

Research Article

Pigeons See Correspondence Between Objects and Their Pictures

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ABSTRACT—*The extent to which nonhumans recognize the correspondence between static pictures and the objects they represent remains an interesting and controversial issue. Pictures displayed on computers are used extensively for research on behavioral and neural mechanisms of cognition in birds, yet attempts to show that birds recognize the objects seen in pictures have produced mixed and inconclusive results. We trained pigeons to discriminate between two identically colored but differently shaped three-dimensional objects seen directly or as pictures, and we found clear bidirectional transfer of the learned object discrimination. Transfer from objects to pictures occurred even when pigeons were trained with 12 views and only novel views of the objects were presented in transfer. This study provides the strongest evidence yet that pigeons can recognize the correspondence between objects and pictures.*

Pictorial presentations of stimuli are used extensively for research on the behavioral and neural mechanisms of various cognitive processes in birds (e.g., Cook, 2001; Laverghetta & Shimizu, 1999), yet attempts to demonstrate that birds recognize the correspondence between static pictures and the stimuli they represent have produced inconclusive results (Fagot, Martin-Malivel, & Depy, 1999). There is clear evidence that pigeons and other birds can derive information from static pictorial stimuli, such as colored slides or images presented on a computer screen. Pigeons, for example, can discriminate between and remember large numbers of pictures (Vaughan & Greene, 1984); categorize pictures according to a perceptual concept such as presence or absence of a particular human (Herrnstein,

Loveland, & Cable, 1976); learn where to peck in pictures of a complex scene (Spetch & Wilkie, 1994); discriminate between line drawings (Wasserman et al., 1996), images, or actual models (Friedman, Spetch, & Ferrey, 2005) of objects that differ in shape; and so forth. These types of results indicate that pigeons are highly visual creatures and that pictorial stimuli provide sufficient information for fine-grained perception and discrimination, but they do not directly show whether pigeons recognize any correspondence between pictures and the objects or scenes that they depict.

Ittelson (1996) set out three criteria that should be met if one is to conclude that an organism perceives the correspondence between pictures and objects: “The animal must, at a minimum, show transfer from pictures of the real world to the real world, transfer from the real world to pictures, and discrimination between the two” (p. 172). Ittelson suggested that “there is little evidence that animals, except perhaps some primates, have this capacity” (p. 172). Two more recent reviews (Bovet & Vauclair, 2000; Fagot et al., 1999) have reached only slightly more positive conclusions regarding nonhumans in general, and neither review concluded that there is strong or conclusive evidence that birds, in particular, recognize the correspondence between objects and static pictures. Moreover, both reviews noted that the relatively little experimental attention given to picture-object correspondence in nonhumans is surprising given the widespread use of pictorial stimuli in comparative cognition and neuroscience.

The question of correspondence between pictures and the objects they represent has been studied in nonhumans using two main approaches. One has been to look for evidence that animals respond to pictures in the same way as they respond to the natural stimuli that the pictures represent, for example by responding aggressively to pictures of competitors or with courtship to pictures of an appropriate conspecific (see Bovet & Vauclair, 2000; Fagot, 2000; Fagot et al., 1999). In birds, such studies have sometimes yielded results that suggest corre-

