Visual recognition by pigeons

"One of the really astounding things the mind does is group similar things and make a concept of them. This is something that, as far as we know, no animal can do."

- Hunt, NY Times, 1982

Q. Pigeons and other birds exhibit conceptual behavior (mate, aggressor, food…). How?

A. Sometimes concepts are defined by simple features. For instance, a European robin defends its territory against anything red (corresponding to a robin's red breast). Such simple features may act as key-signs (refer to presentation).

BUT, most recognition tasks in the real world (or natural concepts) are not so easily characterizable. Concepts in the real world can usually not be defined by any single necessary or sufficient feature. They are 'polymorphous' concepts. They constitute difficult concept formation tasks.

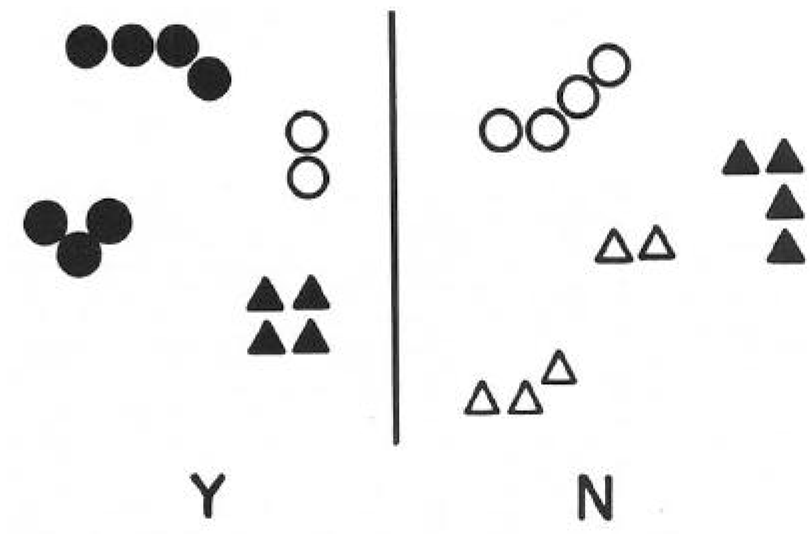

FIG. 14.11. A polymorphous rule separates the Y's from the N's. See text. (Adapted from Dennis et al., 1973.)

FIGURE: An example of a polymorphous concept. What is the concept?

Q. Can pigeons really learn complex visual concepts?

A. Several experimental studies suggest that they can.

- Basic experimental setup – the Skinner box (Methods section in Herrnstein et al, 1976)

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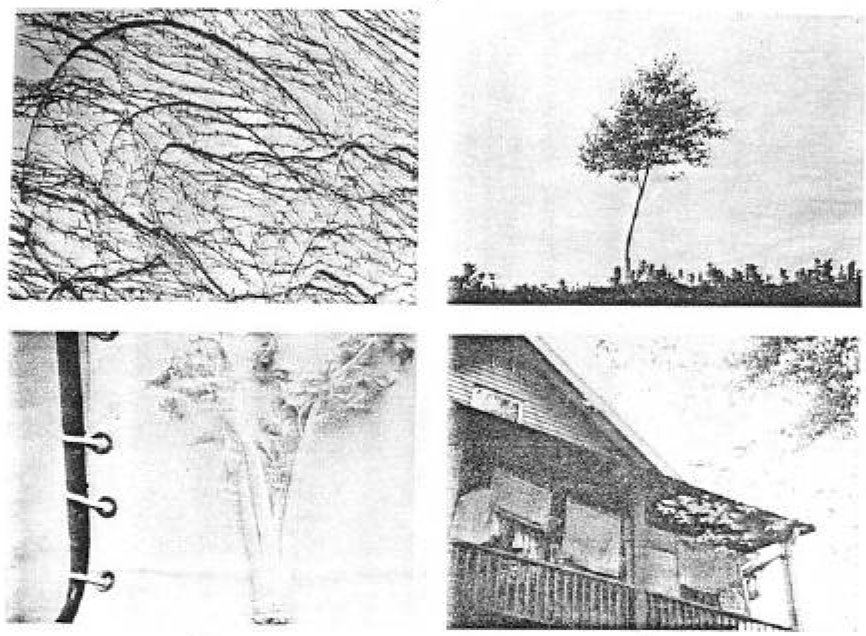

FIGURE 3. Four typical pictures used in Experiment T (trees), which were correctly classified by at least three of the four pigeons. (Negative stimuli are on the left; positive, on the right. The upper left picture shows a vine climbing on a cement wall; the lower left, celery.)

