*COLOR PREFERENCE IN PIGEONS: STIMULUS
INTENSITY AND REINFORCEMENT CONTINGENCY
EFFECTS IN THE AVOIDANCE OF BLUE STIMULI*

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In a procedure intended to determine color preference in pigeons (which partially replicated Catania, Owens, & von Lossberg, 1983), two keys were illuminated by different colors drawn from a set of amber, red, green, or blue stimuli; this was followed by the presentation of grain when either of the two colors was pecked. The grain was illuminated alternately across trials with the colors presented on the keys. In Experiment 1 the intensity of the color stimuli used was not equalized, whereas in Experiment 2 the intensity of the colors was equalized. The low preference for blue found in Experiment 1, as measured by differential key pecking, was not found in Experiment 2. The discriminability of the intensity-equalized colors was confirmed in Experiment 2a, in which equal-intensity color discrimination problems were presented. In Experiment 3, as in Catania et al. (1983), a response-independent reinforcement schedule was used, but with intensity-equalized colors. In contrast to Experiment 2, very low preference for blue was found here and in Experiment 4, which used a within-subject procedure. These findings suggest that pigeon color preference may be a function of intensity, but all controlling variables have not as yet been identified.

Key words: color preference, keylight intensity, reinforcement contingency, key color, two-key procedure, discrete trials, feeder, key peck, pigeons

Catania, Owens, and von Lossberg (1983) reported that pigeons preferred red and amber keys to green and blue keys when preference was defined either as the total number of pecks or the proportion of responses on a given color stimulus, relative to another (Catania et al., 1983, p. 253). When the intensity of the color stimuli was varied, however, color preferences were reduced and in some cases even reversed. Catania et al. manipulated intensity by varying the voltage across lamps, increasing the intensity of blue and green and decreasing the intensity of amber and red. These authors suggested that differential responding could have

been a function of chromatic properties rather than intensity (Catania et al., p. 255) because altering current changes color as well as intensity. The purpose of Catania et al. was to investigate pigeon color preference in the context of autoshaped behavior (Brown & Jenkins, 1968). Clearly, color preference and other response biases are relevant to any study of operant behavior using key color as a discriminative stimulus.

The present study involved a systematic analysis of the role of intensity in pigeon color preference. In Experiment 1, a partial replication of Catania et al. (1983) was attempted using color stimuli of specified wavelengths. In Experiment 2, the possible confounding effect of intensity was controlled by equating intensity for all color stimuli used, and in Experiment 2a, the discriminability of the equal-intensity color stimuli used in Experiment 2 was assessed. Experiment 3 investigated the role of reinforcement contingency in the detection of color preference. Finally, in Experiment 4, a within-subject procedure was used to assess color preference in the context of equal and unequal stimulus intensity and response-dependent and -independent reinforcement.

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Table 1
Specifications of color filters.

Stimulus	Filter number	Dominant wave-length (in nm)	Percent transmittance	Intensity (in lx)
Amber	15	585	75.5	2,800
Red	25	617	22.5	2,200
Green	58	538	19.5	850
Blue	47	470	1.2	350

Note. Filter numbers are from Eastman Kodak Co., no. 15—catalog no. 149 5548, 25—catalog no. 149 5605, 47—catalog no. 149 5787, 58—catalog no. 149 5860. Percent transmittance was provided by Eastman Kodak Company.

EXPERIMENT 1

METHOD

Subjects

Six adult, experimentally naive, male White King pigeons served and were maintained at approximately 80% of their free-feeding weights.

