

Distance and the presentation of visual stimuli to birds

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Abstract. Artificial visual stimuli in the form of photographs, video sequences and computer-generated images are increasingly being used to explore the visual world of birds but their use is controversial as it is still not clear whether birds see them in the same way that humans do. While differences between bird and human colour vision may be one problem with using such artificial images, another and potentially even more important difficulty is the distance at which stimuli are presented. An experiment is described in which hens, *Gallus gallus domesticus*, were trained to move towards one of two real objects viewed at two different distances. Even for real objects, discrimination levels were better when the hens were allowed to view the stimuli from 5–25 cm than when they were forced to choose at 120 cm and this correlated with their ability to transfer to photographs of the same objects at different distances. In a colour discrimination at a short distance, five out of seven hens showed 100% correct responses when first shown photographs of real objects that they had previously learnt to discriminate. The results suggest that photographs can be used as substitutes for real stimuli but that care should be taken over the distance at which they are presented. The results are discussed in relation to the visual behaviour of birds and differences in functioning of their frontal and lateral visual fields.

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Although video and photographic images are potentially powerful tools for analysing the visual worlds of animals, their use has recently been criticized on the grounds that other species may not see them in the way that we do. In particular, it has been claimed that images colour-balanced for human vision may be inappropriate for animals with different colour vision systems from our own, such as birds (Delius 1992; Cuthill & Bennett 1993; Bennett et al. 1994).

However, the fact that some studies have shown that birds respond well to video images (Evans & Marler 1991; Keeling & Hurnik 1993; McQuoid & Galef 1993) suggests that colour is not the only factor determining whether a bird sees an artificial image as representing the real world. We suggest that an even more important factor is how the image is presented to the bird's eye and, specifically, whether the bird is able to view the artificial image from the same distance as it would naturally choose to view real objects. As we show, this

hypothesis has the advantage that it explains why some experiments presenting artificial images to birds 'work' and others do not.

Image distance is particularly important for birds because they effectively have two visual systems which are both anatomically and functionally distinct. The thalamofugal pathway (OPT complex or visual wulst) receives input largely from the monocular lateral field while the tectofugal pathway (nucleus rotundus) receives largely from the frontal field (Shimuzu & Karten 1993), which may have a considerable degree of binocular overlap. The monocular lateral field is specialized for the detection of distant moving objects whereas the frontal field appears to be more concerned with the resolution of static near objects (Hodos 1993). The two fields are separate to such an extent that pigeons, *Columba livia*, may have difficulty transferring a task learnt in one visual field to the other (Goodale & Graves 1982; Mallin & Delius 1983) although such intra-ocular transfer is easier when stimulus presentation is changed from the lateral to the frontal field than from frontal to lateral (Remy & Emmerton 1991). This fact alone should alert us to the possibility

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that exactly where an image falls on the eye may profoundly affect whether a bird recognizes it, particularly if in the real world the bird has been using the frontal (near) field and is then confined in a Skinner box, in such a way that it looks at a photograph, video sequence or even a real object with its lateral (distant) field.

Until recently, the lateral visual field has been considered to have the greater importance for the detection of food, conspecifics and predators, with the frontal field being relatively unimportant and used just for guiding pecks at food (Güntürkün et al. 1993). However, it now appears that in hens, *Gallus gallus domesticus*, the frontal field may be even more important than the lateral field in at least one situation, namely, that of social recognition. Hens seem to be unable to recognize a familiar flock-mate unless they are closer than 30 cm and can 'inspect' each other using the frontal field (Dawkins 1995, 1996). They view other hens with the lateral field when further away (see also Andrew & Dharmaretnam 1993). When shown life-sized photographs of hens' heads, they inspect them in the same way as real hens, often going so close as to peck the photograph on the comb (Dawkins 1996). On the other hand, hens show no evidence of recognizing other known individual hens from coloured slides when shown them at a distance of 1.3 m (Bradshaw & Dawkins 1993). They even have difficulty in discriminating live birds presented in a Y-maze with arms 0.75 m long (Bradshaw 1991). These results become understandable if they are interpreted in the light of birds having two visual systems and experiencing difficulty transferring between them. If hens closely inspect and learn about each other's identity with the frontal field, it is then not surprising that they cannot recognize photographs presented at a distance where they naturally use the lateral field.

