

*MOTION AS A NATURAL CATEGORY FOR PIGEONS:
GENERALIZATION AND A FEATURE-POSITIVE EFFECT*

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Three groups of pigeons were trained with a modified discriminative autoshaping procedure to discriminate video images of other pigeons on the basis of movement. Birds of all groups were shown the same video images of other pigeons, which were either moving or still. The group to whom food was presented only after moving images learned the discrimination very quickly. A second group, to whom food was given only after still images, and a pseudocategory group, to whom food was presented after arbitrarily chosen stimuli, showed no evidence of discrimination during acquisition training. Extinction conditions led to clear differences in peck rates to moving and still images in the second group but not in the pseudocategory group. The result is related to the feature-positive effect. Generalization tests showed that the discrimination performance was based on visual features of the stimuli but was invariant against changes of size, perspective, brightness, and color. Furthermore, discrimination was maintained when novel images of pigeons under different viewing angles and seven other types of motion categories were presented. It is argued that the discrimination is based not on a common motion feature but on motion concepts or high-order generalization across motion categories.

Key words: concept discrimination, movement, feature-positive effect, natural motion categories, video images, key peck, pigeons

Pigeons, like most other animals, are confronted with a huge variety of external stimuli. Most of the stimuli in the natural environment involve movement, and motion information typically preferentially elicits responses from organisms. From an ecological viewpoint, it is obvious that motion information is frequently very important, as a signal for potential food or predators, for orientation when flying, in courtship behavior, or in intention movements. However, given the great variety of dynamic stimuli they see, pigeons probably do not respond on the basis of each individual type of motion; it would be more efficient to behave on the basis of motion categories. Thus, movement stimuli seem to be ideal examples of what are often called "natural categories" (Herrnstein, 1985).

Although much research on pigeons' pattern recognition and categorization has followed

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since the original study of Herrnstein and Loveland (1964), little or none has concentrated on the perception and categorization of moving stimuli. Sporadic efforts have been made to study pigeons' ability to perceive motion displays, mainly in the context of velocity discrimination (Hodos, Smith, & Bonbright, 1975; Mulvanny, 1978; Siegel, 1970) or tracking (Pisacreta, 1982; Rilling & LaClaire, 1989; Wilkie, 1986). These studies demonstrate that pigeons can discriminate different velocities and track moving targets, but the strategy and behavioral basis of the birds' response are still unknown (Wilkie, 1986). Furthermore, the targets used were highly abstract, typically dots in vertical or sinusoidal motion. But some of the most striking demonstrations of pigeons' discrimination abilities have used more natural stimuli (Cerella, 1979; Vaughan & Greene, 1984; von Fersen & Lea, 1990). No study has been done using movements of natural stimuli in the sense of Herrnstein, or using ecologically valid movements, and only one study with more complex motions (though still of dots) has been reported. In this study (Emmertson, 1986), pigeons had to discriminate Lissajous figures and learned to discriminate two successively presented cyclic trajectories of a single dot. Emmertson interpreted this as a demonstration of the recognition of a movement *Gestalt*, in the

virtual absence of figural information. Recognition was highly invariant against variations such as axis rotations or changing contour. However, it has not been investigated whether the processes or components that Emmerston (1986) reported are relevant to perception of complex natural motions.

EXPERIMENT 1

The aim of the present study was to begin the investigation of the behavioral or cognitive processes involved in perceiving and classifying natural movements, with a simple test of whether pigeons can discriminate two sets of stimuli differentiated by the presence or absence of motion. An additional purpose of the experiments was methodological, to test the feasibility of using video images of natural motion scenes as discriminative stimuli for pigeons. Computer-generated and controlled static video images have been used successfully to study pigeons' concept learning (Pearce, 1989; Wright, Cook, Rivera, Sands, & Delius, 1988). Although video images of natural animal movements have been used successfully with chickens in an investigation of the audience effect (Evans & Marler, 1991), they have not been used as discriminative stimuli in learning tasks. If this novel technique can be made to work reliably, it would have many uses in studying the cognitive and behavioral processes involved in motion processing in birds, especially natural motion category discrimination.

METHOD

Subjects

The subjects were 12 pigeons of retired racing stock, with no previous experimental history. They were assigned randomly to three conditions before the start of the experiments, with the restriction that the mean weights of the pigeons under each condition were, as nearly as possible, the same. They were maintained at 85% of ad libitum body weight on a 14:10 hr light/dark cycle, with water and grit continuously available outside test apparatus.

Apparatus

A one-key operant conditioning chamber (69 cm by 49 cm by 39 cm) was used. It consisted of a plywood box whose front wall was an aluminium panel (69 cm by 39 cm). Stimuli

were projected via a video monitor (Sony Profeel®, PAL) onto a screen (37 cm by 52 cm). Signals on the audio channel of the videotape indicated when a stimulus was present on the tape. The screen was 130 cm in front of the experimental chamber. The pigeons could view the monitor through the response key (6.5 cm by 6.5 cm), which was made of transparent perspex and positioned 26 cm above the floor on the front wall of the operant chamber. The screen subtended 16.1° vertically by 22.6° horizontally at the key, but the area in which the image of the pigeon appeared, either moving or still, subtended 6.7° vertically by 22.6° horizontally at the key, the remainder of the screen displaying static background. A shutter, operated by a rotary solenoid, could be used to prevent the bird from seeing the monitor. In addition to the response key, the panel carried an aperture (7 cm by 7.5 cm) that gave access to a solenoid-operated food hopper containing a mixture of food grains. When food was available and the hopper was presented, a white light in the hopper aperture was turned on. The food aperture was positioned 15 cm below the pecking key. A 3.5-W yellow-lensed house-light, 12 cm above the key, gave general illumination. Masking noise was provided by a ventilation fan and through a 35-ohm loudspeaker mounted on the back of the intelligence panel. The chamber and the video monitor were housed in a darkened testing room, and all other equipment was outside this room. An Apple II® microcomputer, programmed in UCSD Pascal, together with interfaces for the operant chamber and signals from the videotape, were used for the control of events and the recording of the responses. The pigeons' behavior was regularly monitored via a video-camera placed outside the chamber that provided a view inside the chamber via a hole (10 cm by 10 cm) in the rear wall.