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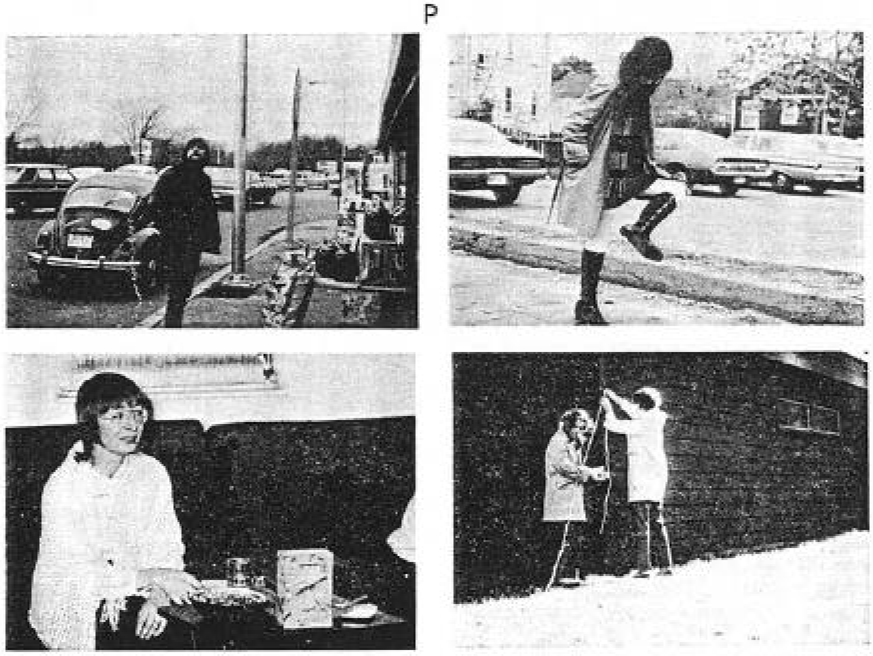

FIGURE 5. Four typical pictures used in Experiment P (specific person), which were correctly classified by at least three of the four pigeons. (Negative stimuli are on the left; positive, on the right. The upper left picture shows the subject's husband wearing her scarf; the lower left shows a different woman in the subject's apartment.)

- FIGURE: Sample tree, water and person slides

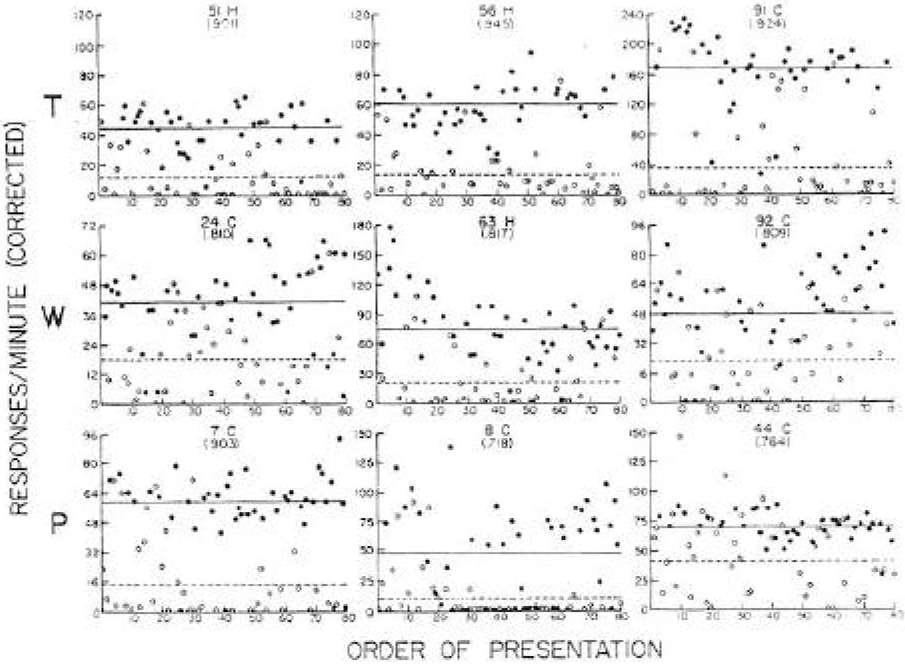

FIGURE 1. Corrected rates of pecking in the presence of each picture during a representative session using only new pictures, plotted against the order in which the pictures were shown. (Each coordinate axis is for one subject; each row for one of the three experiments. Filled circles are for positive stimuli; open circles, for negative stimuli. The solid horizontal line averages the filled circles; the dashed line averages the open ones. The decimals in parentheses are values of an index of discrimination, see text.)

