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The What and the Where of the Pigeon's Processing of Complex Visual Stimuli

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Eight pigeons were trained on a go–no go visual discrimination involving 1 S^+ and 15 S^-s. The 16 discriminative stimuli were black-and-white line drawings created by the factorial combination of 4 different geometric shapes (wedge, cylinder, cone, handle) in 4 different spatial locations (right, left, above, below) in relation to a common shape (cube). All of the pigeons readily learned this complex visual discrimination. Each bird's pecking behavior was controlled by both attributes of the line drawings, but somewhat stronger stimulus control was exerted by the location of the added component than by its shape. Across all 8 pigeons, there was an inverse relation between stimulus control by component shape and component location. These results document pigeons' joint processing of "what" and "where" information in visual discrimination learning.

Largely on the basis of the effects of damage to the temporal and parietal lobes in human and nonhuman primates, Ungerleider and Mishkin (1982) formalized one of the most prominent hypotheses in contemporary behavioral neuroscience, "that the ventral or occipitotemporal pathway is specialized for object perception (identifying *what* an object is) whereas the dorsal or occipitoparietal pathway is specialized for spatial perception (locating *where* an object is)" (p. 549). The general notion of parallel visual processing was suggested long before Ungerleider and Mishkin's formal proposal (Breitmeyer, 1992), and it has undergone substantial refinement and revision as a great deal more anatomical, physiological, and behavioral evidence has accumulated (Brannan, 1992; Goodale & Milner, 1992; Grossberg, Mingolla, & Ross, 1994; Livingstone & Hubel, 1988; Zeki, 1993).

In the realm of behavioral science, increased experimental attention is presently being paid to the related problem of the role of component shape and location in complex visual discrimination learning (Brown & Dooling, 1993; Wasserman, Kirkpatrick-Steger, Van Hamme, & Biederman, 1993; Watanabe & Ito, 1991). A key concern of this area of behavioral science has been with how the components of complex visual stimuli, such as natural and humanmade objects, contribute to animals' recognition of those stimuli. This research was made especially salient by Cerella's (1980) claim that pigeons attend only to the component parts of pictorial stimuli, not to their spatial organization. Here, matters of "what" and "where" do not involve integrated stimuli located in decidedly different regions in space but instead involve indivisible geometric components that are spatially concatenated to create discriminably and functionally different objects, as when the same two components or "geons" are differently configured to construct a cup or a pail (Biederman, 1987). Structural accounts such as Biederman's theory of recognition by components propose that what an object is critically depends on the shape of its component parts and on the location of those parts in relation to one another.

Our own research (Wasserman et al., 1993, Experiment 1) has not only substantiated the importance of component shape in pigeons' pictorial discrimination learning, but it has also disclosed that component location prominently participates in that learning. There, we first trained pigeons with a four-alternative forced-choice procedure to discriminate line drawings of four humanmade objects: a desk lamp, an iron, a sailboat, and a watering can, objects with which we were quite sure that our pigeons had had no prior experience. Each of these objects comprised four separate components. After discrimination learning to about 80% correct, we tested the birds with new drawings of the same four objects, in which the same components appeared, but in different spatial arrangements. Accuracy dropped to 52%. The reliable drop in accuracy testifies to the stimulus control exerted by component location; the fact that accuracy still reliably exceeded the chance level of 25% testifies to the stimulus control exerted by component shape.

Although these results indicate that pigeons do jointly process component shape and location, they do not address at least two remaining questions about such joint stimulus control: (a) What is the relative role played by shape and location information? (b) Is there attentional trade-off be-

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tween the control exerted by one kind of visual information and the other?

We explored these two unanswered questions in the present project, which further developed a new method to study complex discrimination learning in nonhuman animals (predecessors of our procedure can be found in the research of Astley & Wasserman, 1992, and Chatlosh & Wasserman, 1993). Unlike prior discrimination learning methods (e.g., Wasserman et al., 1993), in which subjects could have attended to either or both the shape and the location of the components of a pictorial stimulus, this one encourages subjects concurrently to attend to both aspects of a stimulus.