Stimulus Materials

Acquisition and extinction. Video scenes of pigeons moving in the gallery of an outdoor aviary were recorded with the camera at the same height as the pigeons. The background was identical in all scenes and consisted of a walkway with wire netting and a building behind, as shown on the schematic drawing of the scenery in Figure 1. The recordings were taken in color with a Panasonic MS2® video-camera in S-VHS and edited on a Panasonic

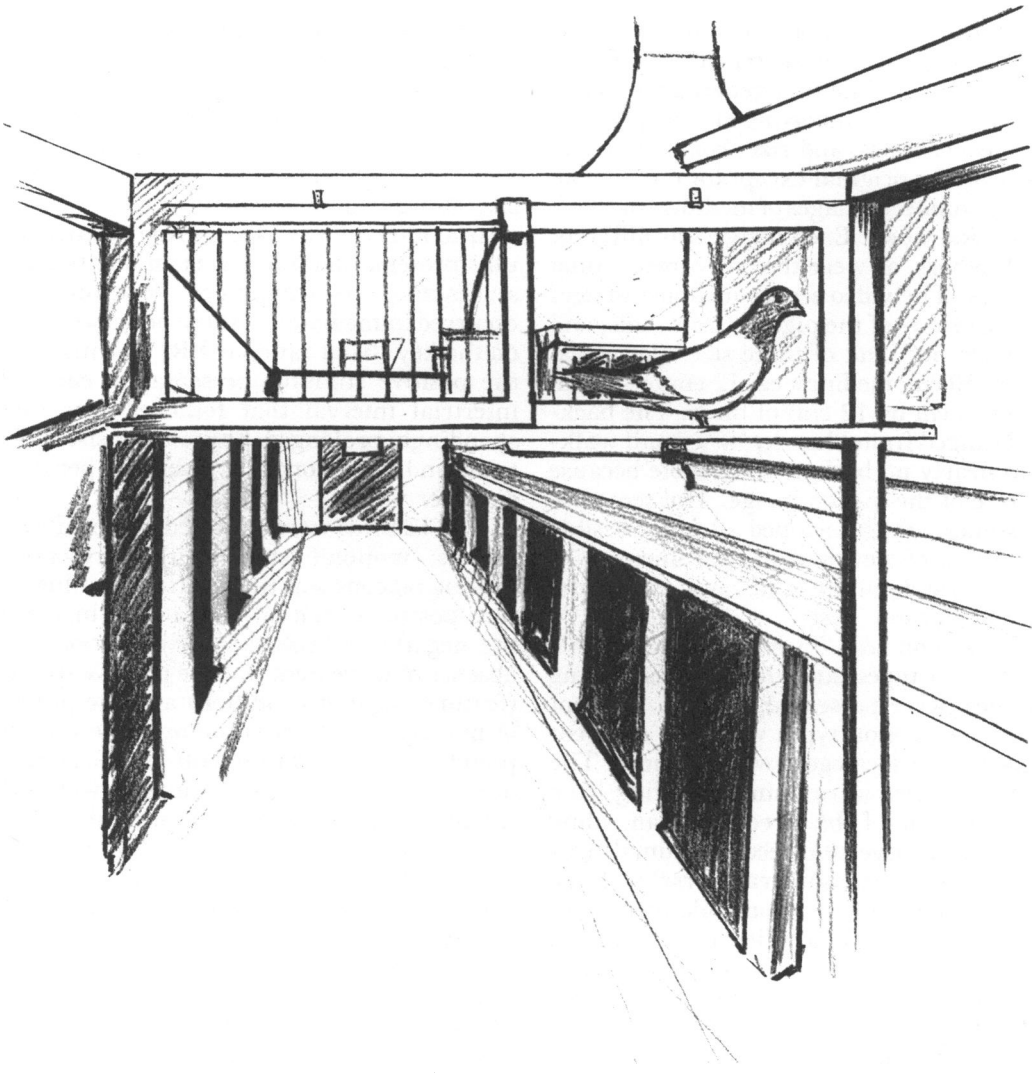


Fig. 1. Schematic drawing of the background of all video scenes during acquisition and extinction conditions.

edit suite to VHS PAL format. The edited tape consisted of 40 scenes involving movement and 40 still scenes, mixed in a quasi-random order. The duration of each scene was 6 s, and the scenes were separated by a randomized intertrial-interval duration of between 14 s and 34 s. In each scene, only single pigeons were shown, and the size of the pigeons on the screen was about 5.3° by 4.9° . The movements consisted of walking to the left and right covering the width of the screen (22.6°), flying a short distance (about 1.5 m) towards the observer,

turning on the spot, or standing still while moving the head in various ways. Movement speed of the pigeons naturally varied but was typically about 14° per second. The still scenes consisted of frozen frames from the moving scenes, so the background and illumination of the two types of scene were identical. All sequences were constrained by the fact that no more than three moving or still scenes were used in succession. For each session, one of two tapes with identical scenes, but presented in a different order, was chosen randomly. In

addition, the starting point on each tape was varied using the automatic repeat function.

Generalization. The first generalization test used 54 novel scenes involving moving pigeons, with pigeons, views, and sizes completely different from the original except for one control condition (namely, images of medium-sized pigeons in side view). Each image was different from all others, as were the 54 corresponding still scenes. The video scenes included images from three views of the pigeon (front, side, and under from 50°) and of three sizes (large: ca. 27 cm by 30 cm; medium: ca. 12 cm by 23 cm; small: ca. 6 cm by 12 cm) of birds. The background ranged from blue sky, to a small walkway, to nearly no background visible because of the size of the pigeon image. The sequence of the scenes, which included all nine possible combinations of view and size parameter, was novel and randomized. This was called the Pigeon Movement Test.

In the second test, 35 novel scenes of different motion types, and their corresponding still scenes, were presented (Motion Concept Test). Seven motion types with five different exemplars of each category were included. The motion categories were human walking from left to right side of the screen, human riding a bicycle in transverse direction, animal (caterpillar, magpie, pheasant, rat, horse) walking in different directions, automobile moving in transverse direction, object (items of furniture) in transverse motion, parts of a tree (leaves and branches) in motion, and computer-generated outlines of geometrical shapes (e.g., helix, square) rotating. In these motion displays, background varied greatly. In general, the motions were slower than the pigeon movements except for the bicycle, automobile, and computer-generated motions. The motions mostly appeared in the main viewing area as described above; exceptions were found in the categories of walking, geometrical shapes, and tree. In these displays, moving parts nearly covered the whole height of the monitor. The tape included 35 stills from these scenes, and the sequence of scenes was again novel and randomized.

Procedure

Acquisition. In the first three sessions, all pigeons were trained by standard procedures to find food in the hopper while the center key was illuminated, and the duration of feeder presentation was gradually reduced to 3 s.

For discrimination training, a modified version of the discriminative autoshaping procedure described by Pearce (1989) was used. Positive stimuli were followed by food, regardless of the bird's behavior, whereas negative ones were never followed by food. The stimulus duration was 6 s, and the mean intertrial interval was 24 s. During positive stimulus presentation, there was an additional instrumental contingency: Reinforcement occurred immediately if three pecks were made on the key (fixed ratio, or FR, 3), thus ending the positive stimulus presentation early; the intertrial interval that followed was correspondingly prolonged. Sessions consisted of 80 trials and were normally given one per day, 4 days per week.

