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Author	渡辺, 茂(Watanabe, Shigeru)
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## VIEWPOINT CONSISTENCY IN THE PIGEON

*Shigeru Watanabe\**

Three experiments dealing with viewpoint consistency in pigeons were described. The first experiment showed viewpoint consistency for a familiar object but not for an unfamiliar one. Experiment 2 showed that experience with a three-dimensional (3-D) form improves visual recognition of a two-dimensional (2-D) representation of that form even when the orientation of the object is changed. However, viewpoint consistency depended upon the shape of the object. The third experiment used three-dimensional real objects in both discrimination training and testing. Viewpoint consistency was not found, that is, the subjects did not recognize the objects when they were shown in orientations different from those used in training. It appears that experience with the objects is important in the development of viewpoint consistency but experience does not directly result in consistency. Estimation or prediction from the experience makes viewpoint consistency possible.

### Introduction

Humans can recognize familiar objects viewed from unfamiliar angles. Viewpoint consistency probably requires a high level of visual processing because it is impossible to memorize huge number of images from many different viewpoints. Brain mechanisms associated with object recognition in the standard view may differ from those in unusual views. There has been extensive work on human viewpoint consistency but much less work has been done with non-humans animals. Pigeons are able to recognize rotated two-dimensional forms (Holland & Delius, 1982, 1995). Cerella (1977) trained pigeons with drawings of a 3-D cubes. The pigeons did not show transfer of the discrimination when the cube was rotated. Recently Wasserman *et al.* (1996), using line drawings, found a generalization gradient along depth rotation in pigeons. Lumsden (1977) trained pigeons on an orientation discrimination using 3-D real objects and obtained a generalization gradient for orientation. He also found generalization with mounted photographs similar to real objects. Generalization was, however, along orientation on the horizontal plane. Stimuli viewed from unusual angles, such as those used in neuropsychological tests, were not presented in his experiment. The following three experiments provide data on viewpoint consistency using

both familiar and unfamiliar objects in two and in three dimensional forms.

### Viewpoint consistency for familiar and unfamiliar objects

I trained six pigeons on a visual discrimination task using a familiar stimulus and unfamiliar stimulus and then tested them with these stimuli upside down or from an unusual viewpoint (Watanabe, 1977). The experimental chamber was an operant chamber with a TV monitor connected to a floppy disk player (Konica, KR-400). The subjects could see the monitor through a transparent pecking key (7 × 9 cm). I used two different objects as discriminative stimuli. One was a picture of the stainless steel feeder that was attached to each of the pigeon's living cage. This object was expected to be familiar for the subjects because they ate food from the feeder every day. Because the feeder was fixed to the front wall of their cages the birds did not have a chance to see it from the top or bottom. The presumably unfamiliar object was a picture of the coffee mug that I use to drink coffee from in my laboratory. Still images of both the feeder and the mug were taken with a floppy disk camera and edited for the experiment. The pigeons were given discrimination training between the pictures of the feeder and the mug using a multiple Variable Interval 30 sec- Extinction schedule. Each training session consisted of 40, 30 sec randomly ordered presen-

\* Department of Psychology, Keio University, Tokyo, Japan

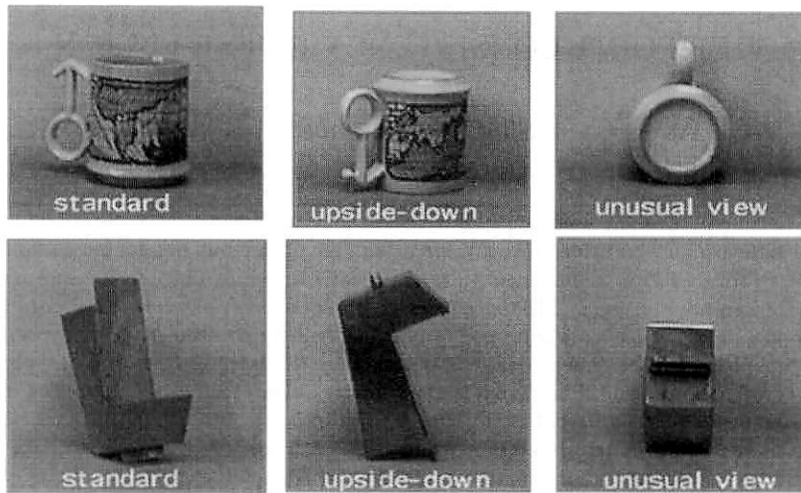


Fig. 1. Examples of still images of unfamiliar coffee mug (upper three) and familiar feeder (lower three).