If this effect of distance on bird vision is important in a wider range of situations than just recognition of flock-mates, then this could profoundly affect the interpretation of many current experimental paradigms, particularly those where birds are constrained in how closely they are allowed to approach stimuli, as in most conditioning experiments, or where photographs, computer images or video sequences are used as stimuli. The natural viewing behaviour of the bird is hardly ever taken into account in the design of the experiment, although much better results are obtained

when it is. For example, birds seem to respond to photographs as good substitutes for real objects where the objects and their photographs are presented in exactly the same place and can be viewed with exactly the same part of the eye (e.g. Delius 1992; Watanabe 1993), while they respond less well where this effect is not controlled for (e.g. Dawkins et al. 1996). Evans & Marler (1991) showed that video stimuli were effective substitutes for live birds as an 'audience' for alarm calling and they were careful to present cockerels with life-size images of conspecific females at the same distance as live companions.

We therefore designed an experiment to test the hypothesis that distance is a critical variable for visual recognition of inanimate objects in hens, both for their ability to recognize real objects and also for how well they respond to artificial visual images, in this case, photographs of those same objects. Our expectation was that there should be a close correlation between the distance at which hens found it easiest to discriminate real objects and the distance at which they showed greatest ability to transfer to photographs. The results are intended as a methodological aid for the design of any experiments involving presentation of visual images to birds.

We used three-dimensional inanimate objects (plastic toy tools) and simple discrimination tasks in which the hens had to move towards one of two objects to obtain food. We varied the distance from which the hens had to discriminate between test objects. We then looked at the hens' ability to transfer their ability to discriminate real objects to life-size photographic prints of the objects, photographs being used in preference to video because of the higher visual quality that can be achieved.

METHODS

Subjects

We used eight ISA Brown hens for this experiment. They were about 2 years old at the time when training began and had been used in previous experiments involving social recognition (D'Eath & Dawkins 1996). The birds were originally part of one of two groups of eight hens kept in pens (3.5 × 1.0 × 2.0 m high) which had wood shavings on the floor, perches and nestboxes, but over the course of the experiment, group numbers were reduced through the death of some of the birds. Two hens were kept in single cages to

prevent them being feather-pecked. All birds were kept in a room heated to 19–20°C on a light cycle of 14:10 h light:dark, and fed on a commercial mixture of grain and mash on an ad libitum basis. Food was removed from the birds 1 h before training or testing but otherwise no food deprivation was found necessary.

Apparatus

Hens were trained in a small room (1.8 × 3.0 × 2.0 m high). At one end of the room was a start box (400 × 430 × 480 mm high) which had both a wooden and a clear plastic door. At the other end of the room, 1.8 m away, were two concrete blocks (200 × 100 × 400 mm) behind one of which we hid food in such a way that the hen could not see whether food was there until she had gone round the back of the block. In front of the blocks, plastic tools (160–180 mm high) were placed on stands (Fig. 1). The tools were either red or blue and either in the shape of a hammer or in the shape of a saw. The hens' task was to learn which of these tools indicated that there was food on the other side of the block. For the sake of convenience, we refer to tests that involved a choice between a red tool and a blue tool as 'colour' tests, although we made no specific attempts to control for brightness as it would not have affected the results if the birds were discriminating on the basis of brightness rather than wavelength. Also for the sake of convenience, we refer to tests involving a choice between a hammer and a saw as 'shape' tests, although nothing is implied about the mechanism the birds employed to solve the discrimination. At any one time, a hen saw two plastic tools, one in front of each block, separated by a barrier down the mid-line of the room. The barrier was either 'short' (extending 5 cm in front of the tools), and allowing the hen to approach the two objects closely, or 'long' (extending 120 cm in front of the tools) and forcing the hen to decide which one to choose further away. Each tool was 25 cm from the midline of the room. Thus, throughout the experiment, a hen was always shown the objects at the same distance (from the start box 1.8 m away from the stimulus objects). What was varied was the distance she was allowed to approach before having to choose to go left or right.

For the tests with photographs, life-size colour prints of the four training objects were substituted

for the real objects at exactly the same place. The photographs were taken using a 50 mm +2 dioptre lens and Fujicolour 100 ASA film in daylight and then mounted on stiff card.