The 12 birds were allocated to the following groups: motion+/static-: the presence of moving pigeons was the positive stimulus (feature-positive condition) and a static image was the negative stimulus; static+/motion-: the absence of movement was the positive stimulus (feature-negative condition) and the presence of moving pigeons was the negative stimulus; pseudocategory: 20 randomly chosen scenes of motion and 20 static video images were arbitrarily classified as positive stimuli, and the remaining scenes were negative. The last condition, which can also be described as a rote learning condition, was included as a control to test whether the birds were making use of whatever it is moving video images have in common (cf. Vaughan & Green, 1984, Experiment 4), to control for unexpected biases towards particular features of individual stimuli, and to control for the possibility that the birds could learn the sequence of positive and negative trials on the videotapes.

Extinction. The static+ and pseudocategory groups were placed on extinction during their 16th session (after five extra acquisition sessions not given to the motion+ group). All procedural details during extinction sessions were the same as before, except that reinforcement was not delivered following either the previously positive or negative stimulus. Three extinction sessions were conducted, followed by a standard acquisition session with discriminative autoshaping but with the instrumental contingency between pecks and reinforcement removed, and a fourth extinction session.

Generalization. For the motion+ group, a discriminative autoshaping method identical to

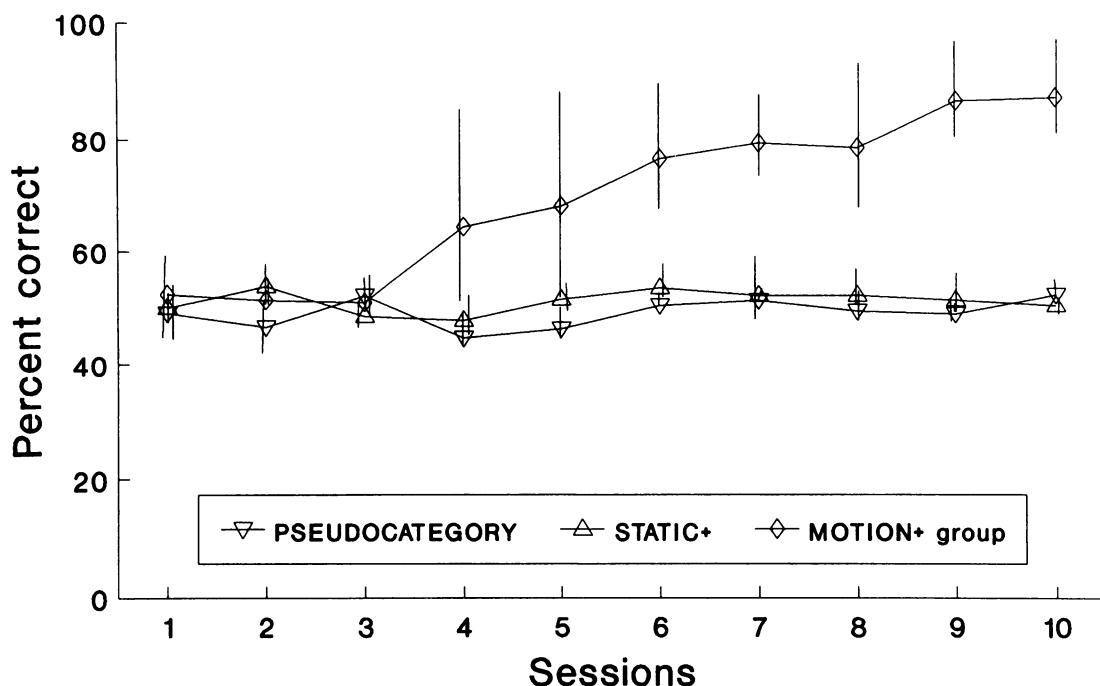


Fig. 2. Experiment 1: Mean percentage of trials with a correct response during acquisition of motion discrimination of each group. Level of statistically significant discrimination = 65%. Error bars represent standard deviation.

the acquisition procedure was used, except that the instrumental contingency was removed. The other groups were tested in extinction, except that in a second test session for the static+ group, conditions were identical to those of the motion+ group in the generalization tests. Each generalization test was repeated once.

RESULTS AND DISCUSSION

Acquisition. The percentage of trials with a correct response (i.e., three pecks to a positive stimulus and fewer than three pecks to a negative one) is shown in Figure 2. Using a chi-square test, significant discrimination of the stimuli under these conditions starts at 65% of trials correct in a session. On the first session, all birds started at the chance level of about 50% correct responses. All birds in the motion+ group showed rapid acquisition and reached at least the criterion level within five sessions, suggesting that the motion feature had acquired the ability to elicit key pecking. The acquisition functions for individual birds were characterized by a sudden and sustained increase in accuracy that occurred in Session

4 (74% and 88%) for 2 birds and Session 6 (68% and 68%) for the other 2. On the other hand, the static+ group showed no progress in discriminating the movement and the still images: They responded in virtually all trials, regardless of whether positive or negative stimuli were displayed (see Table 1). Classifying each bird as succeeding or failing in learning within 10 sessions, the difference between the motion+ and static+ groups was statistically significant (Fisher exact test, two-tailed; $p < .05$). The pseudocategory group also continued to respond on virtually all trials and thus showed no discrimination of the stimuli; again, there was a statistically significant difference between the motion+ group and the pseudocategory group (Fisher exact test, two-tailed; $p < .05$). Furthermore, in five further sessions no bird in either of these groups reached the 65% criterion, because they still responded equally often to positive and negative stimuli.

Jenkins and Sainsbury (1970) reported that, as in our study, pigeons demonstrated a clear asymmetry in their ability to learn a discrimination task based on a distinguishing feature (e.g., a black dot). This distinguishing feature

Table 1

Experiment 1: Scores of individual birds in the last acquisition session, the first session of extinction, and each generalization test for each experimental group. H = number of hits (i.e., trials with a response to the positive stimulus), CR = number of correct rejections (i.e., trials with no responses made to the negative stimulus), FA = false alarms (i.e., trials with a response to the negative stimulus), M = misses (i.e., trials with no responses to a positive stimulus), R = total number of pecks per session.