Our method is best appreciated in conjunction with the visual stimuli shown in Figure 1. This figure depicts 16 different line drawings created by placing four different shapes (wedge, cylinder, cone, and handle) in four different locations (right, left, above, and below) in relation to a common or reference shape (cube). One of these two-component line drawings—for example, the wedge to the right of the cube—is chosen to be the positive stimulus (S^+) of a successive or go–no go discrimination; the other 15 two-component line drawings are chosen to be the negative stimuli (S^-s). If subjects treat each of the S^-s alike, then errors of commission should be the same to all of the S^-s; if, on the other hand, subjects perceive some of the S^-s as more similar to the S^+ than others, then those S^-s should attract a preponderance of errors.

From the perspective of factorial design, selective attention to what the accompanying component is versus where it is located should be disclosed by differential responding to stimuli in the columns and rows of Figure 1. First, given that the wedge-right stimulus is the S^+, more responding to stimuli in the leftmost column than to stimuli in any of the other three columns would suggest that the subject attended to the shape accompanying the cube; more responding to stimuli in the topmost row than to stimuli in any of the other three rows would suggest that the subject attended to the location of the accompanying component. Second, more responding to stimuli in the leftmost column than to stimuli in the topmost row would suggest that the subject attended more to the shape of the component accompanying the cube than to the location of the accompanying component; more responding to stimuli in the topmost row than to stimuli in the leftmost column would, on the other hand, suggest that the subject attended more to the location of the accompanying component than to the shape of the component accompanying the cube. Finally, selective attention to what a component is versus where it is located might also show trade-off; the more attention is paid to one aspect of the composite drawing, the less may be paid to the other.

We gave this task to 8 pigeons, a species that is now attracting increasing interest in the fields of comparative cognition (Wasserman, 1991, 1993) and behavioral neuroscience (Zeigler & Bischof, 1993). All of the birds readily learned to respond to the S^+ drawing and to refrain from responding to the S^- drawings. In the course of discrimination learning, disproportionate errors were committed to those S^-s that shared either a common component or the same spatial organization as the S^+, thus disclosing conjoint control by the shape and the location of the component adjoining the cube. Additionally, individual birds showed differential control by what component accompanied the common cube and by where that component was located. Ordering these attentional preferences from one extreme to the other suggested that there was indeed a trade-off between the pigeons' processing of shape and location information.

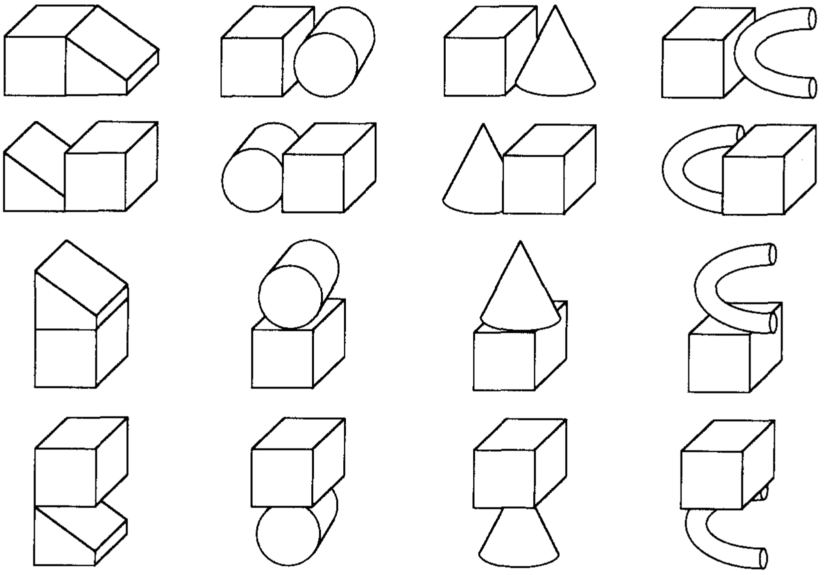

Figure 1. The 16 line drawing stimuli shown to the pigeons.