- Results: Figure 1 (Herr et al, 1976)

Q. But, is this really learning? Couldn't pigeons have possessed these concepts innately?

A. Possibly. So, experimenters tested pigeons on a concept they are unlikley to have innately – fishes.

Q. But, perhaps all 'natural' objects possess some characteristics that the pigeons may be tuned to innately? Also, pigeons might solve the fish task by identifying fishes as instances of some different pre-existing concept (cf our descriptions of stereoisomers of cyclohexane as 'chair' and 'boat' forms)

A. Perhaps. So, experimenters have tested pigeons on controlled artificial concepts such as line-drawings.

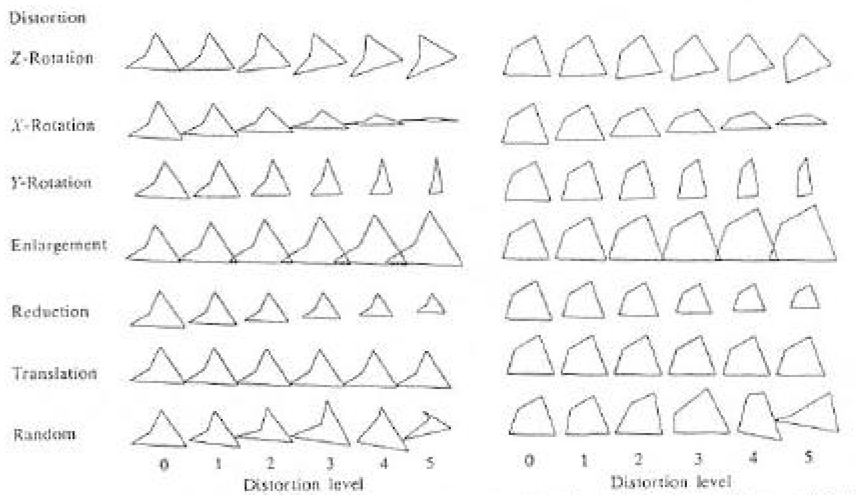

Figure 4. Graded deformations of the chevron target (left half) and the trapezoid target (right half). Deformations are random (bottom row) or systematic (upper six rows), but all are equated across five congruity levels.

FIGURE: Figure 4 from Cerella (1990) Perception

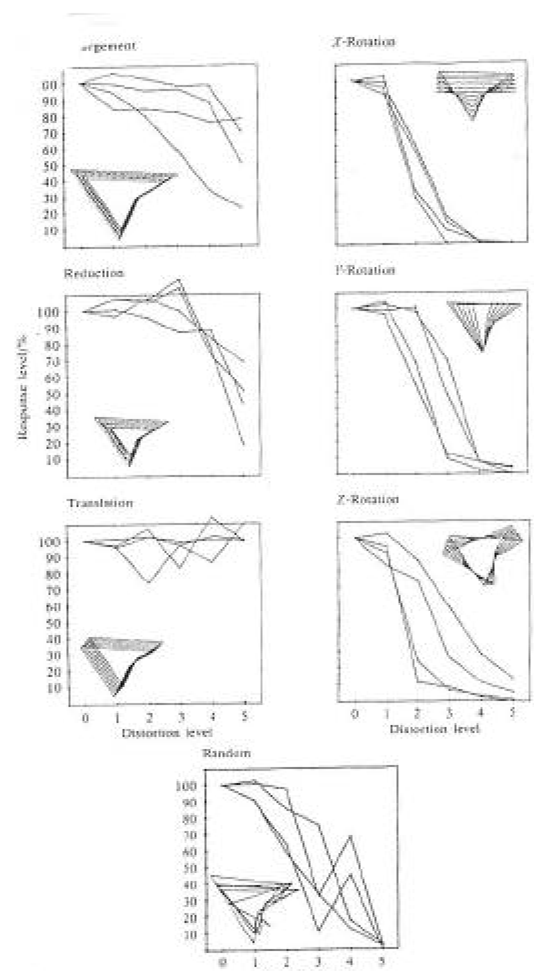

FIGURE: Figure 5 from Cerella (1990) Perception

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MECHANISMS OF DISCRIMINATION