Birds	Acquisition										Extinction 1										Pigeon movements										Motion categories																																																										
	H	M	CR	FA	R	H	M	CR	FA	R	H	M	CR	FA	R	H	M	CR	FA	R	H	M	CR	FA	R	H	M	CR	FA	R	H	M	CR	FA	R																																																						
Pseudocategory group																																																																																									
1	26	14	14	26	228	14	26	28	12	88	28	26	28	26	26	28	28	26	28	26	186	2	33	35	0	18	2	31	9	12	28	213	16	24	25	15	159	16	38	23	31	344	9	26	25	10	73	3	33	7	5	35	400	23	17	23	17	238	22	32	30	24	129	4	31	34	1	34	4	37	3	1	39	396	28	12	10	30	202	26	28	19	35	184	2	33	34	1	29
Static group																																																																																									
5	39	1	4	36	306	35	5	6	34	336	41	13	28	26	560	25	10	17	18	438	6	35	5	7	33	270	35	5	16	24	284	44	10	15	39	379	15	20	28	7	74	7	39	1	7	33	299	10	30	34	6	66	37	17	21	33	244	9	26	26	9	149	8	36	4	14	26	248	25	15	26	14	205	46	9	17	37	341	16	19	25	10	264						
Motion group																																																																																									
9	39	1	28	12	209	—	—	—	—	—	54	0	45	9	766	23	12	31	4	238	10	40	0	29	11	232	—	—	—	—	—	53	1	43	11	819	34	1	20	15	332	11	40	0	40	0	120	—	—	—	—	—	47	7	51	3	306	19	16	34	1	81	12	29	11	32	8	136	—	—	—	—	—	35	19	45	9	189	11	24	35	0	54						

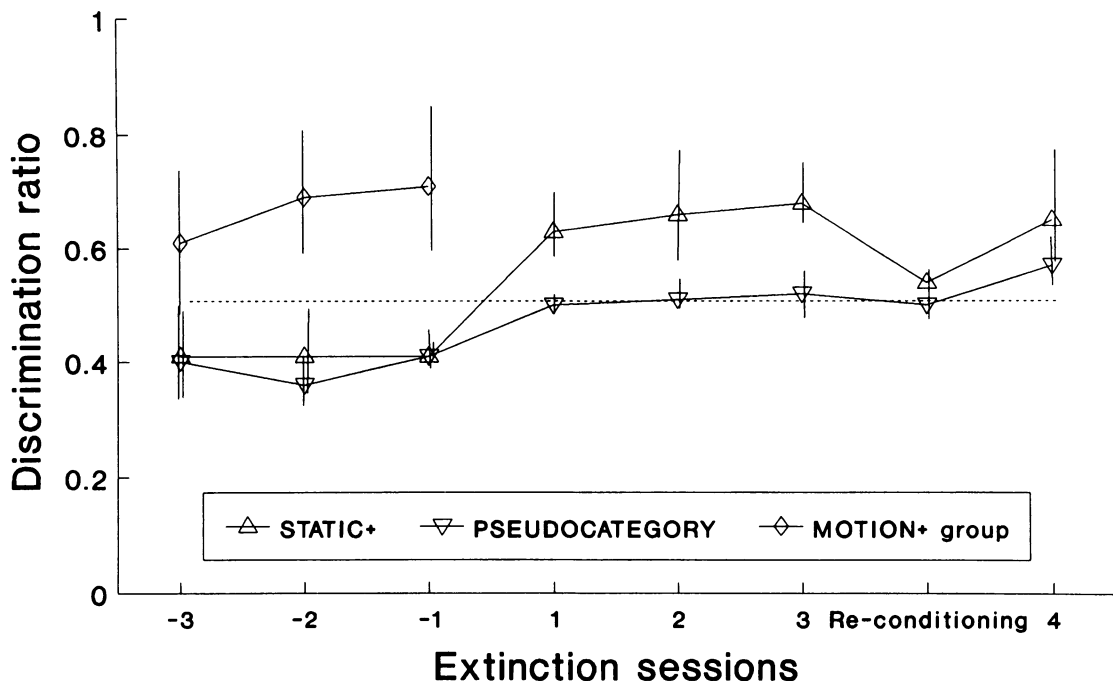


Fig. 3. Experiment 1: Mean discrimination ratios (total responses in presence of positive stimuli/total responses in presence of positive and negative stimuli) for each group on the last three acquisition sessions (-3, -2, -1), the first three extinction sessions (1, 2, 3), a discriminative autoshaping procedure with reinforcement (reconditioning), and a final extinction session (4). Error bars represent standard deviation, and the dotted line represents the chance level.

occurred on positive trials for the feature-positive group and on negative trials for the feature-negative group. Discrimination learning was clearly superior for the feature-positive group. Jenkins and Sainsbury labeled this asymmetry in discrimination learning the feature-positive effect, and it has been demonstrated with numerous other stimuli (Holland, 1991; Lea, 1974; Looney & Griffin, 1978; Morris, 1977; Nallan, Miller, McCoy, Taylor, & Serwatka, 1984; Sainsbury, 1971, 1973). Hearst (1987) argued that it is not a learning asymmetry but a performance asymmetry (i.e., organisms are able to acquire the discrimination, but during conventional conditioning training, their behavior is not controlled by the distinguishing feature). This possibility has to be unmasked by exposing organisms to new procedures, such as extinction or, more generally, weakening the predictiveness of positive reinforcement. Hearst (1987) demonstrated that pigeons for which a small white square on a green illuminated response key was a distinguishing feature showed significant learning if the distinguishing feature appeared

in the positive stimulus, but little or no evidence of feature-negative learning. However, clear differences between key pecking to the formerly positive and negative stimuli were found when the reinforcement contingency was removed. We therefore proceeded to test the performance of the static+ and pseudocategory groups in extinction.

Extinction. Despite the fact that no discrimination learning was evident for either the static+ or the pseudocategory group during the acquisition phase, the extinction procedure immediately led to the appearance of different response rates to the former positive and negative stimuli (see Table 1). These differences are not obvious when the data are plotted as percentage of trials correct, because of the continued high response rates of these birds, but the differences are shown clearly when the data are plotted as discrimination ratios (Figure 3). To compare the results of all groups, the data of the last three acquisition sessions of the motion+ group (see Figure 2) are plotted again as discrimination ratios. During Sessions 1 through 3 of extinction, mean perfor-

mance in the static+ group differed remarkably from its level in acquisition and from the extinction level of the pseudocategory group.

On return to discriminative autoshaping (with classical conditioning contingencies only, i.e., with positive stimuli again being followed by food, but with no immediate food delivery if the bird pecked three times) in the fourth session, the discriminative performance of the static+ group decreased substantially, though not to the level shown prior to the extinction phase. During the final extinction session, discrimination ratios increased again. Thus, the discrimination performance of the birds in the static+ group (i.e., responding correctly to the feature-negative stimulus in contrast to learning the difference between feature-positive and feature-negative stimuli) seemed to depend very strongly on the conditions of food presentation. The pseudocategory group, on the other hand, showed no evidence of discrimination by any measure. Their failure shows that, with this amount of training, pigeons were unable to learn the discrimination task by remembering individual instances of the stimulus set or by memorizing the sequence of positive and negative trials. Furthermore, the birds in the pseudocategory group showed no tendency to peck more often at movement scenes (mean pecks per session, 132.7, *SD*, 65.9) than at static images (mean pecks, 141.5, *SD*, 60.8; Wilcoxon test: $z = 1.78$, two-tailed, n.s.). Thus, the learning differences between the motion+ and static+ groups cannot be explained by preexisting preferences for pecking at moving stimuli or a general arousing effect of such stimuli. Instead, we hypothesize that motion stimuli provide highly inadequate cues to inhibit pigeons' behavior, so that excitatory responding to static background cues, which are present in both positive and negative stimuli, dominates the performance of the static+ group. Thus, it appears that both motion+ and static+ groups learned to discriminate the stimuli in the acquisition phase. However, for the motion+ birds, pecking behavior was selectively controlled by the presence of motion, whereas for the static+ group, the birds' behavior was not selectively controlled by the absence of motion. That is, the motion+ birds responded in the presence of motion and showed inhibition of behavior in its absence, whereas the static+ birds responded in the presence of both motion and static stimuli (i.e.,

their key pecking was not selectively inhibited in the presence of the negative motion stimuli, although learning of the discrimination could be demonstrated under modified conditions of reinforcement).