Method

Subjects

The subjects were 8 feral pigeons maintained at 85% of their free-feeding body weights by controlled daily feeding. The pigeons had previously served in unrelated studies involving different visual stimuli in conventional Skinner boxes that were outfitted with microswitch-activated pecking keys and solenoid-operated grain hoppers. Just prior to the present project, the birds were taught to peck the touch screen and to consume food pellets from the rotary dispenser (see the *Apparatus* section).

Apparatus

We trained the pigeons in four specially constructed chambers. One plywood wall of each chamber contained a large opening with an aluminum frame attached to the outside of the box. The frame held a clear touch screen (Elmwood Sensors DuraTouch Model 70056-001) that was coated with mylar for durability (see Allan & Zeigler, 1989, for more about touch technology in animal behavior research); pecks on the touch screen were processed by a serial controller board (Elographics Model E271-2200). A brushed aluminum panel was placed directly in front of the touch screen to allow the pigeons access to circumscribed portions of a video monitor (13-in. AppleColor™ High-Resolution RGB) that was located 0.9 cm behind the touch screen at its center and 1.1 cm at the outer edges (the difference being due to the slight convex curvature of the face of the monitor). There were five openings in the panel, but we used only the 7 × 7 cm central display area in which the two-component pictures appeared. A clear Plexiglas food cup was centered on the rear wall of the chamber; to discourage the pigeons from perching on the food cup, it was recessed into the wire mesh floor so that the top of the cup was level with the floor. A pellet dispenser (MED Associates Model ENV-203M) delivered 45-mg Noyes pigeon pellets through a vinyl tube into the food cup. A houselight, mounted on the upper rear wall of the chamber, provided constant illumination during experimental sessions. The houselight and pellet dispenser were controlled by a digital I/O interface board (National Instruments Model NB-DIO-24).

For two chambers, control of peripheral stimuli (via the I/O interface) and recording of subjects' responses (via the serial controller board) were accomplished by two Apple Macintosh IIci computers. A video splitter (Network Technologies Model Vopex 2M) connected each computer to the pigeon's monitor and to an identical monitor located in an adjacent room. For the other two chambers, control of peripheral stimuli and recording of subjects' responses were accomplished by two Apple Macintosh Quadra 650 computers. A distribution amplifier (Extron Model MAC/2 DA2) connected each computer to the pigeon's monitor and to an identical monitor located in an adjacent room. Programs were developed in HyperCard 2.2.

Visual Stimuli and Experimental Design

The 16 two-component drawings depicted in Figure 1 were developed in artWORKS™ (Deneba Systems, Inc.). These drawings were the result of placing four different shapes (wedge, cylinder, cone, and handle) in four different locations (right, left, above, and below) in relation to a common shape (cube). The maximum height or width of each drawing was 3.7 cm on the viewing screen; the minimum height or width was 2.3 cm. The drawings always appeared in the center of the viewing screen.

From this pool of 16 drawings, 4 were selected to serve as the S^+ of a successive or go–no go discrimination: wedge-right, cylinder-left, cone-above, and handle-below. Two pigeons received each of these four discriminations, which necessarily involved different combinations of drawings as the 15 S^-s. We created four different discriminations so that our results would have greater generality than would have been the case had we studied only one.

Procedure

Baseline training. From 4 to 8 days of baseline training were given prior to discrimination training to guarantee that the pigeons were responding at high rates to all 16 pictorial stimuli. Discrimination learning would then be manifested as a decrease in erroneous responses to the 15 S^- drawings.

During baseline training, there were 240 trials in each daily session. These trials were organized into 10 randomized blocks of 24 trials each. Those 24 trials involved 8 (unscored) presentations of the to-be-S^+ drawing plus 1 (scored) presentation of each of the 16 drawings in the 4 × 4 matrix shown in Figure 1. The 16 drawings from the 4 × 4 stimulus matrix assumed a special status for us, for they allowed us to measure responding to each of the S^+ and S^- drawings during later discrimination training in precisely the same way for each of the 4 pictorial discriminations on the same number of trials; however, they had no special status for the subjects in baseline training. So, functionally, there were 9 presentations of the to-be-S^+ and 15 presentations of the to-be-S^-s in each of the ten 24-trial training blocks.