tations of each of the stimuli. Images of the feeder were the S+ for half of the subjects and images of the mug were S+ for the remaining birds. Discrimination training continued until the subjects' discrimination ratio exceeded 90 percent on two successive sessions. Five subjects learned the discrimination within 15 sessions; one bird required more than 20 sessions. The difference in the number of sessions to criterion between the feeder S+ subjects and the mug S+ subjects was not significant.

A generalization test given in the absence of reinforcement followed. There were three types of test stimuli: (1) images similar to the training one (standard), (2) images of the side view of the object and (3) images taken from unusual viewpoints. The unusual views included a top view, a bottom view and a side view of the object lying horizontally. Fig. 1 shows examples of these test stimuli. The subjects trained with the feeder S+ responded equally to the three types of the stimuli, that is, they showed viewpoint consistency. On the other hand, the birds trained with the mug S+ responded significantly ( $t = 4.83, df = 2, p < .05$ ) less frequently to the non-standard views of the mug. Although the test stimuli were not varied along a single dimension, test performance suggests some sort of generalization gradient. The unusual views of the mug differed much more from the standard images than did the upside down images. For

example, there was a circular pattern when seen in the top or bottom view but never when viewed from the side. These results suggest that familiarity plays a crucial role in viewpoint consistency. Because the subjects had seen the feeder only upright and from the front the viewpoint consistency observed here is not a simple result of experience. It appears that the subjects responded to the unusual view of the feeder, not because they had seen exactly the same image before, but because there exists for them some kind of equivalence among images of the feeder. In other words, viewpoint consistency requires, not only experience, but also estimation or predictions resulting from that experience.

#### Experimental manipulation of familiarity

The previous experiment suggested that familiarity plays a crucial role in viewpoint consistency. Familiarity in that study was, however, not an experimental operation but rather an assumption. Time of exposure to the stimulus differed from subject to subject depending on their arrival to the laboratory. In the next experiment (Watanabe, in preparation, a) familiarity was experimentally manipulated.

Two pairs of yellow wood blocks were used as stimuli. These blocks are shown as S+ and as S- in Fig. 2 (Pair 1 in the top panel and Pair 2 in the lower panel). At least two weeks prior to the start of the experiment Pair 1 was placed in the