Generalization. In the present experiment, we tested generalization at the level of stimulus categories, rather than the crude physical dimensions of the stimuli (see Lea, 1984). This first test used novel images of conspecifics (Pigeon Movement Test). Birds in the motion+ and static+ groups pecked readily in the presence of novel stimuli, but birds in the pseudocategory group tended not to (see Table 1). Mean percentages of trials with a correct response and discrimination ratios are shown in Figure 4. Both measures revealed significant discrimination of unknown stimuli by the motion+ group. The static+ group failed to discriminate according to the percentage of correct trials measure, because they continued to peck in the presence of both positive and negative stimuli. However, response rates to the two types of stimuli differed, and the discrimination ratios show that the birds of the static+ group did discriminate the static images within the novel stimulus set under extinction conditions (see Table 1). In a second test session for the static+ group using classical conditioning contingencies, this discrimination performance dropped substantially, because the response rate to both stimuli increased drastically and was equally high for positive and negative stimuli (means for percentage of trials correct, 52%; discrimination ratio, .54), as shown in Figure 4. In contrast, the birds of the pseudocategory group showed no evidence of responding differentially to the unknown stimuli. Furthermore, in contrast to the other birds, their pecking rate dropped substantially in the presence of the novel stimuli (see Table 1).

Birds in both the motion+ and the static+ groups classified unknown images with different views and sizes of pigeons correctly, including all nine combinations of three novel views and three novel sizes. As expected, an analysis of variance revealed no difference between the groups or the stimulus parameters view and size. This result concerning the generalization ability across perspectives of natural movements is in agreement with Emmerston's (1986) finding that pigeons clearly showed rotational invariance when the moving

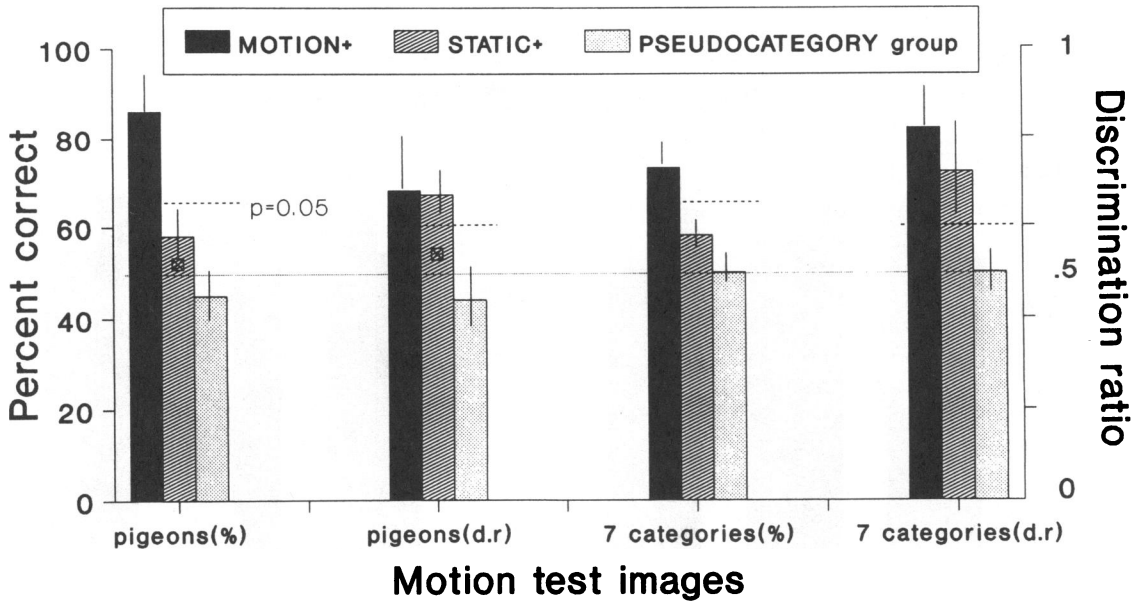


Fig. 4. Experiment 1: Mean percentage of trials with correct responses (%) and mean discrimination ratios (d.r.) for each group on the first session of the Pigeon Movement Test, using different views and movements of novel pigeons, and the first session of Motion Category Test, using different motion types of seven motion categories. The data of the pseudocategory group consist of much lower total key pecks because the birds in this group strongly hesitated in pecking the novel stimuli (see Table 1). On the bars of the static+ group for the Pigeon Motion Test, the result of a second test session with reinforcement is marked with an X. Error bars represent standard deviation, dashed lines represent levels of statistical significance; note the different levels for the two measures.

contours were visible, although it contrasts with Cerella's (1977) finding that pigeons failed to generalize to new views when trained on a limited range of static views of a cube. However, as shown in Figure 5, there was an opposite trend in the discrimination performance of the two groups regarding size (Spearman $r = -.78$) and view ($r = -.77$). For birds in the motion+ group, the movement images that were easiest to recognize seemed to be those from a small-sized pigeon seen from below (discrimination ratio, .78), which is the viewing situation in which the worst discrimination performance of birds in the static+ group (discrimination ratio, .62) was found. Similarly, the worst situation for the motion+ group (i.e., a large image of a pigeon in frontal view: discrimination ratio, .64) caused the best discrimination ratio (.85) in the static+ group. It appears that the behavior of the birds in the two groups was to some extent controlled by the presence or absence of motion, but was also to some extent controlled by particular features that gained control differently in the two groups. There was one exception to this general high negative correlation: The highest dis-

crimination ratio for the motion+ group (.80) was found for the control condition (static+, .72), namely the familiar medium-sized side view of a pigeon that was seen during acquisition learning.