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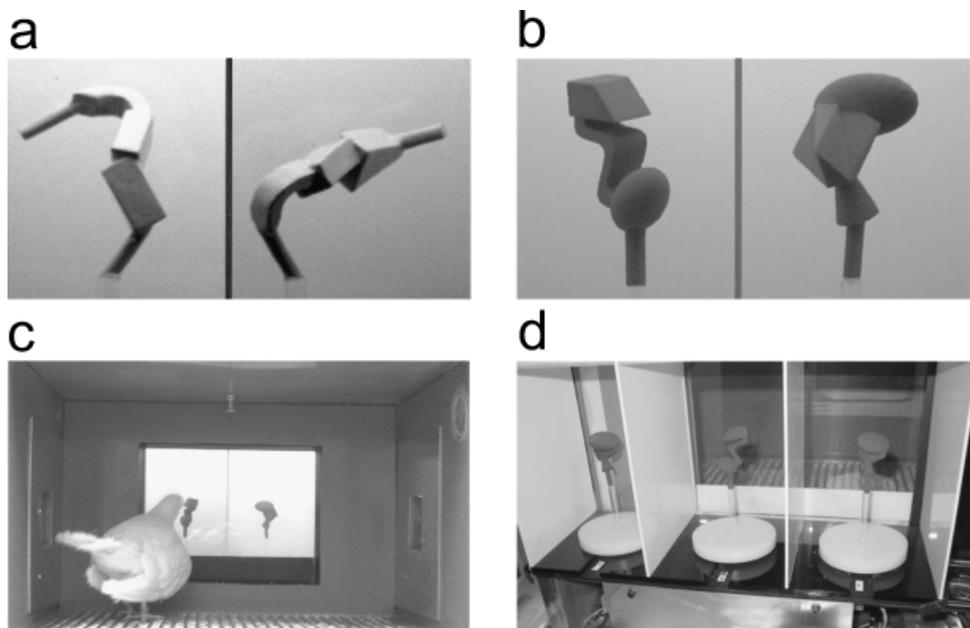


Fig. 1. Photographs showing (a) the pair of objects used in Replication 1 of Experiment 1, (b) the pair of objects used in Replication 2 of Experiment 1 and in Experiment 2, (c) a pigeon viewing a pair of objects, and (d) the back view of the object-rotation apparatus.

spondence (e.g., Shimizu, 1998), but positive results are not always found (e.g., Dawkins, 1996), and the interpretation of positive results is not always clear. For example, an aggressive or courtship response to a picture of a conspecific could plausibly be elicited by features common to the picture and the real object (e.g., a patch of color that serves as a sign stimulus), and does not necessarily require recognition of the picture as corresponding to the actual whole object (see Bovet & Vauclair, 2000, for further discussion of this issue).

A second approach has been to look for transfer of a learned response between pictures and the objects or scenes they represent. Again, results have been mixed. In birds, positive transfer has sometimes been observed, but typically in one direction only. For example, Cabe (1976) trained pigeons to discriminate between two differently shaped objects and showed that they transferred the discrimination to photographs of the objects. Cole and Honig (1994) trained some pigeons to find food at one of two ends of a rectangular room. They reinforced other pigeons for pecking at pictures of one side of the room but not at pictures of the other side of the room. They then transferred the pigeons between the two tasks and found positive transfer from the pictures to the room, but not from the room to the pictures. However, some instances of positive transfer in discrimination tasks could have been based on a single two-dimensional feature. For example, positive transfer in Cole and Honig's study could have been based on a particular color seen in the picture at the reinforced side of the room. In a study supporting this possibility, Watanabe (1997) trained pigeons to discriminate food from nonfood items presented as real stimuli and their photographs, and found transfer to new objects. However, the dis-

crimination ratios fell to chance level when the objects were painted black, indicating that color was the common cue for food recognition with both photographs and real food.

In the present study, we investigated picture-to-object and object-to-picture transfer in a discrimination task that required the pigeons to attend to more than a single two-dimensional feature. We were encouraged by previous results demonstrating that under certain circumstances, pigeons recognize novel views of actual objects as well as they recognize trained views, provided they are trained with more than one view (Friedman et al., 2005). In the present case, the discrimination was between two multipart objects that were identically colored and similar in size (Figs. 1a and 1b). The positive (S+) and negative (S-) objects were viewed side by side, and were seen from more than one viewpoint during training. This change in viewpoint altered the two-dimensional shape of the objects, so that attention to their three-dimensional global shape was required to achieve successful performance. The objects were viewed directly, in a custom-built object-rotation apparatus (see Fig. 1c), or were viewed as digitized images on a computer screen. In Experiment 1, half of the pigeons were trained first with pictures of two or three views of the objects and then tested for transfer to the same views of real objects; the remaining pigeons were trained first with real objects and then tested for transfer to pictures. In Experiment 2, pigeons were trained with 12 views of real objects and tested for transfer to pictures of 12 novel views. During transfer, the contingencies between the objects and reinforcement remained the same as in training (same-contingencies group) or were reversed (reversed-contingencies group). We predicted that if the birds recognized the correspondence

between the objects and their pictures, accuracy would be higher on initial transfer trials for birds in the same-contingencies group than for birds in the reversed-contingencies group.