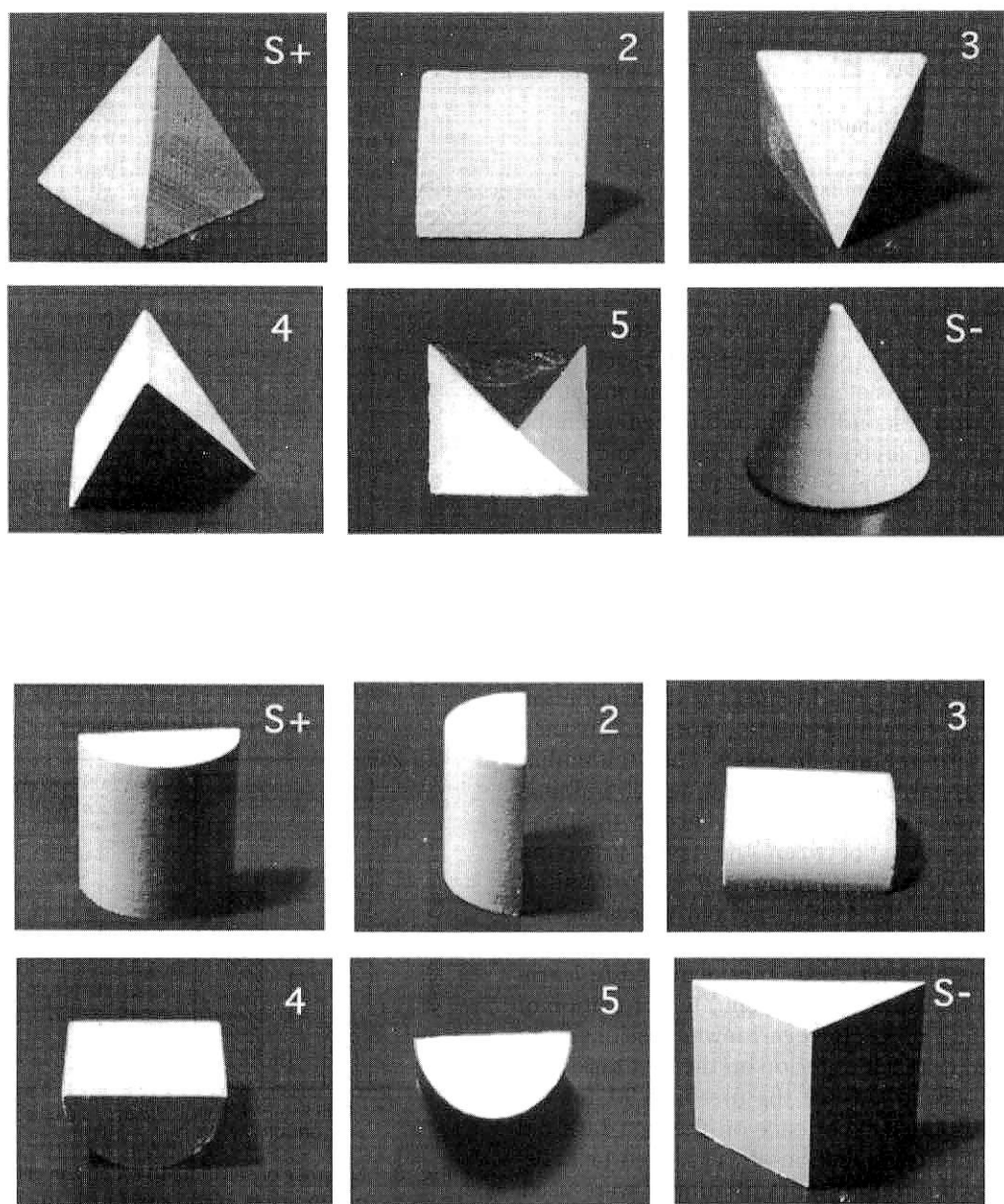


Fig. 2. Still images of training stimuli (S+ and S-) and test stimuli (2 to 5). The upper and lower panel show pair 1 and pair 2.

living cages of one group of pigeons and Pair 2 was placed in the cages on the other group. As a result of this experimental manipulation it was expected that Pair 1 would become a familiar stimulus for one group and Pair 2 for the other. The position of the blocks was purposely changed at least twice a day. This was in addition

to natural changes in position caused by movements of the living birds. The birds were then trained successively on two discrimination tasks—discrimination involving first the familiar pair of stimuli followed by the unfamiliar pair or vice versa with the forms with which the pigeons were familiarized counterbalanced

Table 1. Order of Discrimination trainings

Group	Experience	First task	Second task
Familiar→Unfamiliar	Pair 1	Pair 1	Pair 2
	Pair 2	Pair 2	Pair 1
Unfamiliar→Familiar	Pair 1	Pair 2	Pair 1
	Pair 2	Pair 1	Pair 2

across conditions. One bird was trained on each of the eight conditions described in Table 1. The apparatus and procedure were the same as in the previous experiment. Briefly, each training session consisted of 40 presentations of the stimuli and responding was reinforced when the S+ was displayed on the monitor and extinguished when the S- was displayed. Training continued until the discrimination ratio exceeded 90 percent for two successive sessions.

Fig. 3 shows the number of sessions to criterion. The upper panel presents the data for groups trained with the unfamiliar pair first and the lower panel those trained with the familiar pair first. The birds learned the discrimination involving the familiar stimuli more rapidly than the discrimination between the unfamiliar stimuli regardless of pair or order of training. There was a significant difference in the number of sessions between the tasks involving training with the familiar and the unfamiliar stimuli ( $t=2.46$ ,  $df=14$ ,  $p<.05$ ). Because the subjects were trained on two tasks successively, it is possible that experience acquired in learning the first task might facilitate acquisition of the second one. However, fewer sessions were required to reach criterion on the first task than on the second (7.5 for the first and 9.1 for the second). Thus, experience on the first task did not facilitate acquisition of the second task. Because two different pairs of stimuli were used, discrimination using one stimulus pair might be easier to learn than discrimination with the other pair. The mean number of sessions to criterion was 8 for pair 1 and 8.6 for Pair 2. This difference was not significant.