The average discrimination ratios for the seven categories in the Motion Concept Test are shown in Figure 6. The highest discrimination ratios for the motion+ group were obtained with the categories human walking, bicycle riding, and the automobile motion; these were the most difficult for the static+ group. Interestingly, the most difficult motion category to discriminate for the motion+ group, the tree motion category, was one that the static+ birds discriminated very well, and there is a perfect negative correlation across categories between the discriminability for the motion+ and the static+ groups (Spearman's coefficient: $r = -1$, two-tailed, $p < .05$). When discrimination ratios of the first session with training group and motion categories as relevant factors were submitted to analysis of variance, a main effect of the group factor, $F(1, 7) = 5.44$, $p < .05$, was found, but there was also a significant interaction, $F(6, 56) = 3.49$,

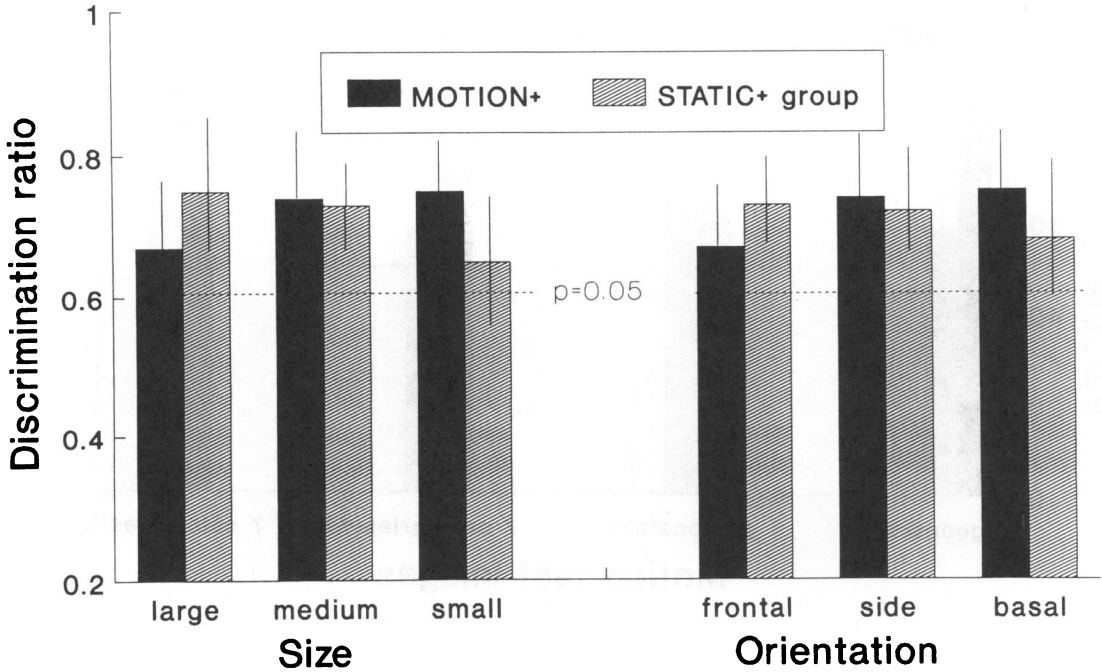


Fig. 5. Experiment 1: Mean discrimination ratios for different sizes and views in the Pigeon Movement Test for the motion+ and static+ groups. Error bars represent standard deviation, and the dotted line represents the statistically significant level.

$p < .01$. Tests of differences concerning individual categories revealed statistically significant differences between the cycling category and both the animal and object categories in the motion+ group. In the static+ group, statistically significant differences were found between the cycling category and both the object and tree categories and between the walking category and the object category. Between-group comparisons revealed a statistically significant difference of discrimination ratios for the cycling category between the motion+ and the static+ groups (Mann-Whitney $U = 0$, one-tailed, $p < .05$).

These results suggest that although pigeons do respond to some common motion cues in all these categories, the discrimination also depends on the category of motion. As Dittrich (1988) has argued, visual concept formation in animals depends both on early visual experience with the stimuli and the actual occurrence of reinforcement of responses that are elicited by these stimuli. The present results clearly indicate that pigeons' ability at concept discrimination is, in addition to the kind of stimuli they see, a function of their previous history of reinforcement.

EXPERIMENT 2

In this experiment, we used the same procedure as in Experiment 1 to examine whether the motion category discrimination that led to the generalization in the last test could be influenced by procedural details of the video apparatus. We also tested some further kinds of generalization.

METHOD

Subjects and Apparatus

The subjects were 6 pigeons, randomly selected from those that were used in an earlier experiment with entirely different stimuli and task (von Fersen & Lea, 1990). The maintenance conditions were the same as described in the previous experiment, as was the apparatus.

Stimuli

During acquisition training and in five test sessions, the stimuli were the same as employed in Experiment 1 during acquisition. In a final test session, 54 novel movement scenes of unfamiliar birds and the corresponding 54 still scenes were used. The novel scenes were

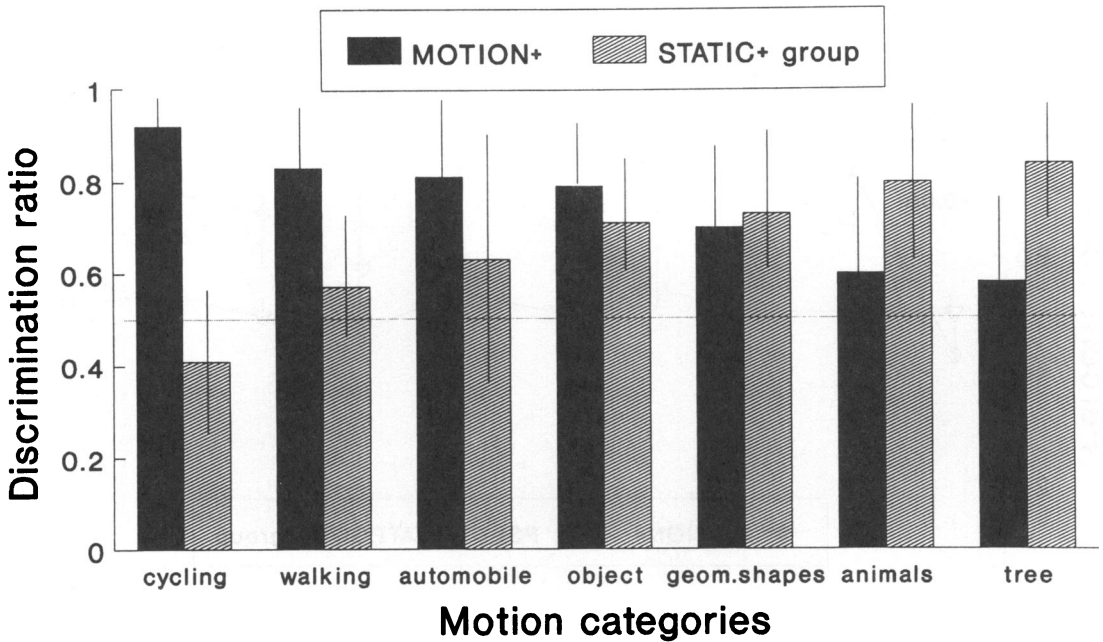


Fig. 6. Experiment 1: Average discrimination ratios for each motion category in the Motion Category Test for the motion+ and static+ groups. Error bars represent standard deviation, and the dotted line represents the chance level.

taken from free-ranging pigeons at Exeter Cathedral. Perspective of filming was mainly from above, recording one moving pigeon. The movements filmed were walking in any direction, turning, and head movements. In all other respects, the stimulus conditions were similar to those described in Experiment 1.