Each trial in baseline training began with the white illumination of the viewing screen. The first peck darkened the screen for 1 s and then illuminated the screen with one of the 16 black-on-white drawings shown in Figure 1; our goal here was to make sure that the pigeon was oriented to the viewing screen when the picture was first shown, so that responding during the ensuing 15 s would not be confounded by the bird's orientation to the viewing screen at trial onset. The first peck after 15 s delivered one pellet of food, changed the screen image to a white-on-black drawing of the picture for 1 s to signal the delivery of the food pellet, and initiated an intertrial interval averaging 10 s (range: 5 to 15 s). Only responses during the first 15 s of picture presentation were recorded and only on the 16 predetermined trials involving each picture from the 4 × 4 matrix within each 24-trial training block.

Discrimination training. During discrimination training, there were again 240 trials in each daily session. These trials were also organized into ten randomized blocks of 24 trials each. Those 24 trials involved 8 (unscored and reinforced) presentations of the S^+ drawing plus 1 (scored and unreinforced) presentation of each of the 16 drawings in the 4 × 4 matrix shown in Figure 1. So, functionally, there were 9 presentations of the S^+ (8 reinforced and 1 unreinforced) and 15 presentations of the S^-s (all unreinforced) in each of the ten 24-trial training blocks.

Each reinforced S^+ trial in discrimination training was exactly like trials in baseline training and involved from one to three food pellets for individual birds; the increase in the number of pellets was necessitated by the decrease in the percentage of reinforced trials from 100% to 33%. Each unreinforced trial in discrimination training began with the white illumination of the viewing screen. The first peck darkened the screen for 1 s and then illuminated the screen for 15 s with one of the 16 black-on-white drawings in Figure 1. When the scoring period ended, 1 s more of picture presentation was begun to equate stimulus presentation time on reinforced and unreinforced trials, and the intertrial interval was initiated. Only responses during the first 15 s of picture presentation were recorded and only on the 16 predetermined trials involving each picture from the 4 × 4 matrix within each 24-trial training block.

Results

Baseline Training

During baseline training, the pigeons responded at high rates to all 16 pictorial stimuli that they were shown. Examining only the 10 scored presentations of each of the 16 drawings depicted in Figure 1 on the final day of baseline training disclosed the following results. First, responding to the to-be-S^+ averaged 99.7 pecks per minute (range: 60.4 to 145.6 pecks per minute). Second, in relation to the to-be-S^+, the mean percentage of response that individual birds exhibited to the most responded to of the to-be-S^-s was 115% (range: 106 to 131%). Third, in relation to the to-be-S^+, the mean percentage of response that individual birds exhibited to the least responded to of the to-be-S^-s was 86% (range: 81 to 90%). So, generally, the birds responded to the to-be-S^-s within the range of ±15% of their response to the to-be-S^+.

Discrimination Training

During discrimination training, the pigeons continued to respond to the S^+ drawing at high rates, whereas responding to the 15 S^- drawings fell. Most important, the speeds at which response rates fell to the different S^-s differed systematically depending on whether the S^- drawing contained the same added shape as the S^+ and whether the added shape was in the same location in relation to the cube as the accompanying shape in the S^+ drawing.

Gaining an appreciation of the systematic nature of the stimulus control acquired by what and where information required that performance be examined after discrimination learning had begun, but before discrimination learning was complete. Prior to the onset of discrimination learning, the pigeons responded quite similarly to the S^+ and to the S^- drawings; subsequent to discrimination mastery, the pigeons responded primarily to the S^+ drawing. After trying many alternative strategies, we adopted the following rule of thumb for selecting sessions for data analysis: We examined the run of consecutive daily sessions that began with the first session on which responding to at least one S^- fell below 67% of the rate to the S^+, that ended with the first session on which responding to all 15 S^-s fell below 33% of the rate to the S^+, and that entailed no reversion of discriminative performance to any S^- above the 67% level of response to S^+. (The final stipulation guaranteed that the progression toward highly discriminative performance did not entail any "false starts.")