These results clearly demonstrates that pigeons learned to discriminate between familiar objects faster than to discriminate between the unfamiliar objects. Order of training and the particular stimuli used made little difference.

After reaching criterion on each discrimina-

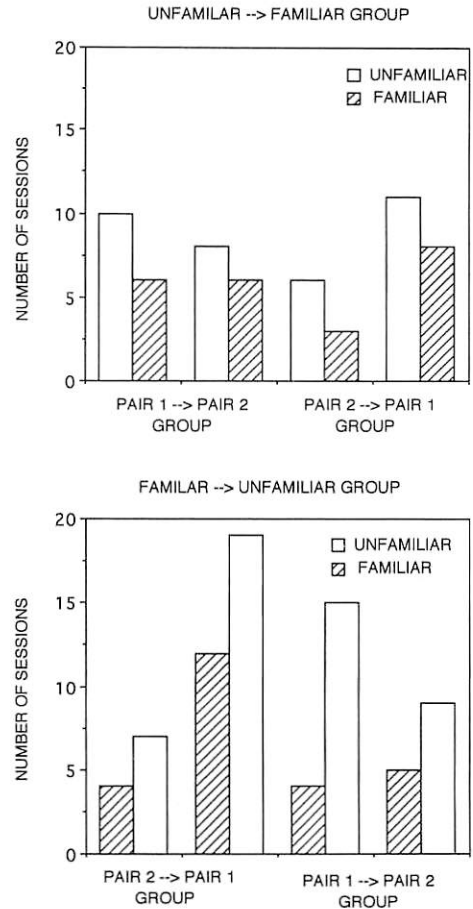


Fig. 3. Number of sessions to reach the criterion in each bird. Each pair of bars (open and shaded) indicates performance of one birds.

tion, the subjects were given a viewpoint consistency test in which six different stimuli appeared four times each in a random sequence. Reinforcement was not given during the test. As shown in Fig. 2, these stimuli included the original S+ and S- views and four novel views of these stimuli. A mean response ratio was calculated for each of the four novel (unusual

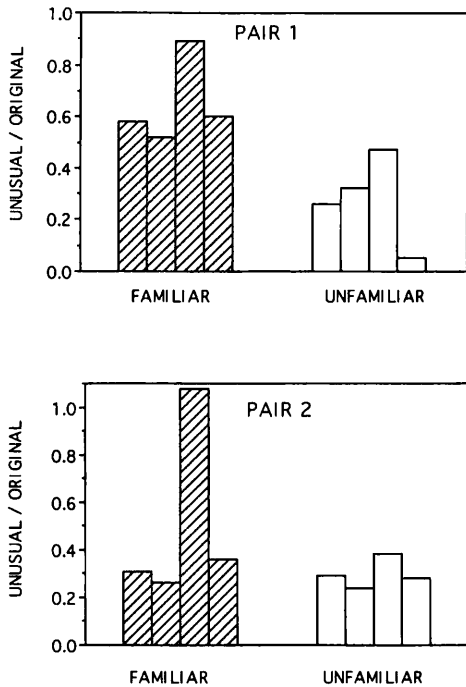


Fig. 4. Mean relative response to test stimuli.

view) stimuli by dividing the number of responses emitted to the test stimuli by the responses to the original S+ (ratios less than 1.0 occur when fewer responses are made to the novel stimuli than to the S+). The response ratios for each of the four familiar and each of the four unfamiliar novel stimuli are shown in Fig. 4 separately for Pairs 1 and 2. After training with Pair 1 (the upper panel), the subjects responded to the test stimuli more often in the familiar condition than in the unfamiliar condition. However, except for one subject, after training with Pair 2 (the lower panel), the birds emitted almost the same number of responses in the presence of the familiar and the unfamiliar stimuli. The difference between the familiar and unfamiliar conditions with Pair 1 was significant ( $t=2.88$ ,  $df=6$ ,  $p<.05$ ), while this difference was not significant for Pair 2. These results suggest that familiarity enhanced viewpoint consistency but also that the type of stimuli interact with the effects of familiarity.