Procedure

Except for the first four sessions, acquisition and testing procedures were the same as described in Experiment 1. Each session consisted of two blocks of 40 trials. The procedure used during the first four acquisition sessions was based on that described by Gamzu and Schwartz (1973). The modification was that 20 motion and 20 static scenes, mixed in a random acquisition order, were shown for 30 s each, with a variable-time (VT) 30-s interval between trials. During S+ trials, food was presented independently of responding for 4 s at the end of the trial. In these four sessions only the sequential order and duration of the scenes were different from the identical scenes in the later sessions in which the procedure described in Experiment 1 was adopted. Sessions were normally given once per day, 5 days per week.

The 6 birds were allocated to the following

two groups: motion+: the presence of moving pigeons was the positive stimulus and a static image was the negative stimulus; and pseudocategory: half of the motion scenes and half of the static video images were arbitrarily classified as positive stimuli and the remaining scenes were classified as negative (rote learning condition).

During generalization testing, the sequential order of the 80 scenes presented in daily test sessions was always different, and the following test conditions were used in consecutive sessions:

Sequence. Only the sequential order of the scenes was changed.

Memory. After 2 weeks without any training or testing, variations of the original stimuli of the last acquisition session were presented.

Image blurring. The video image was changed by setting the levels of contrast and sharpness to the lowest possible level and brightness to a low level, so that for human vision the image was slightly blurred, with no sharp edges between objects or pigeon's shape (low blur). Subsequently, contrast and brightness were changed in such a way that to human vision the images were totally blurred and identification of images seemed impossible (high blur).

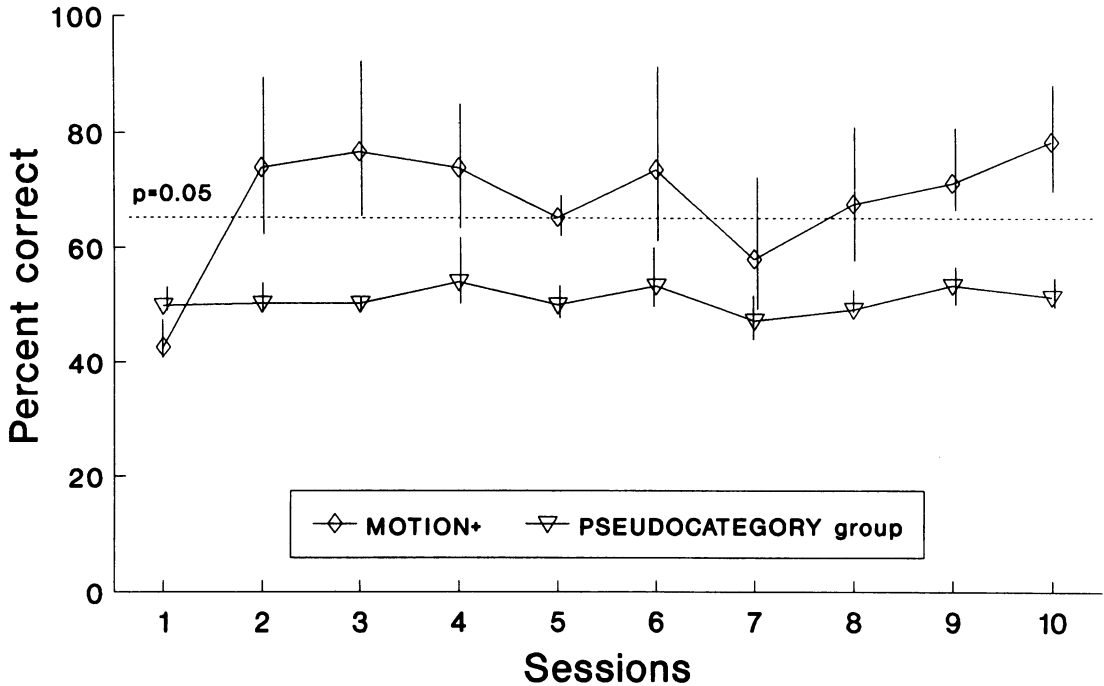


Fig. 7. Experiment 2: Mean percentage of trials with a correct response during acquisition of motion discrimination of motion+ and pseudocategory groups. Note that each data point represents blocks of two sessions. Bars show ranges of percentage correct trials across birds, and the dashed line represents the .05 significance level.

Black-and-white image. The original colored video image was shown as a black-and-white image.

Blurring and black-and-white image. The original scenes were shown as slightly blurred black-and-white images.

Motion concept. A set of 108 novel images of moving and static birds was presented.

During testing, food was given independent of the bird's behavior at the end of positive stimulus presentations.

RESULTS AND DISCUSSION

Acquisition. The percentage of correct responses for both types of stimuli is shown in

Table 2

Experiment 2: Mean latencies (s) of movement and static images for individual pigeons during the last seven acquisition sessions in Experiment 2 (Wilcoxon tests; $p < .05$ for each bird).

	Motion+ group			Pseudocategory group		
	2	4	5	1	3	6
Dynamic images	1.3	3.7	2.9	5.2	1.6	2.2
Static images	0.6	3.1	2.1	2.6	1.3	1.5

Figure 7. On the first session, all birds started at the chance level of about 50% correct responses. All birds in the motion+ group responded selectively to colored images involving movement within 10 sessions. They started to discriminate the stimuli in the second, third, and fourth sessions when the stimuli were presented for 30 s. After changing the procedure, only 1 bird maintained its high level of performance (about 80%). The other birds started to discriminate the stimuli again in the eighth and ninth sessions. Birds in the pseudocategory group failed to discriminate the stimuli; they responded regardless of whether positive or negative stimuli were presented.

There was a difference in response latency for movement and still scenes. As shown in Table 2, the latencies of all birds were longer when movement scenes were shown. In both groups, the pigeons observed the moving stimuli longer than the static ones before they pecked three times.