Apparatus

An automated experimental chamber (Grason-Stadler model no. E6446 CA-1, 32 cm wide, 34 cm high, and 35 cm deep) was modified so that two 2.5-cm response keys were separated by 6.5 cm and were 23 cm above the grid, as in the study by Catania *et al.* (1983). A standard Gerbrands feeder was centered below the keys. The surfaces of the experimental chamber were brushed aluminum and plastic with low reflectivity. The chamber was housed in a ventilated, noise-attenuating case with white noise delivered through a speaker in the chamber. A white houselight was illuminated at the start of each experimental session and remained on throughout. Color stimuli were presented via IEE one-plane readout in-line projectors modified with Kodak Wratten® gelatin filters in amber (A), red (R), green (G), and blue (B). The specifications of these filters are given in Table 1. Intensity was varied through a potentiometer system that independently regulated each color stimulus. In the present experiment, each 7.5-W stimulus lamp was set at its maximum and judged to be approximately equal in intensity by four observers. (Within each projector four bulbs were used and were inspected daily before each session. Observers agreed that each bulb was equally bright before use; bulbs were replaced

as necessary.) Intensity measurements are also given in Table 1. Throughout the study, light intensity was measured by a Gossen Lunasix 3® meter placed directly on each key. A lens system and a similar arrangement of filters provided identical colors, alternating trial by trial, for the illuminated food magazine.

Procedure

Each pigeon was trained to eat grain from a food magazine with a white lamp illuminating the magazine when the feeder was accessible. During magazine training, 5-s access to grain was provided on a (response-independent) variable-time (VT) 30-s schedule. Magazine training terminated when pigeons were observed to have eaten from the magazine on five consecutive opportunities. Subjects then received six sessions, each consisting of 60 illuminated key and grain magazine pairings. An intertrial interval (ITI) of 24 s followed each trial, in which the sequence of events was either the illumination of the keys for a maximum of 3 s, a peck to one of the two keys followed by immediate access to the food hopper for 3 s followed by a 24-s ITI, or no peck during the 3-s key illumination followed by 3-s access to the hopper at the offset of the illumination. In each session a different pair of colors appeared on the keys, and each subject was exposed to all possible paired comparisons. Each pigeon received 360 trials with two colors on each trial, so that each color was presented 180 times. The position of a particular color was randomized over the 60 pairings within each session so that there was a 50% probability that the same color would appear on the same key on pairing *N* and *N* + 1. The two colors used in each session alternated in illuminating the grain magazine, changing each time the magazine was operated. These stimulus arrangements follow Catania *et al.* (1983, p. 252, Table 1, p. 253). Preference was determined by the number of responses to each color.

RESULTS AND DISCUSSION

The proportion of trials with at least one key peck on a given color is given in Table 2; blue was clearly the color least responded to by each pigeon. Overall, amber was responded to in 61% of pairings, red was chosen in 52% of pairings, green in 42%, and blue in only 4% of pairings (means, Table 2). This is compa-

Table 2

Proportion of trials with a peck on a given key color across all pairings of each color in Experiment 1. A, amber; R, red; G, green; B, blue.

Sub- ject	A	R	G	B	Percent trials with keypeck	Left pecks (left/ total)
1	.58	.29	.40	.00	64	.53
2	.47	.28	.68	.01	72	.44
3	.74	.78	.29	.07	94	.31
4	.75	.68	.47	.05	97	.75
5	.30	.55	.33	.09	64	.68
6	.83	.55	.37	.02	88	.57
Mean	.61	.52	.42	.04	80	.54
Catania et al. (1983, Table 2) means:						
	.58	.55	.22	.17		.52

table but not identical to the outcome reported by Catania et al. (1983, Table 2). Analysis of variance showed a significant "color" preference effect, $F(3, 15) = 6.39$, $p < .01$. A significant linear trend was found for the total number of responses on color stimuli on the basis of intensity from the lowest (blue) to the highest (amber), $F(1, 15) = 37.74$, $p < .01$. The preference for color stimuli in Experiment 1 is consistent with the suggestion of Catania et al. that subjects may have been responding on the basis of light intensity. This suggestion was further examined in Experiment 2, in which the intensity of color stimuli was equalized.

EXPERIMENT 2

METHOD

Subjects, Apparatus, and Procedure

Six additional naive subjects with characteristics identical to those in Experiment 1 served as subjects. The apparatus and procedure were the same as in Experiment 1 except that the intensity level of each stimulus was set at 350 lx by adjusting the current through the lamps.