EXPERIMENT 1

Method

Subjects

Eighteen adult pigeons (*Columba livia*) participated. Eleven were experimentally naive, and the remainder had served in unrelated experiments that did not involve object discrimination. None had previously viewed the objects used in the study, and none had been trained in the apparatus used to display real objects. The birds were maintained at approximately 85% of their free-feeding weight by grain obtained during experimental sessions and supplemental feedings of pigeon pellets. The experiment was conducted in two systematic replications, with 8 birds in Replication 1 and 10 birds in Replication 2.

Stimuli

The stimuli were one pair of yellow objects (Replication 1) and one pair of red objects (Replication 2). The two objects in each pair were similar in size and identical in color. Each object contained three distinctive parts that were attached at different angles to each other (Figs. 1a and 1b). All objects were attached to the apparatus with thin cylinders. The yellow objects also had thin cylinders at the top. The two yellow objects were constructed of the same three distinctive parts, but arranged in different orders. The two red objects were composed of different distinctive parts. Either object in a pair could be designated as S+ or S−, and either could appear on the left or the right side of the visible part of the display. Each pigeon was trained and tested with a single pair of objects.

For each object, we arbitrarily designated a particular pose as the 0° pose. The objects were rotated to produce two views 90° apart (Replication 1) or three views 60° apart (Replication 2). The task was to respond to the S+ irrespective of its pose.

For the picture condition, we used a digital camera to photograph the displays in each possible combination of pose and side. The objects in the computer displays looked similar in size to the actual objects: Specifically, the actual objects were approximately 7 cm tall and were recessed 8 cm from the screen, whereas the objects in the images were approximately 5 cm tall.

Apparatus

The apparatus for real-object training is described in detail in Friedman, Spetch, and Lank (2003). Briefly, a small movable table with three object chambers was placed behind and attached to a standard pigeon operant chamber (Figs. 1c and 1d). Between the table and the operant chamber, there was a sliding-door cover and a computer touch screen mounted on a piece of Plexiglas. When the door was opened, two of the three objects on

the table were visible. Sideways movement of the table allowed the viewing area to display either the left and center objects or the right and center objects, and each object could be automatically rotated to show it from specified views.

The sliding door was closed when the pigeons were placed in the operant chamber, and all lights in the chamber were turned off between trials to prevent the birds from seeing the moving table or rotating objects. To prevent the use of auditory cues, we rotated the objects at least 360° and moved the table on all trials. Photocells measured head entries into the feeder to limit feeding duration to 2 s per food presentation.

For the picture condition, a similar operant chamber was attached to a touch-screen-equipped color computer monitor.

Design and Procedure

All pigeons were trained to discriminate between a pair of identically colored objects that differed in global shape. The stimuli were three-part yellow objects for 8 pigeons and three-part red objects for the remaining pigeons. Nine pigeons were trained with pictures of the objects and then tested for transfer to real objects; the remaining 9 pigeons were trained with real objects and then tested for transfer to pictures. During training and transfer sessions, S+ and S− were shown side by side in a simultaneous discrimination; choice of S+ was followed by access to food, whereas choice of S− terminated the trial without food. The objects were shown at two (yellow objects) or three (red objects) depth rotations, during both initial training and transfer testing. For 8 randomly assigned pigeons (same-contingencies group), the contingencies between the objects and reinforcement were the same during transfer and training (i.e., S+ during training remained S+ during transfer), whereas for the remaining pigeons (reversed-contingencies group), the contingencies were reversed for transfer (i.e., S+ became S−).