Fig. 5 makes possible a comparison between responses to each of the test stimuli when these are familiar or unfamiliar. Data for Pair 1

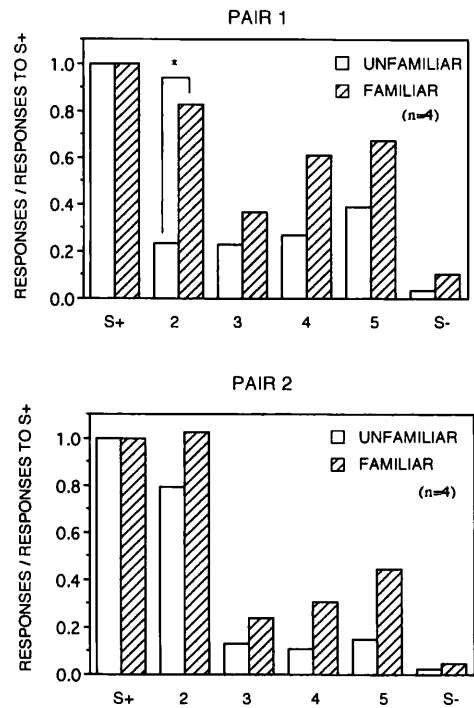


Fig. 5. Relative responses to each test stimulus.

are shown in the upper panel. When the original stimulus was unfamiliar to the subjects, they emitted few responses non-differentially to all test stimuli. The difference between the original and the unusual stimuli was clear. When the original stimuli were familiar, the subjects emitted more responses to the unusual stimuli in comparison to the unfamiliar condition. Their responding to the unusual stimuli differed among the stimuli. The smallest number of responses were made to stimulus 3. While this stimulus does not appear particularly unusual to the human observer (see Fig. 2) it is the only novel stimulus that lacks a vertical straight line. The other test stimuli have at least one vertical line (stimuli 2 and 5 have two vertical lines) and S- does not have a straight vertical line). Response rates were highest in the presence of stimuli 2 and 5. These data suggest that local cues, such as a straight vertical line, may control the behavior of the subjects. It must, however, be pointed out that there were individual differences in responding to the test stimuli. Some subjects responded

readily to some test stimuli but not others while other subjects showed different patterns of responding. In other words, stimuli that the subjects treated as equivalent to the original objects differed among the subjects. Differences were not significant except for a weak tendency in the case of stimulus 2 ( $t=2.36$ ,  $df=6$ ,  $p < .10$ ).

In the presence of Pair 2 (lower panel), the subjects also tended to respond at a higher rate to the unusual views of the stimuli (views 2, 3, 4 and 5) stimuli in the familiar as compared to the unfamiliar condition. The statistical analysis showed, however, no significant differences between the familiar and unfamiliar conditions for each of these stimuli. In both the familiar and unfamiliar conditions, the subjects responded most often to stimulus 2. This is the only test stimulus in the upright position and it contains two long vertical lines. One distinctive difference between S+ and S- is the presence of curvature in S+. All test stimuli except for stimulus 3 contain curvature. However, the pigeons do not appear to have used this feature in discriminating between S+ and S-.

Thus, while the present experiment suggests that familiarity improves viewpoint consistency effects of stimulus type were also observed. Moreover, although familiarity in this experiment was defined by the experimental operation of placing the stimuli in the living cage, the pigeons could attend to the stimuli but they could ignore them. The positions of the objects in the cages differed from subject to subject depending on movement of the subjects. The feeder in Experiment 1 possibly had some ecological significance for the birds. The wood blocks used in the present experiment probably were less meaningful for the pigeons. These factors might have contributed to the large individual differences in responding to the stimuli when presented in unusual orientations.








#### **Viewpoint consistency for 3-D real objects**

The two experiments described above used still video images as stimuli. Familiarity, based on experience with real objects, improved viewpoint consistency using video images. These observations suggest that there is an equivalent relationship between of three and two dimensional visual cognition. I reported bidirectional

transfer of discrimination between real objects and their printed photographs (Watanabe, 1993). There are several reports that showed behavior similar to real stimuli was observed with video images (Clark & Uetz, 1990; Mcquoid & Galef, 1993; Evans *et al.*, 1993), but there are no reports of direct transfer of a discrimination of real objects to their representation in the form of video images. In fact there are several problems resulting from use of video displays as stimuli that should be considered when using video displays in animal experiments. For example, critical flicker fusion for non-human animals may be different from ours, color displays based on the three color components that can be combined to produce equivalent color experiences for most humans may be seen differently by species with different color systems.