RESULTS AND DISCUSSION

The results of Experiment 2 are given in Table 3. In contrast to Experiment 1, the avoidance of blue was eliminated in all pigeons, and in one case Pigeon 9 showed a preference for blue. The marked difference between the present experiment and Experi-

Table 3

Proportion of 180 trials with a peck on a given key color across all pairings of each color in Experiment 2. A, amber; R, red; G, green; B, blue.

Sub- ject	A	R	G	B	Percent trials with keypeck	Left pecks (left/ total)
7	.42	.65	.40	.38	92	.29
8	.46	.73	.05	.37	81	.37
9	.44	.11	.47	.64	83	.46
10	.26	.49	.47	.23	73	.82
11	.38	.23	.53	.49	81	.72
12	.39	.36	.59	.33	84	.54
Mean	.39	.43	.42	.41	82	.53
Catania et al. (1983, Table 2) means:						
	.58	.55	.22	.17		.52

ment 1 is shown in the means of Table 3. Analysis of variance showed no overall significant color preference ($p > .05$) in contrast to the findings of Experiment 1, in which intensity was not equalized. The possibility exists that in equalizing the intensity of stimuli in Experiment 2, the discriminability of the four colors was reduced to the point where pigeons could not detect differences, obscuring any preference that might exist. This appeared unlikely inasmuch as human observers could easily discriminate the four equal-intensity colors. To assess the possibility of a lack of discriminability, we trained pigeons to discriminate the equal-intensity color stimuli from Experiment 2 in Experiment 2a.

EXPERIMENT 2a

METHOD

Subjects, Apparatus, and Procedure

Six naive pigeons with characteristics identical to those of the subjects in Experiments 1 and 2 were used. The same apparatus was used as in Experiments 1 and 2 to present simultaneous color discrimination tasks (cf. Biederman, 1968). Responses were auto-shaped by pairing 3-s white keylight with 5-s access to the food magazine, followed by a VT 30-s ITI. Next, a two-key color discrimination task was arranged. If a response was made on the key with color designated as S+, that response produced immediate access to the grain magazine. If a response occurred on S-, a 35-s ITI followed with the keys darkened and deac-

Table 4

Individual performance in terms of percentage of correct responses in 20 trial blocks in Experiment 2a.

Sub- ject	Problem		Block				
	S+ vs. S-		1	2	3	4	5
13	Amber	Red	75	90	85	95	90
14	Green	Blue	30	80	75	80	75
15	Green	Amber	50	75	90	85	85
16	Red	Blue	75	65	85	80	75
17	Red	Green	90	95	85	100	95
18	Blue	Amber	85	85	95	100	100
Mean			68	82	86	90	87

tivated. As in Experiment 2, the magazine was illuminated in an alternating arrangement by the two colors comprising the discrimination task. One hundred simultaneous discrimination trials were presented to each animal with each trained in a different discrimination. The location of S+ was prearranged in a random sequence with the provision that S+ not appear on one side for more than three consecutive trials. In this experiment, as in Experiment 2, all stimuli were presented at 350 lx.

RESULTS AND DISCUSSION

As indicated in Table 4, the results of Experiment 2a indicated that subjects discriminated each pair of equal-intensity colors within the 100 trials. The individual-subject performance data are given in Table 4 in 20-trial blocks with a correct response defined as an S+ response on a given trial. Because of the good performance for each subject (performance above 70% is presumed to be significantly above chance, according to the binomial expansion), it is reasonable to conclude that the lack of preference for color in Experiment 2 was not attributable to a lack of color discriminability.

The results of Experiments 1, 2, and 2a suggested that color preference as described by Catania *et al.* (1983) may have been controlled by the intensity of the stimuli rather than by the chromatic properties. We obtained samples of three of the original color stimuli used by Catania *et al.* and measured their respective intensities, which were 44,000 lx for red, 6,875 lx for green, and 5,500 lx for blue. On the basis of intensity, this ordering corresponds to

the order of preference for color reported by Catania *et al.*

In Experiments 1 and 2, each peck was followed by reinforcement, whereas in Catania *et al.* (1983) grain was delivered in a strictly response-independent arrangement that was, in effect, an autoshaping procedure similar to that of Brown and Jenkins (1968). The importance of this difference between Experiments 1 and 2 and those of Catania *et al.* was assessed in Experiment 3, in which we used a response-independent reinforcement procedure.