Pretraining. After being adapted to the experimental chambers, all pigeons were trained to peck on the left or right portion of the screen whenever it was illuminated with a solid patch of color (yellow for Replication 1 and red for Replication 2).

Object Discrimination Training. The experimental task was a simultaneous discrimination in which S+ and S− were presented side by side on each trial until the pigeon pecked at an area (5 cm high by 4 cm wide) centered on the left or right side of the touch screen. Correct choices of S+ were reinforced with 2-s access to food, and incorrect choices terminated the trial without food. To prevent position biases from developing, we repeated trials on which an incorrect choice was made; each such correction trial was repeated until the pigeon chose correctly. The correction trials were excluded from analysis. Each training session lasted for a maximum of 50 min or until a maximum of 128 noncorrection trials were completed. Trials were preceded by a warning stimulus, which consisted of three brief flashes of the overhead houselight. The intertrial interval was 10 s.

For each training view, S+ was equally often on the left or right side of the viewing area. In Replication 1, prior to the transfer test, the birds received a series of unreinforced tests in which the objects were shown at novel orientations; the data from these tests are reported in Friedman et al. (2005). In Replication 2, the birds moved directly to transfer testing after training to an accuracy criterion of two consecutive sessions in which the proportion of correct choices was .8 or higher for each training view.

Transfer Testing. Transfer-testing sessions were identical to training sessions except that the stimulus environment (real objects or pictures) was switched. Each bird continued with transfer testing until the overall proportion of correct choices was .8 or higher for two consecutive sessions, or for a maximum of 30 sessions.

Results

Figure 2 presents the mean proportion of correct choices by each group during the final 50 pretransfer trials and the first five 50-trial blocks of transfer trials, for picture-to-object transfer (top panel) and object-to-picture transfer (bottom panel).

We first conducted an analysis of variance (ANOVA) on the test trials only, with group (same-contingencies or reversed-contingencies), transfer environment (objects or pictures), and trial block (1–5) as factors. There were significant effects of group, $F(1, 14) = 12.2, p_{rep} = .97, \eta_p^2 = .47$, and trial block, $F(4, 56) = 25.1, p_{rep} > .99, \eta_p^2 = .64$ (see Killeen, 2005, for a discussion of p_{rep}), but there was no significant effect of transfer environment ($p > .5$), and no interactions were significant (all $ps > .1$). Regardless of transfer environment, the birds in the same-contingencies group performed consistently above chance, and better than the birds in the reversed-contingencies group.

The birds in the same-contingencies group also required fewer test sessions to reach an accuracy criterion of two consecutive sessions above 80% than did the birds in the reversed-contingencies group: The average number of sessions to criterion for transfer to pictures and objects, respectively, was 4.4 and 2.7 for birds in the same-contingencies group and 11.5 and 14.5 for birds in the reversed-contingencies group. An ANOVA with group and transfer environment as factors revealed a significant effect of group, $F(1, 14) = 7.23, p_{rep} = .93, \eta_p^2 = .34$. Neither the main effect of transfer environment nor the interaction approached significance ($ps > .5$).

We also compared accuracy on the last 50 trials prior to transfer with accuracy on the first block of 50 transfer trials, using a Group \times Transfer Environment \times Block Type (pre- or posttransfer) ANOVA. This analysis yielded main effects of group, $F(1, 14) = 7.54, p_{rep} = .94, \eta_p^2 = .35$, and block type, $F(1, 14) = 238.67, p_{rep} > .99, \eta_p^2 = .95$, as well as an interaction between those factors, $F(1, 14) = 18.99, p_{rep} = .99, \eta_p^2 = .58$. The interaction reflected the fact that performance