Q. What might be the possible mechanisms underlying this ability of pigeons?

A. There are a couple of possibilities:

1. Individual example recognition via global template matching

Supporting evidence:

Anish's study (1978)

With a single tree slide, generalization only to similar tree slides

With multiple tree slides (distant views ot close-up views)

- generalization to similar views

A natural concept may be made of multiple such concepts based on global templates

Q. But, doesn't this require too much memory? Can pigeons remember so many images?

A. Yes. Vaughan and Greene's (1984) expts show that they can. Pigeons can remember more than 1000 slides (arbitrarily marked + or -) even 2 years after initial training.

Q. But, how does this relate to the concept formation studies. Aren't pigeons doing the classification on the basis of the concepts?

A. Not necessarily. Pigeons may just be remembering each slide (and its valence) individually.

- Pigeons can acquire pseudoconcepts (as fast or sometimes a little slower than real concepts)

<u>Caveats regarding the absolute discrimination via global templates idea:</u>

- No studies have probed whether pigeons trained on pseudoconcepts show similar generalization as pigeons trained on real concepts.
- Cerella's unpublished data on image scrambling seems to argue against global templates.
- No mechanism for global image matching has been specified so far. Is it just a normalized correlation using L1 or L2 norms?
- Many studies using man-made patterns seem to argue for a more local-feature based strategy.

2. Recognition via local templates

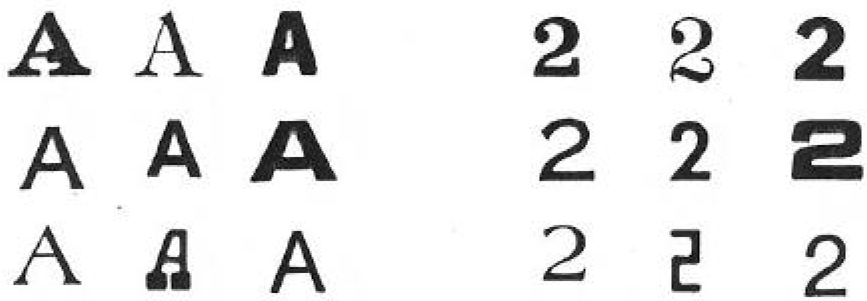

Figure 8.2 Patterns of the sort used by Morgan et al. (1976). In their experiment, pigeons successfully distinguished A's from 2's.

FIGURE: Figure 8.2 from Cerella, 1982

After being trained on the discrimination between ‘A’ and ‘2’ across 18 typefaces, pigeons generalized to 22 new typefaces.

But, this doesn’t rule out global templates; only rigid global templates. How about using flexible templates? Yes, but that does not explain the Charlie Brown experiments.

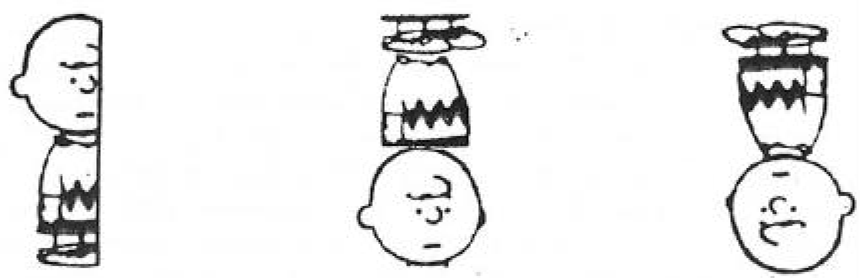

Figure 8.4 Truncated, scrambled, and upside-down Charlie Brown. Pigeons treated 3(truncated images and 18 scrambled images as equivalent to intact Charlie Brown images Response to upside-down images was inconsistent. Data from Cerella 1980.

FIGURE: Figure 8.4 from Cerella, 1982

After being trained on discriminating between CB and Lucy, Linus etc., pigeons were tested on novel CB images – truncated, scrambled, inverted. They transferred the discrimination and were unable to distinguish the transformed CBs from intact ones! This seems to argue for local templates.