EXPERIMENT 3

METHOD

Subjects, Apparatus, and Procedure

Six naive pigeons with the same characteristics as in Experiments 1, 2, and 2a were used. The apparatus and procedure were identical to Experiment 2 (in which all stimuli were presented at 350 lx), except that reinforcement was programmed in a response-independent procedure identical to that used by Catania *et al.* (1983), in which the sequence of trial events was an ITI of 24 s, 3 s of lit keys, and finally a 3-s presentation of the feeder.

RESULTS AND DISCUSSION

The results of Experiment 3 are given in Table 5; there was an average overall preference for amber, red, green, and blue, in that order, although individual preferences were not consistent. In the experiments of Catania *et al.* (1983) there was a clear difference between A-R and G-B. In the present Experiment 3, no such preference was seen. In two cases green was preferred, but the clearest finding was that blue was the least preferred color in each case. The most striking difference in our present Experiment 3 and Experiment 2 is the failure in Experiment 3 to obviate avoidance of blue. The only difference between these experiments was the use of response-independent reinforcement in the latter. The discrepancy between our findings and those of Catania *et al.* might similarly be a function of the reinforcement procedure used. Catania *et al.* used a response-independent reinforcement procedure that may have permitted color preference to emerge more readily. This could be attributable to the free responding possible in

Table 5

After Catania et al. (1983) Table 2. Proportion of trials with at least one peck on a given key color, mean pecks per trial across all pairings of each color in Experiment 3. A, amber; R, red; G, green; B, blue.

Subject	Proportion of trials				Pecks per trial				Left pecks (left/total)
	A	R	G	B	A	R	G	B	
21	.17	.17	.34	.16	0.38	0.39	0.57	0.34	.13
22	.72	.28	.20	.07	2.86	1.00	0.37	0.14	.52
23	.49	.35	.22	.22	1.53	0.91	1.00	0.35	.71
24	.15	.24	.04	.03	0.19	0.49	0.06	0.03	.77
25	.21	.22	.36	.12	0.28	0.30	0.79	0.22	.67
26	.53	.48	.46	.14	2.09	2.46	2.04	0.48	.36
Mean	.38	.29	.27	.12	1.22	0.95	0.81	0.26	.53
Catania et al. (1983, Table 2) means:									
	.58	.55	.22	.17	4.6	4.0	1.2	1.0	.52

their procedure, in which a trial was not immediately terminated by a single peck.

To attempt to clarify the role of intensity and reinforcement contingency in pigeon color preference, we turned to a within-subject procedure in Experiment 4.

EXPERIMENT 4

METHOD

This experiment involved a within-subject procedure to assess the role of light intensity and the independence or nonindependence of responding and reinforcement in color preference in pigeons.

Subjects and Apparatus

Six experimentally naive pigeons with the same characteristics as in the previous experiments served as subjects. The same apparatus was used as in the previous experiments.

Procedure

A 2×2 design with two intensity and two response-reinforcer dependency conditions was used with each pigeon exposed to all conditions. Magazine training procedures were the same as in Experiments 1, 2, and 3. Each pigeon was then exposed to the four conditions in randomly determined order: (a) Condition ED, wherein stimulus intensity was equalized (E) and reinforcement was response dependent (D), (b) Condition UI, wherein the stimulus intensity was unequalized (U), using the same

values as in Table 1, and the reinforcement was response independent (I), (c) Condition EI, wherein the stimulus intensity was equalized and reinforcement was response independent, and (d) Condition UD, wherein the stimulus intensities were as in Table 1, and the reinforcement was response dependent. As in previous experiments, each pigeon received six sessions within a condition, each consisting of 60 illuminated key and grain magazine pairings. The stimulus arrangements within each session were the same as in Experiments 1, 2, and 3. Each bird's sessions were conducted on alternate days, with one condition following the previous one upon completion of the six sessions (see Table 6 for order within subject).