Procedure

The eight hens were trained and tested singly. They were first trained to come out of the start box and go behind a block to find food (mash and grain mixture). For this pre-training the relevant block had one of the four training objects in front of it and the other block had nothing. Once the hens had learnt this task, they were presented with two objects, one of which indicated behind which food was to be found ('positive' object). To avoid the possibility that the hens might find some distances easier to discriminate than others because they had simply been trained at one distance rather than another, we trained half the hens to discriminate objects with the long barrier in place and the other half with the short barrier. All hens were trained on two tasks (1) red versus blue object ('colour') and (2) hammer versus saw ('shape'). Four of the hens were trained on the colour task first, the other four on the shape task first. In the colour task, half the hens were trained with red positive and half with blue positive, and half were trained with red and blue hammers and the other half were trained with red and blue saws. In the shape task, half the birds were trained to discriminate a blue hammer from a blue saw and the other half to discriminate a red hammer from a red saw. Because there were eight not 16 birds, not all the 2⁴ conditions could be uniquely represented and the four birds that received their short barrier tests first were all trained on saw positive (half blue and half red positive), but as the effect of one or other stimulus being positive was not specifically being tested for, this could not confound the main results. Thus, although numbers in each 'group' were too small for specific statistical testing, the design of the experiment was such that none of the following variables could confound the results: colour of positive or negative object; order of learning tasks; length of baffle used in initial training. Throughout training and testing, the position of the positive and negative objects was systematically varied. Hens were given six to eight training trials/day. For each trial, we placed a bird in the start box with both doors down and the short barrier in position. After 30 s,

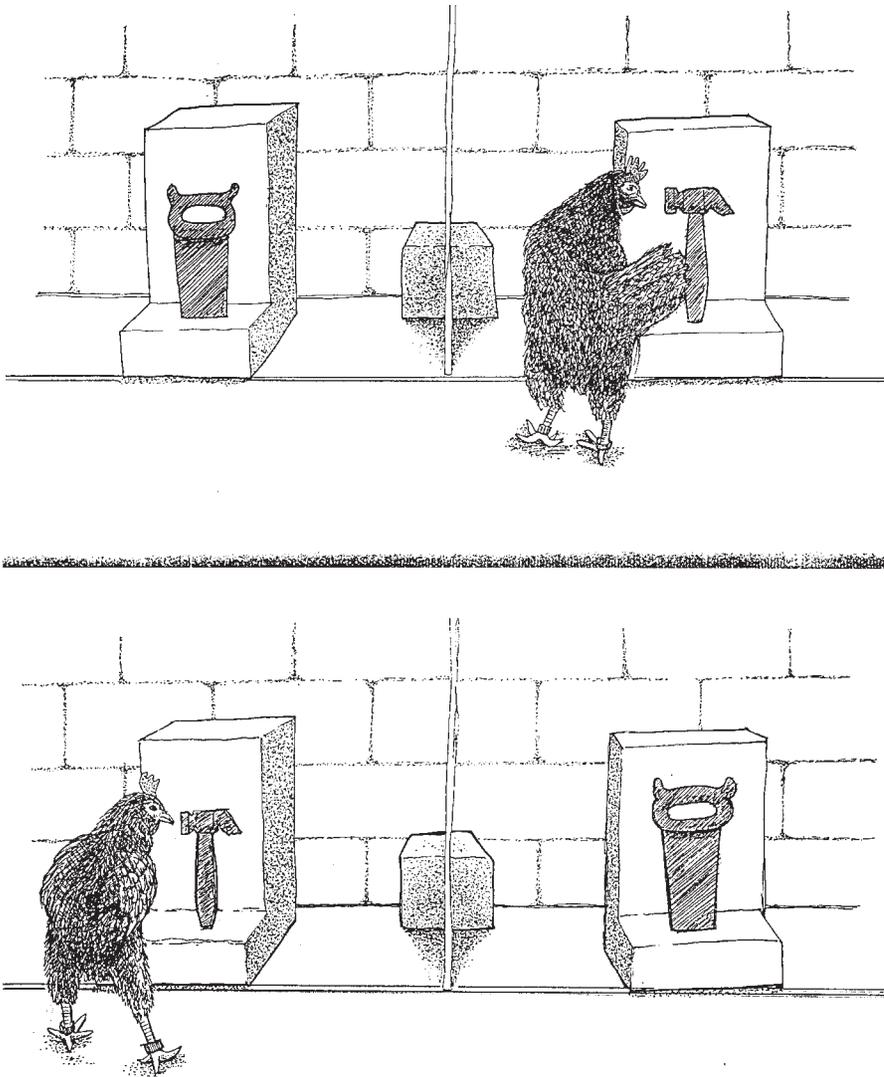


Figure 1. Hen during a shape test in which the positive (i.e. rewarded) stimulus was a hammer. Whether the hammer was on the right or on the left, this particular hen approached the right-hand stimulus and 'inspected' it from a few centimetres, moving over to the opposite side if it was incorrect before making her choice which was defined as crossing the line drawn on the floor on either side of the stimuli. Drawings by Wayne Clack from photographs.

we raised the wooden door, giving the bird a sight of the stimuli through the clear plastic door. After a further 20 s, the clear plastic door was raised and the bird released into the room and allowed to choose. A choice was defined as the hen crossing a line of white tape level with the stimuli (Fig. 1). After being allowed to eat for 15 s, the bird was caught by hand and replaced in the start box.