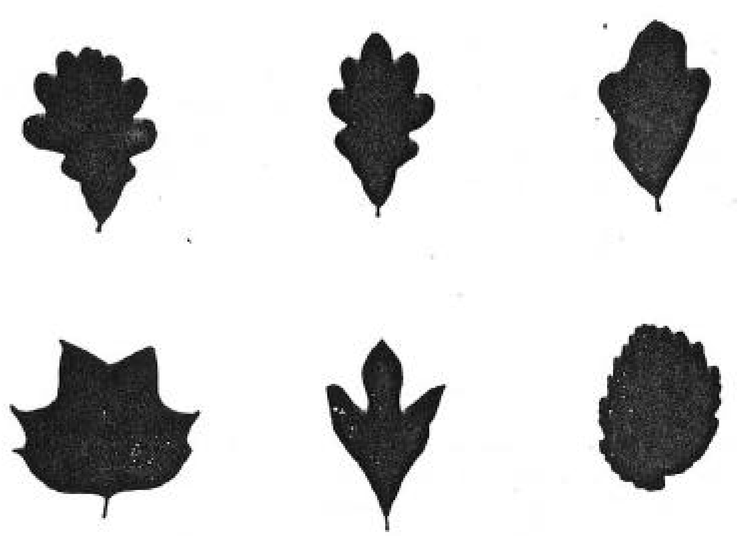

Figure 8.6 (Top) White oak leaves. (Bottom) Leaves from other tree genera. Pigeons' tendency to generalize from the center oak to 40 other oaks was so strong that they were unable to distinguish this oak from the 40 others. Source: Cerella 1979.

FIGURE: Figure 8.6 from Cerella, 1982

After being trained on a single oak leaf, pigeons were able to distinguish it from other kinds of leaves, but were unable to distinguish it from other oak leaves that shared the same local features, but had different global structures.

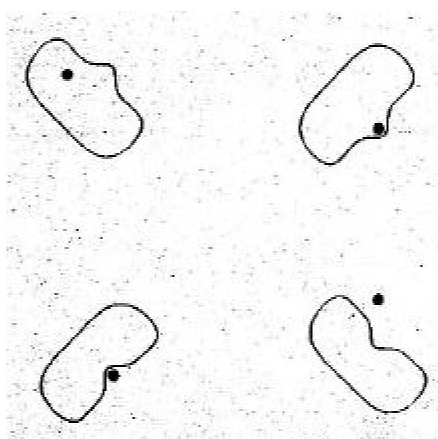

FIGURE: Figure 1 from Herrnstein et al (insideness), 1989

In 49 sessions (~4000 presentations) pigeons failed to learn to sort a collection of 80 stimuli composed of a closed curve and a dot, divided into two categories, according to whether the dot was or was not inside the curve.

<u>The student presentation will also show cases where local features seem to underlie object discrimination performance in gulls.</u>

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THE RELATION BETWEEN PICTURES AND REAL OBJECTS

Q. Do pigeons perceive pictures as representations of objects? In other words, are picture discrimination studies allowing us to explore object discrimination by pigeons in the real world, or are we just playing games here?

A. Some disturbing evidence that line-drawings may not correspond to meaningful objects in the pigeon's head come from Cerella's exp eriments with Charlie Brown scramblings. Pigeons are nable to distinguish such scramblings from the intact CB. Additionally, Cerella's experiments with cubes suggest that pigeons' classification is based on local features alone and not the overall 3D shape of the object.

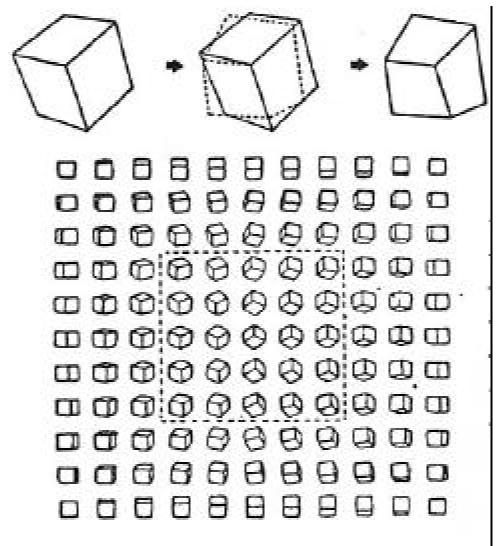

FIGURE: Fig 8.5 top and left from Cerella, 1982

Pigeons could not distinguish between cubes and distorted cubes even though they are very different in their 3D shapes. Probably because they share the same local features.