RESULTS AND DISCUSSION

In this experiment controlling for intensity did not eliminate the avoidance of blue. The stimulus intensity effect found in Experiment 2, in which avoidance of blue was removed by equalizing intensities, was not confirmed in equal-intensity conditions in Experiment 4. Inspection of Table 7 shows that despite the manipulation, blue was avoided in all cases. Table 6 shows that 3 of 6 individual subjects showed a slight $G + B > A + R$ preference in condition ED, the condition equivalent to that of Experiment 2. In Experiment 2, 3 of 6 pigeons also showed a clear $G + B > A + R$ preference. That preference is found with only 1 other pigeon (Pigeon 45, Condition EI) in any of the three other conditions in Exper-

Table 6

Individual subject total first-choice responding on trials by color and condition in Experiment 4. Maximum number of responses per color is 180 within each condition and color (proportion of trials with at least one peck on a given key color is given in parentheses).

Condition (order of presentations in parentheses)					
Pigeon 41	UD (1)	UI (2)	ED (3)	EI (4)	Total
Amber	112 (.62)	93 (.52)	106 (.59)	104 (.58)	415
Red	124 (.69)	100 (.56)	67 (.37)	102 (.57)	393
Green	80 (.44)	43 (.24)	91 (.51)	106 (.59)	320
Blue	0 (.00)	0 (.00)	14 (.08)	24 (.13)	38
Pigeon 42	UD (2)	UI (3)	ED (1)	EI (4)	
Amber	108 (.60)	107 (.59)	21 (.12)	134 (.74)	370
Red	122 (.68)	88 (.49)	67 (.37)	101 (.56)	378
Green	103 (.38)	90 (.50)	68 (.38)	91 (.51)	352
Blue	0 (.00)	0 (.00)	24 (.13)	0 (.00)	24
Pigeon 43	UD (4)	UI (2)	ED (1)	EI (3)	
Amber	144 (.80)	127 (.71)	119 (.66)	135 (.75)	525
Red	141 (.78)	104 (.58)	160 (.89)	106 (.59)	511
Green	12 (.07)	11 (.06)	30 (.17)	43 (.24)	96
Blue	0 (.00)	28 (.16)	9 (.05)	46 (.25)	83
Pigeon 44	UD (3)	UI (1)	ED (4)	EI (2)	
Amber	53 (.29)	30 (.17)	83 (.46)	64 (.36)	230
Red	77 (.43)	8 (.04)	65 (.36)	64 (.36)	214
Green	50 (.28)	15 (.08)	88 (.49)	26 (.14)	179
Blue	53 (.29)	1 (.01)	69 (.38)	6 (.03)	129
Pigeon 45	UD (1)	UI (4)	ED (2)	EI (3)	
Amber	101 (.56)	112 (.62)	121 (.67)	92 (.51)	426
Red	109 (.61)	108 (.60)	125 (.69)	64 (.36)	406
Green	55 (.31)	97 (.54)	84 (.47)	93 (.52)	329
Blue	0 (.00)	32 (.18)	14 (.08)	100 (.56)	146
Pigeon 46	UD (2)	UI (3)	ED (4)	EI (1)	
Amber	107 (.59)	74 (.41)	87 (.48)	86 (.48)	354
Red	105 (.58)	85 (.47)	68 (.38)	90 (.50)	348
Green	50 (.28)	101 (.56)	119 (.66)	53 (.29)	323
Blue	0 (.00)	6 (.03)	35 (.19)	2 (.01)	43

iment 4. In other words, where equal-intensity, response-dependent reinforcement conditions were used, in Experiments 2 and 4, half the pigeons chose $G + B > A + R$.