For each series (colour or shape), the hens were each given 48 training trials (spread over 6 days). These training trials were then followed by 16 test trials with the same stimuli, eight trials for each hen with the short barrier and eight trials for each hen with the long barrier, the order of the two sets of eight trials being systematically varied. Tests with the photographs were identical except that

photographs of the two objects were used in place of real objects for four of the eight trials. Having completed one series, hens were then retrained on the other series.

RESULTS

Initial Training

All eight hens learnt the colour discrimination easily and achieved at least 80% correct within 40 trials, regardless of whether the barrier was long or short. Six out of the eight hens achieved 100% correct. However, the four hens initially trained with the long barrier in the shape discrimination failed to learn within this time and only one bird achieved higher than 60%. For this reason, they were subsequently given a further series of 40 training trials with the short barrier, whereupon three showed levels of discrimination above 75%. One hen completely failed to learn the shape discrimination even with the short barrier and was dropped from the analysis altogether.

Tests with Real Objects at Two Distances

For both shape and colour tests, hens achieved higher scores with the short barrier than with the long barrier (Wilcoxon signed-ranks test, two-tailed: for shape $T=0$, $N=7$, $P=0.05$; for colour $T=0$, $N=7$, $P=0.05$; Fig. 2). The very low success rate in the shape tests with the long barrier is striking and the behaviour of the hens during these tests strongly suggested that this was because the long barrier prevented them from 'inspecting' the test objects from a short distance which they did with the short barrier (Fig. 1). Frequently, hens either paused each time they approached the test objects or even pecked them before moving behind the relevant block.

Transfer to Photographs

Hens showed clear evidence of transfer to photographs under some circumstances. Five out of the seven hens chose the correct stimulus 100% of the time in the colour test series with photographs when there was a short barrier and six out of seven chose the correct stimulus on the majority (at least 75%) in the same test (Fig. 3). Figure 3 shows the relationship between discrimination between real objects and photographs of

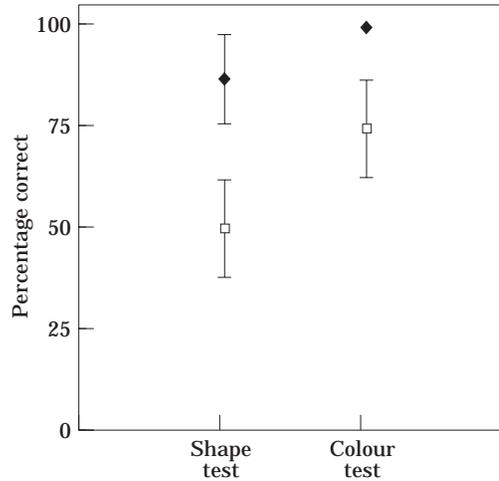


Figure 2. The effect of barrier length in tests on discrimination between objects of different shape and colour. Medians and inter-quartile ranges for $N=7$ hens of tests with a long barrier (□; 120 cm) and with a short barrier (◆; 5 cm). See text for details.

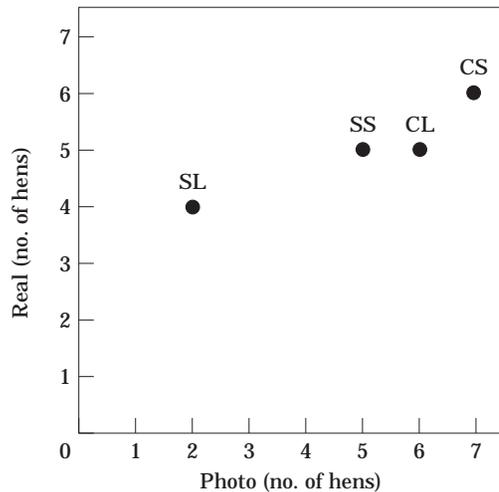


Figure 3. Relationship of ability to discriminate real objects and ability to discriminate photographs of those same objects, shown here as the number of hens giving the majority (75% or more) of their choices to the positive stimulus in the two types of test. SL: shape test with long barrier; SS: shape test with short barrier; CL: colour test with long barrier; CS: colour test with short barrier. See text for details.