Data from these sessions are shown in Tables 1, 2, 3, and 4, with subjects paired in terms of the specific drawing that served as the S^+. To facilitate the comparison of different birds' performance whose absolute rate of pecking and whose number of scored sessions differed from one another, these tables depict responding to each of the 16 drawings as the percentage of total responses to all of the 16 drawings. Several features of the organization and contents of the tables are noteworthy.

First, discrimination learning was very rapid with a mean of only 11.25 sessions (range: 5 to 26) elapsing before responding to all 15 S^-s fell below 33% of the rate to the S^+. Given that the first session of the scored run had a mean of 3.88 (range: 1 to 15), the mean number of sessions whose data are included in these tables was 8.38 (range: 4 to 12).

Second, the upper left entry in each bird's table indicates the percentage score for the S^+ drawing. That percentage was in all cases the largest entry (ranging from 10.47 to 29.21%), showing that the pigeons pecked the S^+ much

Table 1
Percentage of Total Pecks to All 16 Stimuli in Training Set for the Two Birds That Received Handle-Below Drawing as Their S^+

Component location	Added component				Sum
		Bird 1[a]			
	Handle	Wedge	Cone	Cylinder	
Below	15.61	6.00	4.96	5.46	32.03
Right	10.39	5.05	4.89	4.95	25.28
Above	6.23	5.67	5.60	4.79	22.29
Left	5.99	4.85	4.93	4.60	20.37
Sum	38.22	21.57	20.38	19.80	99.97
		Bird 8[b]			
	Handle	Cylinder	Cone	Wedge	
Below	10.47	6.18	7.35	7.58	31.58
Right	9.42	5.87	5.36	5.78	26.43
Above	6.19	6.22	5.66	4.87	22.94
Left	5.23	5.03	4.37	4.42	19.05
Sum	31.31	23.30	22.74	22.65	100.00

Note. [a] 16,113 total pecks from Day 1 to Day 10. [b] 26,840 total pecks from Day 4 to Day 14.

Table 2

Percentage of Total Pecks to All 16 Stimuli in Training Set for the Two Birds That Received Wedge-Right Drawing as Their S^+

Component location	Added component				Sum
	Bird 2[a]				
	Wedge	Cylinder	Cone	Handle	
Right	18.69	11.70	8.18	6.04	44.61
Left	6.54	5.45	6.48	4.95	23.42
Above	5.12	3.47	4.53	4.00	17.12
Below	4.14	2.82	3.87	4.03	14.86
Sum	34.49	23.44	23.06	19.02	100.01
	Bird 7[b]				
	Wedge	Cone	Cylinder	Handle	
Right	17.43	10.02	10.42	6.21	44.08
Left	5.98	5.26	5.95	5.30	22.49
Below	4.62	4.57	3.87	4.02	17.08
Above	5.46	3.95	3.20	3.75	16.36
Sum	33.49	23.80	23.44	19.28	100.01

Note. [a] 6,955 total pecks from Day 3 to Day 6. [b] 21,749 total pecks from Day 3 to Day 14.

more than they pecked any of the S^-s (a chance score here would be 6.3% in any of the 16 cells).

Third, the specific orders of shapes and locations that appear in each column and row for each pigeon were determined by the marginal totals, with the column and row designations ordered from the highest to the lowest marginal totals. For each pigeon, those orderings eventuated in the highest marginal scores for the shape and the location represented in the S^+ drawing. Those pairs of pigeons receiving the same discrimination never gave the same high-to-low ordering of shapes; in two of the four pairs, they did give the same ordering of locations.

Fourth, there is clear evidence of discriminative control by component shape and location even if the S^+ is excluded from data analysis. Here, we rank ordered the scores in each of the three rows (to assay control by component shape) and columns (to assay control by component location) that did not involve the S^+. In Table 1, for example, within each of the rows Right, Above, and Left, Bird 1 always responded most to the Handle component; similarly, within the three columns Wedge, Cone, and Cylinder, Bird 1 responded most, secondmost, and most to the added component Below the cube, respectively. Across all 8 pigeons, the mean rank of the correct shape (given the incorrect location) was 1.38, and the mean rank of the correct location (given the incorrect shape) was 1.25. These ranks are far less than the 2.50 expected by chance ($\chi^2 = 32.00$ for shape and $\chi^2 = 43.56$ for location, both $ps < .001$).