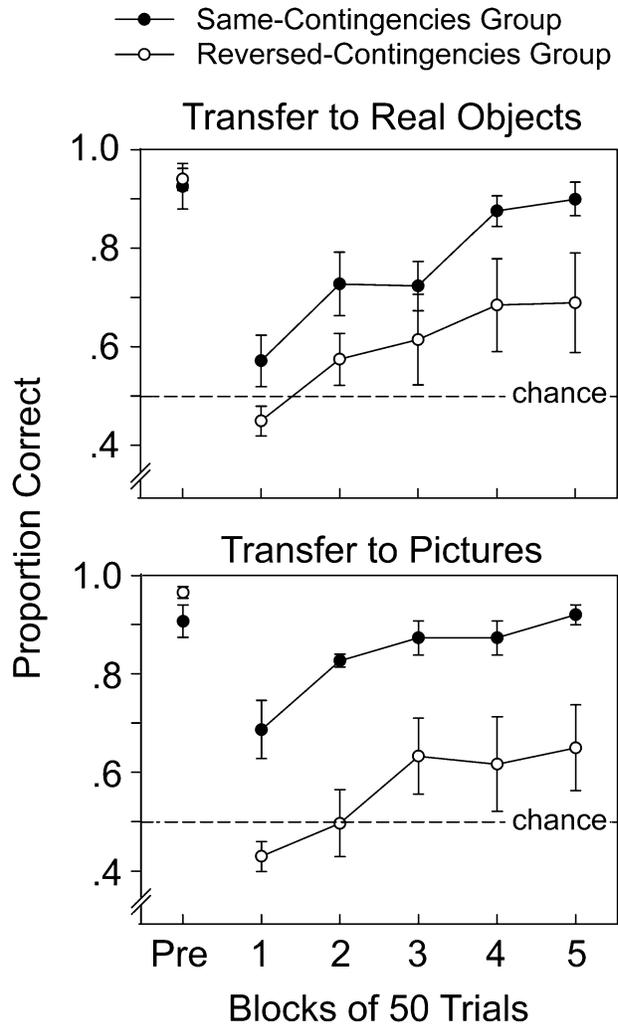


Fig. 2. Proportion correct during the last 50 training trials before transfer (“Pre”) and the first five 50-trial blocks of transfer trials, as a function of whether the contingencies during transfer were the same as the contingencies during training or reversed, and whether the transfer environment was from pictures to real objects (top panel) or from real objects to pictures (bottom panel). Error bars indicate standard errors of the means across subjects, computed separately for each group and block.

was highly accurate and equivalent across the groups during the last pretransfer block, regardless of the type of environment the birds were transferred to, whereas accuracy on the first block of transfer trials decreased more for the reversed-contingencies group (.53) than for the same-contingencies group (.30; see Fig. 2).

Discussion

The difference between birds tested with the same contingencies as during training and those tested with reversed contingencies indicates that the birds recognized the correspondence between the three-dimensional objects viewed directly and the digitized images of the same objects viewed on a computer screen. It is important to note that unlike in previous demon-

strations of transfer, we required the pigeons to discriminate between identically colored objects shown from multiple views. Thus, the correspondence we observed could not have been based on a discrimination of the colors of the objects, and was unlikely to have been based on the two-dimensional shape or alignment of the objects, because these properties changed across views. Unlike studies of courtship or aggressive responses, which may have evolved to be triggered by a single feature, this experiment shows transfer between pictures and objects in a learned task that required processing of global shape. Furthermore, the dramatic decrease in accuracy observed between the last block of pretransfer trials and the first block of transfer trials, for both the object-to-picture and the picture-to-object groups, provides evidence for Ittelson's (1996) third criterion for demonstrating an understanding of the correspondence between an object and its representation. That is, both groups demonstrated that they perceived a difference between objects and their pictures.