In Experiment 4, each subject received a total of 1,440 trials in which color pairs were available for choice, with each color appearing on the keys in 720 trials. In Experiments 1 and 2, only half as many trials were used and it seemed likely that the intensity factor facilitated preference in Experiment 1. The response-dependent reinforcement arrangements with relatively few trials and with equalized stimulus intensity seemed to have suppressed the development of color preference in some animals in Experiment 2. However, in Experiment 4 all pigeons, with one exception (Pigeon 42), showed the amber-red pref-

erence during the first session (180 presentations of each color). It is interesting to note that Pigeon 42 showed marked blue avoidance overall, with amber, red, and green virtually equally preferred (see Table 6). Subject 44 showed nonblue preference most weakly, but still did so despite a strong left-key preference.

GENERAL DISCUSSION

Experiment 1 was a systematic replication of experiments by Catania *et al.* (1983), who found consistently low preference for pecking blue as well as low preference for green; they reported that 8 of 8 subjects showed a preference for amber and red to blue and green. Only 4 of our 6 subjects showed a similar pattern, although all 6 did show least pref-

Table 7

After Catania et al. (1983) Table 2. Proportion of trials with at least one peck on a given key color, mean pecks per trial in response to independent conditions only, and relative left-key pecks, across all pairings of each color in Experiment 4. A, amber; R, red; G, green; B, blue. Note that the pecks-per-trial measure is available only when the first response does not terminate a trial.

Overall proportions all conditions combined									
Pi- geon	Proportion of trials				% left pecks				
	A	R	G	B					
41	.57	.54	.44	.05	28				
42	.51	.52	.48	.03	65				
43	.72	.70	.13	.11	52				
44	.31	.29	.24	.17	91				
45	.59	.56	.45	.20	40				
46	.49	.48	.44	.05	56				
Mean	.53	.52	.36	.10	55				
Response-independent reinforcement conditions (Conditions UI + EI)									
				Pecks per trial					
				A	R	G	B		
41	.55	.56	.41	.07	2.70	3.10	1.80	.10	26
42	.67	.53	.50	.00	1.90	1.20	1.30	.00	66
43	.73	.58	.15	.21	3.20	2.75	.55	.40	52
44	.26	.20	.11	.02	.40	.28	.19	.02	94
45	.57	.48	.53	.37	3.10	2.70	2.00	1.25	37
46	.44	.49	.43	.02	1.40	1.40	1.70	.03	56
Mean	.54	.47	.35	.11	2.12	1.90	1.26	.30	55
Response-dependent reinforcement conditons (Conditions ED + UD)									
41	.61	.53	.47	.04					33
42	.36	.53	.47	.07					62
43	.73	.84	.12	.03					52
44	.38	.39	.38	.34					89
45	.62	.65	.39	.04					55
46	.54	.48	.47	.10					57
Mean	.54	.57	.38	.10					58
Equal stimulus-intensity conditions (Conditions ED + EI)									
41	.58	.47	.55	.11					26
42	.43	.47	.44	.07					69
43	.71	.74	.20	.15					52
44	.41	.36	.32	.21					98
45	.59	.53	.49	.32					53
46	.48	.44	.48	.10					43
Mean	.53	.50	.41	.16					57
Unequal stimulus-intensity conditions (Conditions UI + UD)									
41	.57	.62	.34	.00					36
42	.60	.58	.54	.00					61
43	.75	.80	.06	.08					52
44	.23	.24	.18	.15					80
45	.59	.60	.42	.09					25
46	.50	.53	.42	.02					68
Mean	.54	.56	.33	.06					54