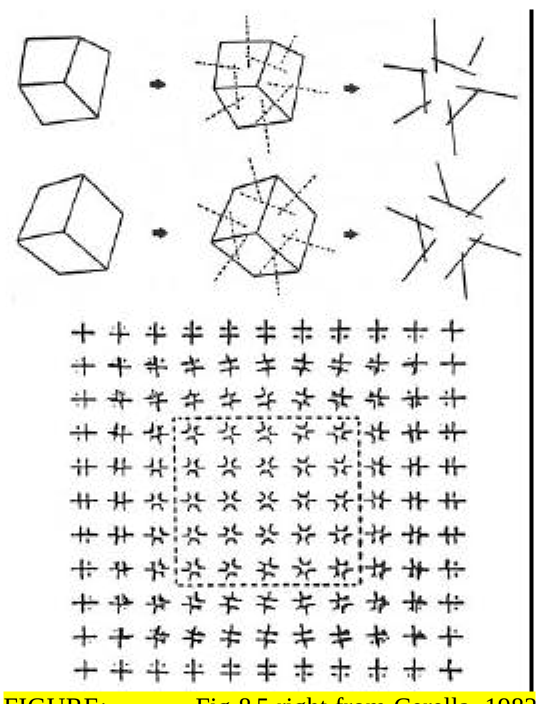

FIGURE: Fig 8.5 right from Cerella, 1982

The degree of difficulty here was the same as for the previous case for pigeons, but very different (much harder) for humans.

But, maybe that's because CB doesn't have meaning for pigeons and the images used are line-drawings. When more meaningful and natural patterns are used, response patterns change.

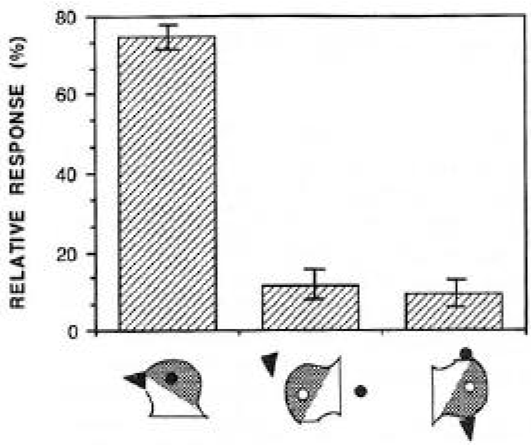

Figure 20.3 Response to colored photographic slides of scrambled parts of a pigeon's head. Six birds were trained to discriminate color slides of two different conspecific individuals, then tested with the full face (left), separated parts (middle), and randomly connected parts (right) of the S+ bird. The stimuli shown in the figure indicate the type rather than the actual stimuli that were used. The birds emitted few responses to abnormal, scrambled figures. Bars indicate standard deviations (Watanabe and Ito, 1991).

FIGURE: Fig 20.3 from Watanabe

The task was to discriminate two conspecifics (like discriminating between CB and Lucy). Scrambling significantly reduced responses.

Q. Does experience with real objects influence responses on corresponding object pictures?

A. Yes. Pigeons were initially trained to discriminate between images of corn grains and inedible junk objects (stone, paper, dice etc.). They were then tested on images of strange looking red corn grains after one of three conditions:

1. right after the initial training
2. after feeding on good tasting red corn grain
3. after feeding on bitter tasting red corn grain

These experiences were reflected in their responses to pictures.

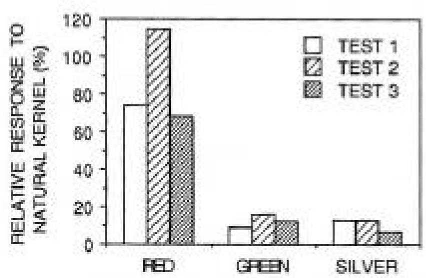

Figure 20.4 Effect of consummatory experience on discriminative behavior in the operant chamber. Responses to the colored corn were expressed relative to those made to the natural corn. Each bar indicates the mean of four subjects. Eating experience with red corn increased responding to slides of red corn (test 2) and aversive experience decreased responding (test 3). Color slides of four kinds of corn (natural, red, green, and silver) were presented in the tests. (Watanabe, unpublished data).