EXPERIMENT 2

The use of more than one view of the objects during both training and transfer testing in Experiment 1 reduced the likelihood that discrimination and transfer were based on the objects' two-dimensional shapes. Nevertheless, Experiment 1 did not completely rule out this possibility because the pigeons could have memorized the two-dimensional appearance of the objects at each training view. To provide a more conclusive demonstration of transfer based on the structural properties of the three-dimensional objects, we trained pigeons with 12 views of real objects and then tested transfer to pictures of the objects seen at 12 novel views. Thus, even if the pigeons memorized the two-dimensional images of the two objects at each of the 12 training views, this would not explain positive transfer because all of the views of the objects in transfer testing were different from the training views.

Method

Subjects

Seven adult pigeons (*Columba livia*) were maintained as described in Experiment 1. One additional bird was trained, but we could not use the data from this bird because of an equipment failure during the first transfer session. The birds had varied experimental histories that were balanced to the extent possible across the same- and reversed-contingencies groups. One bird in each group was experimentally naive, and 1 bird in each group had experience with pictorial stimuli in operant chambers but had never been trained with real objects. The remaining pigeons (1 in the same-contingencies group and 2 in the reversed-contingencies group) had experience with both pictorial stimuli and real objects but had never seen the objects used in this study.

Stimuli and Apparatus

The objects were the same as those used in Replication 2 of Experiment 1. Each object was digitally photographed in 15° steps starting at the 0° pose, which resulted in 24 different poses. For 3 birds, the 0° pose and every second pose after that were selected for training with real objects, and the poses in between were the poses shown in pictures during transfer testing. For the remaining birds, the opposite assignment of poses to training and transfer testing was used; that is, every second pose starting at 15° was used in training, and the poses in between were used in testing. The apparatuses were the same as those used in Experiment 1.

Design and Procedure

All pigeons were first trained to eat from the food hoppers and to peck at a red square on the screen in the operant chamber used to present pictures (i.e., the picture box). They were then moved to the other chamber and given discriminate training between the two objects. The assignment of the objects as S+ and S− was random across subjects. Each object was seen at each of 12 different poses in each session, but all other aspects of the procedure were the same as in Experiment 1. Upon reaching the training criterion (i.e., a proportion of correct choices of .8 or higher for each training pose for two consecutive sessions), the birds were transferred to the picture box for transfer testing. Three pigeons were tested with the same reinforcement contingencies for each object as during training (same-contingencies group), and 4 pigeons were tested with reversed contingencies (reversed-contingencies group). For both groups, all pictures in transfer testing presented the objects at novel poses (i.e., the 12 poses that fell between the 12 poses seen in training). Each bird continued with transfer testing until it completed 250 trials (typically two to three sessions).

Results

As in Experiment 1, the same-contingencies group performed considerably more accurately than the reversed-contingencies group following transfer from the real objects to the pictures. Figure 3 presents the mean proportion of correct choices by each group during the final 50 pretransfer trials and the first five 50-trial blocks of transfer trials. An ANOVA on only the transfer blocks, with group (same-contingencies or reversed-contingencies) and trial block (1–5) as the factors, revealed a significant effect of group, $F(1, 5) = 10.08, p_{\text{rep}} = .92, \eta_p^2 = .67$, and trial block, $F(4, 20) = 3.24, p_{\text{rep}} = .90, \eta_p^2 = .39$. There was no significant interaction, $F < 1$. The mean proportion correct for the same-contingencies group was .68, but the performance of the reversed-contingencies group was at chance (.47).

The Group (same-contingencies or reversed-contingencies) \times Block Type (pre- or posttransfer) ANOVA comparing each group's accuracy on the last 50 pretransfer trials with their accuracy on the first block of 50 transfer trials yielded a significant