erence for blue. The differences between our Experiment 1 and that of Catania *et al.* were that our colors were more homogeneous and dimmer, our response keys were larger, exposure to each color pair was for one rather than for three sessions, and food presentation could be response dependent. In Experiment 2, we systematically replicated Experiment 1, with intensities equalized, and no longer found avoidance of blue in any of the 6 subjects. It therefore seemed likely at that point that low preference for blue was related to intensity rather than chromatic characteristics of the stimuli (Experiment 2a confirmed that all hues were discriminable at the intensity used). In Experiment 3, we more closely replicated the procedures of Catania *et al.*, with food presentation response independent and with intensities equalized. Surprisingly, very low preference for blue was seen again, indicating that equating intensity was not sufficient to eliminate this tendency. Because the only difference between Experiments 2 and 3 was the possibility of response-dependent food presentation in the former, it seemed that that had washed out the effect of equalizing the intensity of the stimuli used in Experiment 2. Catania *et al.* reversed an amber-red preference by reversing the intensity difference in favor of green-blue, strongly suggesting a functional relationship between intensity and preference. However, we were unable to reproduce that effect within-subject. In Experiment 4, we arranged within-subject replications of Experiments 1, 2, and 3 and added a new condition with unequal intensities and response-independent food presentation (UI) which was, in effect, a direct replication of Catania *et al.*, but in Condition UI only 3 of 6 subjects showed the patterns of preference reported by Catania *et al.*, whereas 5 of 6 showed least preference for blue and the 6th had low blue preference. It would therefore seem that the evidence of Catania *et al.* showed blue and green preference covarying more than in our experiments (e.g., Pigeons 41, 42, 45, 46). Condition ED (equal intensity, response-dependent food presentation) exactly replicated the conditions of Experiment 2, but blue was avoided by every pigeon in this condition, in marked contrast to the 6 pigeons in Experiment 2. Nonetheless, it is interesting to note that in every subject in Experiment 4, more responses occurred to blue

in ED than in UD conditions, which resembles the differences between Experiments 1 and 2.

The present method of equalizing color intensity (and that used by Catania *et al.*, 1983) consisted of adjusting the current passing through lamp filaments. This method changes the color of the light that passes through the filters; inasmuch as the filaments produce a distribution of wavelengths that is shifted toward the red end of the spectrum as the current is reduced, it is possible that the present results and the results of Catania *et al.* could have been different if some other method of adjusting light intensity were introduced, such as the use of neutral density filters. If the red end of the spectrum is preferred, increasing the amount of red passing through wide-band filters might, for example, accentuate the amount of red in the amber key. The type of color filter used in the present experiments was of the wide-band variety with a dominant wavelength specified in Table 1. These filters produced distinct color stimuli easily discriminable to human observers; it is unlikely that narrow-band filters would have produced differences in the present results, in that narrow-band filters mainly provide more highly saturated colors (easier to discriminate). Because discriminability was no difficulty here (see Experiment 2a), narrow-band filters would provide no important difference in preference if discrimination were the only factor. The large intensity differences between the stimuli used by Catania *et al.* and in the present experiments may be significant with respect to the differences in results between them. In the present experiments, for example, red measured 2,200 lx at our open potentiometer setting, whereas we measured the red stimulus lamp used by Catania *et al.* at 44,000 lx. One possibility is that at the intensities used by Catania *et al.*, the effects of all other variables, such as hue and reinforcement contingency, are superseded. In the procedures of Catania *et al.*, commercial ornamental "Christmas tree" lamps were used to provide the color stimuli, which introduced a potentially significant source of variation in terms of the chromatic quality and the intensity of the transmitted light. The present experiments which used standard, highly reliable chromatic stimuli with systematic control of intensity, should have reduced variability in results, and yet the main

finding of the elimination of blue avoidance in Experiment 2 was not replicated in Experiment 4. This suggests that although intensity is surely a significant factor in pigeon color preference, there remains a disturbing degree of unreliability in the effect reported by Catania et al. and the strong suggestion that the list of variables controlling preference is still incomplete.

The results of the present experiments at least underline the importance of equalizing the intensity differences normally correlated with standard color stimuli used in operant research and emphasize the value in using neutral density filters to control luminance, so that an unambiguous interpretation of color discrimination and/or preference may be made where appropriate. The determination of color preference in pigeons (Delius, 1968; Lander, 1968; Saghal & Iversen, 1975; Straka, 1966) has practical implications in several areas of research where performance in complex schedules is studied using key colors correlated with different schedules. In experiments in which color preference could confound the experimental interpretation, limiting free-responding in equalized stimulus intensity conditions by using response-terminated trials in re-

sponse-dependent reinforcement arrangements (in addition to equalizing stimulus intensity) may be useful in attenuating the development of color preference.

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