Fifth, for 7 out of the 8 birds, the marginal score for the location of the added component in the S^+ drawing generally exceeded the marginal score for the shape of the added component (two-tailed binomial $p < .07$). All of this evidence suggests that both component shape and location in the pictorial stimuli controlled the birds' pecking behavior

Table 3

Percentage of Total Pecks to All 16 Stimuli in Training Set for the Two Birds That Received Cone-Above Drawing as Their S^+

Component location	Added component				Sum
	Bird 3[a]				
	Cone	Cylinder	Wedge	Handle	
Above	18.52	13.49	13.77	8.58	54.36
Below	3.85	8.14	5.45	2.29	19.73
Left	4.82	4.07	4.45	4.18	17.52
Right	2.26	2.17	2.42	1.52	8.37
Sum	29.45	27.87	26.09	16.57	99.98
	Bird 6[b]				
	Cone	Wedge	Cylinder	Handle	
Above	29.21	15.04	4.62	2.48	51.35
Left	9.44	4.31	3.19	3.17	20.11
Below	3.17	4.21	3.44	3.65	14.47
Right	4.21	3.17	3.65	3.02	14.05
Sum	46.03	26.73	14.90	12.32	99.98

Note. [a] 23,796 total pecks from Day 1 to Day 10. [b] 6,682 total pecks from Day 2 to Day 5.

Table 4
Percentage of Total Pecks to All 16 Stimuli in Training Set for the Two Birds That Received Cylinder-Left Drawing as Their S^+

Component location	Added component				Sum
		Bird 4[a]			
	Cylinder	Handle	Wedge	Cone	
Left	17.01	11.81	7.01	6.32	42.15
Right	6.86	6.38	7.25	6.07	26.56
Above	7.07	4.47	2.88	3.19	17.61
Below	3.33	3.06	3.25	4.03	13.67
Sum	34.27	25.72	20.39	19.61	99.99
		Bird 5[b]			
	Cylinder	Handle	Cone	Wedge	
Left	24.47	14.12	7.45	6.36	52.40
Right	5.06	4.67	3.96	4.17	17.86
Above	7.42	3.57	2.99	2.87	16.85
Below	4.34	2.62	3.19	2.73	12.88
Sum	41.29	24.98	17.59	16.13	99.99

Note. [a] 24,613 total pecks from Day 15 to Day 26. [b] 7,923 total pecks from Day 2 to Day 5.

and that the latter exerted somewhat stronger stimulus control than the former.

A final fact can be gleaned from the contents of Tables 1–4. If we correlate the marginal stimulus control exerted by component shape with that exerted by component location across all 8 pigeons—taking each bird's topmost row and leftmost column sums (after subtracting the common S^+ score from each total)—that correlation is −.838 (Spearman r, $p < .001$). This significant negative correlation suggests that the more stimulus control was gained by one aspect of the line drawings, the less control was gained by the other, a classic attentional trade-off.

Discussion

Our pigeons' successful mastery of the present complex visual discrimination indicates that their pecking behavior was jointly controlled by the shape and the location of one component that accompanied another common or reference form in two-component line drawings. This conjoint stimulus control was rapidly established. Despite the fact that all of the birds showed clear stimulus control by both the shape and the location of the added component, across birds there was a statistically significant negative correlation in such stimulus control; apparently, the more attention that a pigeon pays to what a component is, the less attention it pays to where the component is located, at least during the early phase of discrimination learning.

There are several points that deserve discussion in connection with these findings. First, conjoint control by the shape and the location of the components of a stimulus accords with other demonstrations of conjoint stimulus control in pigeons using a variety of different experimental procedures (e.g., Blough, 1993; Chatlosh & Wasserman, 1993; Riley & Roitblat, 1978; Wasserman, Grosch, & Nevin, 1982). Given the many different situations in which it has now been observed, such conjoint stimulus control cannot be considered to represent an isolated and exceptional finding; instead, there is good reason to believe that animals are able to concurrently process a broad range of stimulus information in their complex environments.