FIGURE: Fig 20.4 from Watanabe

Q. Can pigeons transfer learned discriminations between real objects and their pictures?

A. Yes, there is some experimental evidence to support this possibility.
Pigeons sat over a conveyor ferrying grain and junk in 80 boxes (40 grain, 40 junk). They were trained on 3 tasks:

- Food +ve, junk –ve;
- Food –ve, junk +ve;
- Pseudoconcept

Pigeons showed good transfer (objects to pictures and vice-versa) in the concept tasks, but not in the pseudoconcept tasks. The reason for the failure in the pseudoconcept tasks is not entirely clear.

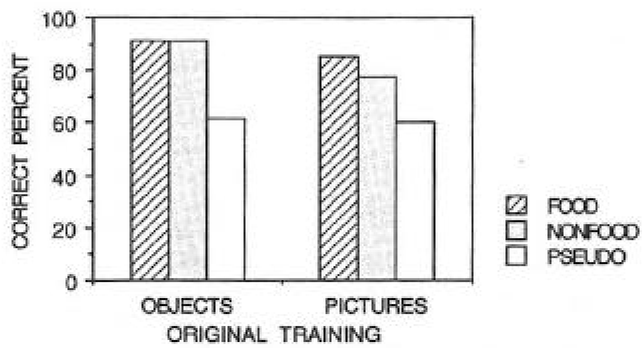

Figure 20.5 Results of transfer tests. Pigeons showed real-to-picture (left) and picture-to-real (right) transfer of a food concept and a nonfood concept discrimination but no transfer of a pseudoconcept discrimination. Correct responses were calculated by dividing the total responses to the four S+ items by the total responses to all eight items. Each bar indicates the mean of four subjects.

FIGURE: Fig 20.5 from Watanabe

Q. Are there any differences in real object discrimination and picture discrimination?

A. Yes, there is some preliminary evidence that real-object discrimination training leads to better generalization to related classes.

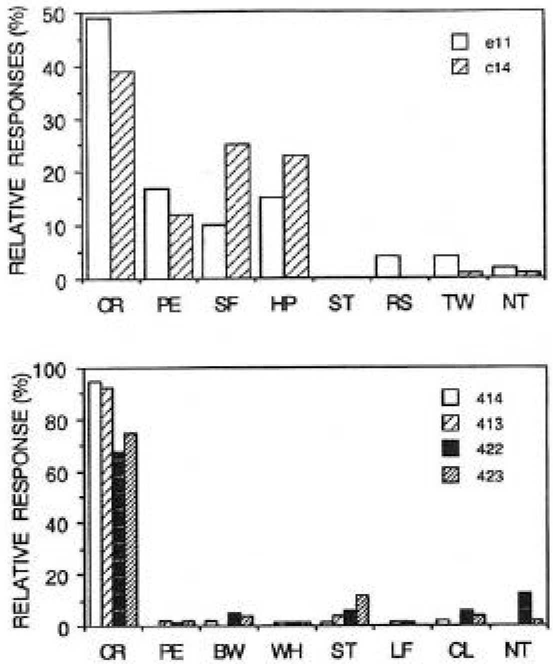

Figure 20.6 Generalizations after training with real corn (upper panel, two birds) and color slides of corn (lower panel, four birds). Test stimuli were different for the two tests. CR, corn; PE, pea; BW, buckwheat; WH, wheat; ST, stone; LF, maple leaf; CL, paper clip, NT, nut; SF, safflower, HP, hemp seed; RS, electric resistor; TW, twig. (Watanabe, unpublished data).

FIGURE: Fig 20.6 from Watanabe

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SUMMARY

We can make three tentative inferences:

1. Pigeons can perform complex visual concept discrimination tasks
2. The underlying mechanism is probably based on local image matching
3. Pigeons perceive naturalistic images as representations of real-world objects

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OPEN QUESTIONS:

- Do pigeons extract objects from backgrounds or is an image just an amorphous collection of low-level attributes?

- Is it worthwhile conducting experiments with synthetic objects when there is evidence that natural classes may be treated differently from synthetic ones?

- What is the right model for pigeons' visual concept formation processes? Can we test it on real images to determine if it can qualitatively replicate pigeon performance?

- Do humans need to learn to see images as representations of objects?