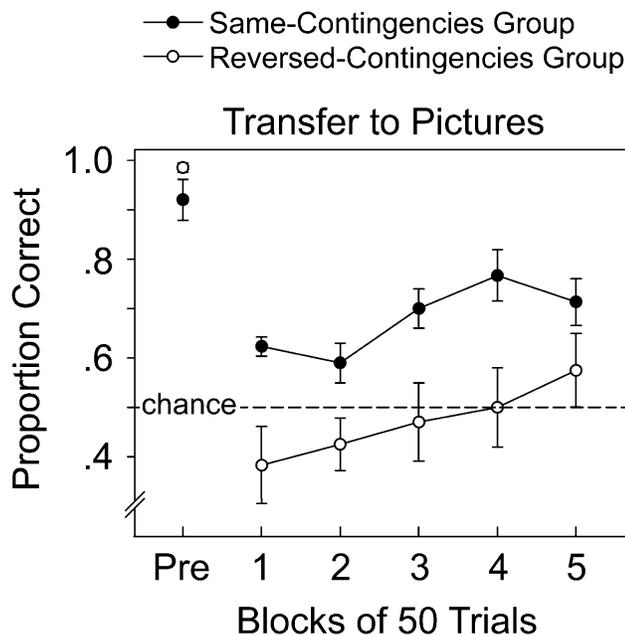


Fig. 3. Proportion correct during the last 50 training trials before transfer (“Pre”) and the first five 50-trial blocks of transfer trials, as a function of whether the contingencies during transfer were the same as the contingencies during training or reversed. All birds were tested on transfer from real objects to pictures. Error bars indicate standard errors of the means across subjects, computed separately for each group and block.

effect of block type, $F(1, 5) = 80.45, p_{rep} = .99, \eta_p^2 = .94$, and a Group \times Block Type interaction, $F(1, 5) = 9.31, p_{rep} = .91, \eta_p^2 = .65$. Once again, the groups’ performance hardly differed during the last 50 pretransfer trials, but differed substantially during the first block of transfer trials. Moreover, the decrease between pretransfer and transfer trials was twice as large for the reversed-contingencies group (.60) as it was for the same-contingencies group (.30; see Fig. 3).

GENERAL DISCUSSION

Our results provide the strongest evidence to date for transfer of learning between pictures and objects in pigeons. First, we found positive transfer in both directions, from pictures to objects and from objects to pictures. Second, the drop in accuracy from pretransfer to initial transfer trials, even for birds that were tested with the same contingencies as during training, suggests that the positive transfer was unlikely to reflect an inability to tell the difference between the objects and pictures. Third, use of a learned discrimination rather than spontaneous reactions to pictures avoids the problem that the reaction might be triggered by a feature of the object that serves as a releasing stimulus (Bovet & Vauclair, 2000). Fourth, to prevent the birds from using simple two-dimensional features of the objects to discriminate between them, we used identically colored objects, and we trained the birds with multiple views. In fact, these procedural features of our study may have encouraged the birds to attend to

the structure of the objects, and this may have facilitated their detection of correspondence between the directly viewed and pictured objects. Finally, the positive transfer seen in Experiment 2, in which all transfer views of the objects were novel, strongly suggests that the discrimination was based on the three-dimensional structure of the objects and that the birds recognized the correspondence between the directly viewed objects and the pictures of those objects.

Our demonstration of object-picture correspondence in pigeons is important because pictures, and particularly digitized images, are being used increasingly in studies of comparative cognition. In fact, reviews by Bovet and Vauclair (2000) and by Fagot et al. (1999) both noted the inconsistencies in the literature and highlighted the need for additional research on recognition of picture-object correspondence in animals. Our results indicate that at least under some circumstances, digitized images can provide the necessary information for pigeons to process the structure of objects.

Our results indicate that the pigeons recognized the correspondence between the objects presented in the images and the objects they viewed directly, but do not directly address the issue of whether the pigeons recognized the representational nature of the pictures. Conceivably, even without understanding that a picture “stands for” an object, an organism could (a) recognize that an object viewed directly and one viewed in a picture share the same structure, (b) recognize that the picture is different in kind from the actual object, and (c) apply a learned discrimination based on the object structure to both the picture and the object. The extent to which abstract representational processes underlie pigeons’ ability to perceive the correspondence between objects and pictures is a difficult issue, but one that may be addressed in future research now that evidence for recognition of such correspondence has been found.

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