Testing. The percentages of correct responses are shown in Figure 8, in which the main interest focuses on birds in the motion+ group, although three tests with birds in the pseudocategory group were included as con-

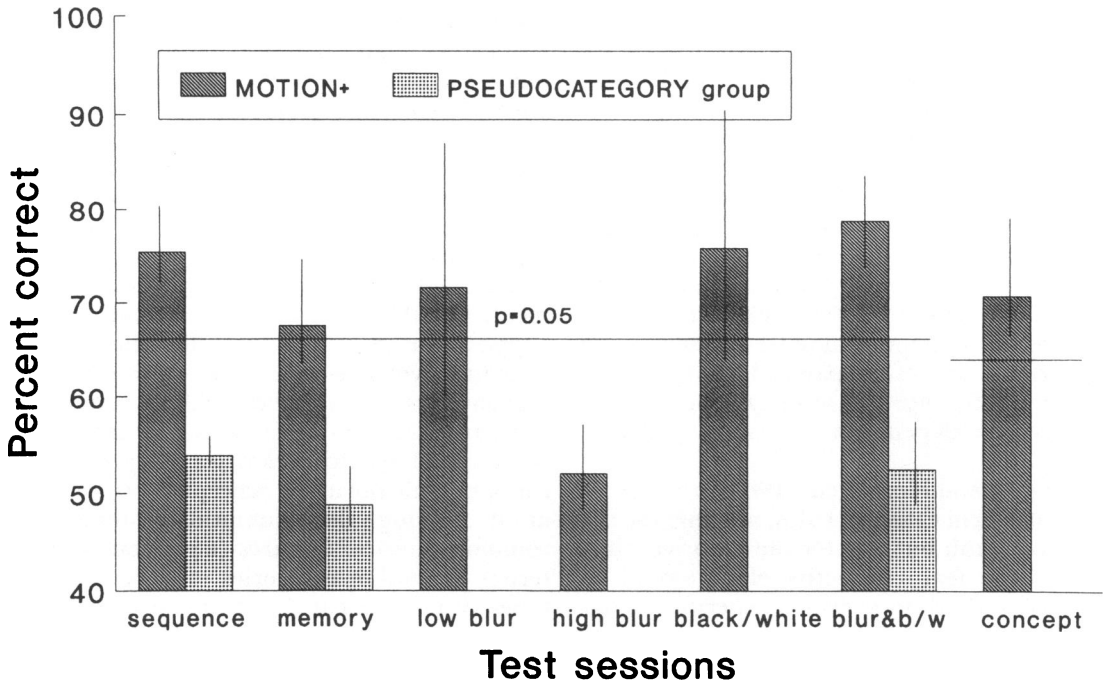


Fig. 8. Experiment 2: Mean percentage of trials with a correct response during testing of motion+ and pseudocategory groups. All tests included 80 trials (.05 significance level = 65%), except the motion concept test, which included 108 trials (.05 significance level = 63%). Three tests were conducted involving 2 birds of the pseudocategory group as controls. Bars show the range of percentage correct trials across birds, and the thin line represents the .05 significance level.

controls. Results from birds trained under the motion+ condition showed that selective response to video images involving moving pigeons was unaffected by changes in the color and brightness of the stimuli. These birds continued to respond correctly when the sequence of positive and negative trials was changed, when the images were presented in black and white instead of color, and when the brightness of the screen was varied over a wide range. Discrimination performance was also unaffected by slightly blurring the images. However, the discrimination failed if the stimuli were presented with a very low brightness and totally blurred. Thus, the use of possible nonvisual cues was ruled out. Furthermore, pigeons remembered the discrimination of motion from static images after a time span of 2 weeks; when novel images of the original pigeons were presented, they correctly discriminated novel moving stimuli from novel static ones. Pigeons generalized the learned discrimination to unknown stimuli, which we interpret as a further indication of pigeons' ability to use motion concepts. The inability of the pseudocategory birds

to discriminate the stimulus set strongly supports the assumption that visual cues were relevant and that no direct cues from the video monitor controlled correct responding.

GENERAL DISCUSSION

In both experiments, pigeons successfully discriminated between video images of moving pigeons and video images of the same pigeons not moving at all. To our knowledge this is the first time it has been shown that pigeons can discriminate images of natural scenes solely on the basis of motion cues. Pigeons can remember an immense number of individual images and respond to them adequately (Vaughan & Greene, 1984; von Fersen & Delius, 1989), but the results for our pseudocategory groups make it unlikely that the successful discrimination of moving and static images depended upon remembering the sequential order of the 80 scenes. Furthermore, the generalization test results show that it is highly unlikely that non-image cues from the video monitor controlled performance.

Pigeons were able to generalize the learned discrimination to unknown stimuli. Invariance of brightness, color, size, and perspective was clearly demonstrated. Furthermore, novel moving and static scenes of humans, pigeons, and other animals, and a wide variety of other objects were discriminated without additional training. We interpret this as further evidence that the pigeons used a concept of motion (i.e., their responses were independent of the individual images of pigeons used in training and, even more important in this context, were also independent of the particular kind of motion shown by pigeons, although they did, to some degree, depend on the category of motion).

Vaughan and Herrnstein (1987) argued that if pigeons form category rules, not only for the positive stimuli but also for the negative stimuli, then no feature-positive effect would be expected; indeed, in previous experiments using natural categories, feature-positive effects have not been found. Following their explanation for the absence of asymmetries in their studies of natural categories, we argue that the strong feature-positive effect found in Experiment 1 shows that it is easy to form a motion concept but much more difficult to form a non-motion concept. Thus, the behavior of the motion+ group came under control of the motion concept, whereas the lack of a nonmotion concept led to the failure of correct responses in the static+ group. In addition, this assumption is supported by the ability of all pigeons to discriminate both stimuli, although pigeons' performance was controlled by both stimuli only in the motion+ group. This result underlines the point, made by Dittrich (1988) and Wasserman, Kiedinger, and Bhatt (1988), that animals' ability to discriminate between stimuli is not identical to their ability to identify different stimulus categories.

The striking feature-positive effect found in Experiment 1 and the consistency of our results in the extinction test with those of Hearst (1987) suggest that movement may be an elementary feature of high salience for pigeons; as elementary, perhaps, as the black dot or red star that served as features in Jenkins and Sainsbury's (1970) experiments. Yet in other respects our data show that movement is not a simple feature, and the feature-positive effect we observed is probably better called a category-positive effect, because in this experiment

discrimination seemed to be based on categories rather than on single features. Furthermore, we assume that the perspective invariance of dynamic stimuli (in contrast to static stimuli) is possible because of the categorical nature of the movement stimuli. Movements of different kinds led to different degrees of generalization. It could be argued that this represents a simple generalization of single physical features across categories of movement. On this argument, we would have to suppose that the velocity and duration (e.g., of human movements) are relatively like those of pigeons' movements, whereas those of tree motions are not. But discrimination of motion on the basis of specific velocities or specific durations would not allow concept discrimination at all. Although the assumption of underlying common physical features (e.g., Fourier patterns) in motion categories of very different types cannot be ruled out at the moment, it seems more likely that "motion" is a higher order category generated (if at all) from lower order categories like "tree motion" and "pigeon movement," so that generalization is from category to category rather than across values of individual dimensions of motion (e.g., velocity). Thus, we argue that the differentiation of single features in motion displays (e.g., duration or velocity) or even highly complex features, such as perspectives or motion vectors, is not sufficient to explain the whole performance of motion discrimination. This seems directly related to the open question of why motion stimuli seem to elicit but fail to inhibit pigeons' behavior. Thus, the categorical nature of motion information and its different effects on behavior demands further study.

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