Previously I reported that pigeons, trained to discriminate between vertically presented 3-D objects maintained the discrimination when the stimuli were horizontally presented (Watanabe, 1997). However, while this experiment showed viewpoint consistency to some degree, the changes in viewpoint from vertical to horizontal might not be particularly unusual. In this preliminary experiment (Watanabe, in preparation b), I used 3-D real objects as training stimuli and examined responding to 3-D rotated stimuli. The experimental chamber was an operant chamber with two conventional keys and a rectangular window (4×7 cm) through which subjects could see inside the box described below. The stimulus presenting device was a motor-driven belt conveyor with 40 small boxes (4×7×7 cm) in which stimulus objects were placed. Wood balls and wood cones were used in this experiment. These stimuli were successively presented in a random series during each 80 trial session. Each trial started with illumination of a small lamp above the box just in front of the window. Pecking on the window on a fixed interval (2 sec) schedule resulted in the illumination of two side keys. The left key was illuminated by a green light and the right by a red light. A peck to the left key ("cone key") was reinforced by food reward when the stimulus in the box was a cone and a peck to the right key ("ball key") was reinforced when the stimulus was a ball. Incorrect pecks resulted in a black-

Table 2. Number of responses in test. (cone response/sphere response)

	721	611
	34/2	34/2
	1/7	0/8
	1/7	1/7
	1/7	1/7
	1/7	0/8
	8/0	6/2
	7/1	8/0

out followed by a correction trial. Discriminative training continued until accuracy exceeded 80 percent on two successive sessions.

The birds were then tested with six new stimuli. Table 2 shows the results of these tests. Separate tests were given for each of these six test stimuli. The test stimulus was presented eight times within an otherwise normal 80 trial session with 36 presentations of the cone and 36 presentations of the ball. There were six tests, each with a different test stimulus (the first with the cone lying on its side, the second with it up-side-down, the third with the bottom of the cone facing the subject, the fourth with the top facing the subject, the fifth with the small cone and the last with the tall cone. On test trials a peck to either key was reinforced by a brief (1.5 sec) presentation of food. Table 2 shows the test stimuli and the number of responses to each key for the six test stimuli. The number of responses to the cone key is shown to the left of the diagonal; the number of responses to the ball key is shown to the right of the diagonal. Perfect identification in the presence of the cone used in training should be 36/0. The results showed that the subjects maintained the original discrimination during these test sessions. Also, both pigeons showed size constancy, that is, they pecked the cone key on most trials when the small or large cone appeared. On the other hand, they pecked the ball key on most trials when the cone was presented in new positions,

even when it was rotated 90 degrees. The performance with the cones when viewed from different angles indicates that the pigeons did not show viewpoint consistency. Interestingly, if a test stimulus was not perceived as a cone or a ball, the subjects' choices should be at chance level (four pecks to the ball key and 4 pecks to the cone key would be expected). In fact, the pigeons clearly preferred the ball key in the presence of the cone except when it was in its original orientation. This behavior suggests that the birds learned a cone vs. other object discrimination but not the cone vs. ball although the training procedure called for a discrimination between cones and balls. Because both cones and balls are unfamiliar objects for the subjects, the present results agree with the results of the previous experiments using unfamiliar 2-D stimuli. As demonstrated in Experiment 2 the shape of the stimulus itself affects viewpoint consistency. The present observation must be confirmed with different training objects and different testing objects.

One problem in studying the effects of 3-D rotation is difficulty in specifying the of degree of rotation. There may be a subjective dimension of "usualness" but this dimension probably can not be reduced to single physical dimension. Moreover, the dimension may differ from object to object.

### Conclusions

The series of the experiments described above showed limited viewpoint consistency in pigeons. The pigeons did not show viewpoint consistency even when real objects were used in training and testing. However, viewpoint consistency tended to improve when the objects were familiar either through natural experience or experimental manipulation. These data suggest that viewpoint consistency is acquired through experience. Because the improvement in viewpoint consistency was not observed with all objects further examination with different objects, especially ecologically meaningful objects, is necessary if we are to understand viewpoint consistency in the pigeon.

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