those objects. As there were only four different tests, it was not possible to carry out a statistical test on just these four points. However, each of

the seven birds that completed the experiment had contributed eight separate scores, that is, performance in the four real tasks (colour and shape with two different barrier lengths) and performance on the same four tasks involving photographs. For each bird we computed a mean difference score, based on differences in her rank performance between real object tests and photograph tests. Each bird therefore contributed a single number to the subsequent analysis based on a comparison of her performance in real object tasks and in photograph tasks. These seven numbers were then subjected to a Spearman rank correlation (two-tailed) which effectively asked whether there was a correlation between performance with real objects and performance with photographs of those objects. The results were significant ($r_s=0.844$, $N=7$, $P<0.05$).

DISCUSSION

This experiment is instructive in two ways. First, it shows that distance is important to discrimination tasks in hens when they are discriminating between real three-dimensional inanimate objects and not just in social situations. Performance was better when the birds were allowed to approach the stimulus objects closely. Since the pecking and inspection of the stimulus objects shown by several of the birds only served to delay their obtaining food this strongly suggests that these behaviours were part of their object recognition and way of learning about the world. Close-up inspection of objects that we would probably discriminate at a distance may thus seem to be an important part of their normal vision.

Second, the experiment shows that good transfer to colour photographs can be obtained but that transfer is better under some circumstances than others. The fact that many birds showed 100% correct responses to photographs of red and blue toy tools plus the aggressive pecking to photographs of hens reported by Dawkins (1996) suggests to us that although bird colour vision may be different from ours, they still see the colours in at least some photographs in ways that are not all that different from the way we do. Distance and position on the retina may be even more critical to whether transfer occurs.

It follows that any experiment aimed at uncovering what birds can and cannot discriminate or

even what they do or do not prefer should take into account the distance at which the stimuli are presented. This will apply to discriminations between real animals and between real inanimate objects since if the birds are constrained by the experiment from being able to get as close to the stimuli as they normally do, false conclusions could be drawn. It will apply even more, however, to experiments in which birds are confined in Skinner boxes and shown photographs, video sequences or computer-generated images at distances that are completely different from the distances they would normally view such objects. This is not to say that birds cannot be trained to make complex discriminations at any distance determined by an experimenter, as their ability to do this is well documented (e.g. Ryan 1982; Bradshaw & Dawkins 1993), but any researcher interested in the way birds see in the world outside a Skinner box and wanting to use such artificial visual stimuli as in some sense representing the real world should take account of how birds see real stimuli. We cannot expect birds to see photographs and videos in the way we do, because they may not see real objects in the way we do.

We used photographic prints in this study because even with the rapid technological advances in image manipulation that have occurred over the last few years, higher resolution and image quality can still be obtained with prints than with video. Image quality will be particularly important wherever birds recognize objects using close-up 'scrutiny' or inspection since the artificial nature of video or computer-generated images rapidly becomes apparent when they are viewed from only a few centimetres away. (Even we do not see video images as particularly life-like if we view them from 10–20 cm.) This may explain why negative results have been obtained with video studies on social recognition in hens (D'Eath & Dawkins 1996) where close-up inspection with the frontal field is important (Dawkins 1995, 1996), but more naturalistic responses have been obtained with images viewed from further away (Evans & Marler 1991; Evans et al. 1993; Keeling & Hurnik 1993) or where detailed form analysis is not called for (McQuoid & Galef 1993).

It follows that the most successful use of current technology video images with birds are likely to be those in which birds use the lateral (distant) field in real life and are presented with artificial visual stimuli in an experiment where they can also use

the lateral field. Recognition of predators, presence (although not always identity) and even behaviour of conspecifics would be obvious candidates as would signals designed for long distance perception. Indeed, it may be even be that many visual signals in birds are specifically designed to stimulate the lateral field of conspecifics, using movement and colour as attention-grabbers (Fleishman 1988; Dawkins & Guilford 1996) and could be quite easily mimicked by video, leaving the more detailed analysis, for example of identity or parasite load (Zuk et al. 1990), to close-up scrutiny that would be far harder to reproduce artificially. Without a prior knowledge of how birds use their eyes, we could be misled either into thinking that our new high-tech visual images can tell us more about how birds see the world than they actually can or conversely into thinking that they cannot be used at all.

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