	87	12	14	2
18	112	59	120	4	180	21	96	56	99	2	121	7	75	7	89	19	2	1
19	134	41	108	2	122	9	133	19	113	14	126	14	92	11	71	9		
20	161	47	132	3	98	8	122	22	117	6	144	33	93	15	78	15		
21	147	41	120	2	59	6	123	20	116	9	145	30	100	14	81	8		

Appendix B

Table 1. S- stimulus patterns

Percent Overlap		1	2	3	4	5	6	7	8
					N=2				
0%	4 5				│	│			
50%	4				│	—			
	5				—	│			
					N=4				
0%	3456			│	│	│	│		
25%	345			│	│	│	—		
	346			│	│	—	│		
	356			│	—	│	│		
	456			—	│	│	│		
50%	34			│	│	—	—		
	35			│	—	│	—		
	36			│	—	—	│		
	45			—	│	│	—		
	46			—	│	—	│		
	56			—	—	│	│		
75%	3			│	—	—	—		
	4			—	│	—	—		
	5			—	—	│	—		
	6			—	—	—	│		


N=8
1 2 3 4 5 6 7 8
0%
12345678
25%
234567
123678
124578
134568
345678
123456
50%
1278
1458
1357
3456
5678
1234
75%
18
27
36
45
12
78

Appendix C

Mean latencies in seconds of the first response in S- following S+ and the first response in S+ following S- and listed for each subject across the ten discrimination tasks.

Table 1. Mean latencies for S+ to S- stimulus change (number left of slash) and for S- to S+ stimulus change (number right of slash) for all subjects).

	Subjects					
	S33	S39	S40	S104	S108	S110
Task						
1	28.0/7.1	16.3/1.8	1.2/2.4	1.1/1.9	71.2/3.7	1.3/1.8
2	13.0/5.9	.3/2.5	.8/2.1	1.6/1.5	.1/9.8	86.4/10.8
3	.2/7.9	.2/6.5	.7/2.9	28.2/21.7	91.3/106.4	14.3/43.6
4	29.3/2.5	46.8/1.7	.6/2.2	21.7/12.2	43.2/3.3	1.8/9.3
5	24.6/6.2	47.1/1.7	.6/3.1	9.3/1.7	60.0/2.9	1.3/1.9
6	.6/5.4	24.4/4.3	0/85.8	14.9/1.8	11.3/4.8	.2/3.3
7	0/11.0	0/7.0	0/5.0	1.6/2.0	35.4/6.8	1.3/13.2
8	0/7.2	0/7.2	.2/6.7	23.6/2.5	23.3/1.5	19.2/15.3
9	14.7/8.8	1.4/7.7	13.8/4.8	1.0/3.3	24.0/5.0	9.5/40.0
10	1.0/28.8	1.4/12.0	.8/6.2	1.0/3.0	23.0/6.0	0/8.0

References

Attneave, F. _Applications of information theory to psychology_. New York: Holt, Rinehart & Winston, 1959.

Blough, D.S. Visual search in the pigeon: hunt and peck method. _Science_, 1977, _196_, 1013-1014.

Butter, C.M. Stimulus generalization along one and two dimensions in pigeons. _Journal of Experimental Psychology_, 1963, _65_, 339-346.

Egeth, H.E. Parallel versus serial processes in multidimensional stimulus discrimination. _Perception and Psychophysics_, 1966, _1_, 245-252.

Garner, W.R. _Uncertainty and structure as psychological concepts_. New York: John Wiley & Sons, Inc., 1962.

Mackintosh, N.J. Selective attention in animal discrimination learning. _Psychological Bulletin_, 1965, _64_, 124-150.

Neisser, U. Decision time without reaction time: experiments in visual scanning. _American Journal of Psychology_, 1963, _76_, 376-385.

Rabbit, P.M.A. Ignoring irrelevant information. _British Journal of Psychology_, 1964, _55_, 403-414.

Rabbit, P.M.A. Learning to ignore irrelevant information. _American Journal of Psychology_, 1967, _80_, 1-13.

Restle, F. Additivity of cues and transfer in discrimination of constant clusters. _Journal of Experimental Psychology_, 1959, _57_, 9-14.

Reynolds, G.A. Attention in the pigeon. _Journal of the Experimental Analysis of Behavior_, 1961, _4_, 203-208.

Shannon, C.E. A mathematical theory of communication. Bell System Technical Journal, 1948, 27, 379-423, 623-656.

Sternberg, S. High speed scanning in human memory. Science, 1966, 153, 652-654.

Sutherland, N.S. Visual discrimination in animals. British Medical Bulletin, 1964, 20, 54-59.

Thorndike, E.L. Educational Psychology, Vol. II. New York: Teachers College, Columbia University, 1910.

Wagner, A.R., Logan, F.A., Haberlandt, K., and Price, T. Stimulus selection in animal discrimination learning. Journal of Experimental Psychology, 1968, 76, 171-180.

Wilkie, D.M. and Masson, M.E. Attention in the pigeon: a reevaluation. Journal of the Experimental Analysis of Behavior, 1976, 26, 207-212.