Second, despite the long-standing use of matching-to-sample procedures, the present discrimination method is also effective in showing attentional trade-offs (see Chatlosh & Wasserman, 1993, for additional evidence of attentional trade-offs involving the pigeon's concurrent processing of color, time, and orientation information). This new method may even prove to be preferable, as it does not appear to be subject to many of the troubling confoundings, such as primary stimulus generalization decrement, that have plagued the use of the otherwise powerful and versatile matching-to-sample procedure (Riley & Brown, 1991).

Third, the very clear evidence that we obtained here for the pigeon's processing of location information joins other recent findings showing that spatial relations do gain control over birds' pecking behavior (e.g., Brown & Dooling, 1993; Wasserman et al., 1993; Watanabe & Ito, 1991). It can no longer be concluded that the pigeon is purely a "particulate" processor of visual information, one that is oblivious to global or organizational properties of the visual environment (cf. Cerella, 1980).

Fourth, our pigeons actually evidenced somewhat stronger stimulus control by where a component was located than by what the shape of the component was. Is it possible that we happened to choose shapes to add to the reference cube that were especially difficult for the pigeons to discriminate? Maybe. We obviously know very little about the discriminability of these or other geons we could have chosen to study. We did, however, do our best to select geons that differed from one another in a determinate way. In accord with Biederman's (1987) theory of recognition by components, each of the selected geons differed from one another in at least one nonaccidental structural property.

This selection process should have ensured highly discriminable stimuli.

Is it also possible that our having given perspective to the line drawings by placing them at an angle might have put stimulus control by the added shapes at a competitive disadvantage, because in half of the drawings (cube-right and cube-above) the added component was partially obscured? Perhaps. Any effort to use at least modestly realistic stimuli will run into the inevitable conflict between experimental control and verisimilitude. Nevertheless, within the constraints of the present experimental materials, we examined this issue by separately calculating the stimulus control exerted by component shape and component location for those pigeons whose S^+ involved an obscured view (Birds 1, 4, 5, and 8) or an unobscured view (Birds 2, 3, 6, and 7) of the added component. One might suspect that birds with an obstructed view of the added component might show less stimulus control by its shape and more control by its location than would birds with an unobstructed view of the added component. The mean marginal scores of the birds with an obscured view of the added component (for shape, 36.27 and for location, 39.54) actually showed more equitable stimulus control by its shape and location than did the mean marginal scores (for shape, 35.87 and for location, 48.60) of the birds with an unobscured view of the added component, which showed stronger stimulus control by the location of the added component than by its shape. Although the scores of these two subgroups did not differ significantly from one another, these results nevertheless argue against our having handicapped stimulus control by component shape through the use of perspective drawings.

Also arguing against any special role being played by pictures containing intact views of the component stimuli are the generalization data of the 4 pigeons trained with S^+ drawings affording an unobstructed view of the added component. One might suspect that these birds would more strongly generalize responding to pictures with unobstructed views of the added component than to pictures with obstructed views of the added component. So, Birds 2 and 7, whose S^+ was wedge-right, should have pecked most to wedge-above among all three S^-s depicting wedges (wedge-left, wedge-above, and wedge-below), which they did not. Birds 3 and 6, whose S^+ was cone-above, should have pecked most to cone-right among all three S^-s depicting cones (cone-right, cone-left, and cone-below), which they did not.

Finally, we know of no data indicating that pigeons, like primates, process different kinds of visual information in different neural pathways. It therefore becomes all the more imperative to pursue the pigeon's visual discrimination behavior at the neural level. That pursuit may be greatly aided by our new discrimination technique. This technique may afford unique advantages to researchers interested in elucidating the biological bases of complex visual processing, because it assesses stimulus control by multiple kinds of visual information within individual subjects within individual sessions. A host of confounding factors may thereby be eliminated in efforts to pinpoint control by several kinds of stimulation. Our method may not only prove to be useful for understanding how an object's component parts combine to create the perception of an intact object, but it can easily be modified to explore the behavioral control exerted by the location and identity of an integrated stimulus comprising many components. We do hope that this promise will be realized by those interested in elucidating distributed visual processing by the central nervous system.

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