

Perceptual Processes, Attention and Discrimination Learning

Differential reactions to certain classes of stimulus input are characteristic products of most forms of learning, and discriminatory abilities can be studied using the procedures of habituation.

“Discrimination learning” however, refers to procedures in which one stimulus, or set of stimuli, is associated with certain motivational outcomes, and another with different outcomes.

In many of the experiments to be discussed, there is a simple rule, such as —

“when the light is green, responses will be rewarded; but when the light is red, no rewards are available.”

This is a **“successive discrimination”** — where only one stimulus is presented at a time. **“GO/ NO GO”** procedures are the most basic form of successive discrimination, where a single response is rewarded with one cue, but not with another. Many more complex procedures are possible, such as “press right when there's a picture of a knife, press left when there's a picture of a fork”. This could be used to measure whether animal subjects can discriminate between pictures of several different object categories (e.g. Bhatt *et al.*, 1988)

It is also possible to use **choice** procedures: the simplest is **“simultaneous discrimination”** — e.g. “when presented with both a circle and a square, direct a response to the square”.

The stimuli used in discrimination procedures are often called **discriminative stimuli**. (In a GO/ NO GO procedure they may be referred to as S+ and S–, or positive and negative stimuli).

Theoretical Issue

Generally, the **relative complexity of animal perceptual learning**. This can be divided into two sub-areas:

1. Pattern recognition: categorization and “concept” learning; the formation of **internal descriptions and representations**; rote learning explanations including feature analysis and “exemplar” or template theories of stimulus classification. Theoretical models of visual object recognition deal with these issues (Gauthier and Palmeri, 2002; Riesenhuber and Poggio, 2000, 2002; Peissig & Tarr, 2007). These models are intended to explain human object recognition but have relied heavily on neurophysiological evidence obtained using rhesus monkeys (Desimone *et al.*, 1984; Hubel and Wiesel, 1979; Perrett *et al.*, 1992; Muhammed *et al.*, 2006). However, evidence from human brain imaging (e.g. Vogels *et al.*, 2002; Martin 2007) and even more direct human neurophysiological evidence (Lee *et al.*, 2000; Krieman *et al.*, 2000, 2002; Quiroga *et al.*, 2005) is increasingly available. (see also page 2)
2. The contrast between the **conditioning/extinction** theory of discrimination learning (Spence, 1937) and two-stage **attentional accounts** (Lieberman, 2000; pages 384-6).

Another theoretical question for discrimination learning is whether it can be explained in terms of a simple conditioning theory (the Hull/Spence theory or the “conditioning-extinction theory”), or whether certain of the phenomena require more complex cognitive processes for their explanation.

The standard answer is that some discrimination learning procedures tap **more complex processes**. E.g. (From Mackintosh, 1983).

“..... the special procedures of discriminative experiments make available a set of stimuli whose representation calls on processes not normally studied in simple conditioning experiments” (p.272-4)

Sample Essay

Consider the evidence for visual pattern recognition and categorization in animal learning experiments.

1. Pattern recognition and stimulus categorization.

It is often emphasised that sensory processes, especially vision, must allow animals to recognise real objects in the natural world and that this requires complex information processing (Sutherland, 1968; Bernays & Wcislo, 1996; Logothetis & Sheinberg, 1996; Riesenhuber and Poggio, 2000; Tarr and Cheng, 2002. Miller et al., 2003).

“Imagine waiting for incoming passengers at the arrival gate at the airport. Your visual system can easily find faces and identify whether one of them is your friend’s. As with other tasks that our brain does effortlessly, visual recognition has turned out to be difficult for computers. In its general form, it is a very difficult computational problem, which is likely to be significantly involved in eventually making intelligent machines. Not surprisingly, it is also an open and key problem for neuroscience.

The main computational difficulty is the problem of **variability**. A vision system needs to generalize across huge variations in the appearance of an object such as a face, due for instance to viewpoint, illumination or occlusions. At the same time, the system needs to maintain specificity. It is important here to note that an object can be recognized at a variety of levels of specificity: a cat can be recognized as ‘my cat’ on the individual level, or more broadly on the categorical level as ‘cat’, ‘mammal’, ‘animal’ and so forth.” (Riesenhuber and Poggio, 2000; page 1199).

“The ability to readily adapt to novel situations requires something beyond storing specific stimulus-response associations. Instead, many animals can detect basic characteristics of events and store them as generalized classes. Because these representations are abstracted beyond specific details of sensory inputs and motor outputs, they can be easily generalized and adapted to new circumstances. Explorations of neural mechanisms of sensory processing and motor output have progressed to the point where studies can begin to address the neural basis of abstract, categorical representations. Recent studies have revealed their neural correlates in various cortical areas of the non-human primate brain.” Abstract of Miller et al., (2003)

“Visual recognition of objects is an impressively difficult problem that biological systems solve effortlessly.” (Tarr and Cheng, 2003)

“Visual object recognition is of fundamental importance to most animals.” (Logothetis and Sheinberg, 1996)

Herrnstein (1990) suggested that 5 kinds or levels of categorization can be observed in animal discrimination learning.

1. *Simple discrimination* refers to sensitivity to precisely defined physical stimulus characteristics, as in absolute wavelength or brightness discriminations.

2. *Categorization by rote*. This can be regarded as a list of simple discriminations, as in Vaughan and Greene (1984).

3. *Open-ended categories*. Herrnstein's example is learning to recognize acorns, in the sense that new examples of an acorn do not have to be learned separately. This can arise from perceptual similarity.

4. *Concepts*. Herrnstein's definition of a concept is an open-ended or rote-learned category in which a change to one member of the stimulus category is reflected in reactions to the other

members. His informal example is an animal which discovers that one acorn tastes bitter, and thereafter associates bitterness with acorns in general.

5. *Abstract relations*. These have been studied in animals in the case of oddity or matching relationships, which are abstract in the sense that they are *independent of the precise physical characteristics of any stimulus category*. However Herrnstein says that “It is at the level of abstract relations that a large gap opens up between human categorizations and categorization by other animals.” (Herrnstein, 1990; p.133; see Lieberman, 2000, pp. 508-514).

2. Attentional processes.

The Conditioning/Extinction Theory (Spence, 1937).

This can be illustrated in the context of relational learning (discrimination in terms of “larger than”, “greener than”, etc.) and the peak shift result (Hanson, 1959). The theory assumes minimal analysis of incoming stimuli, and that absolute stimulus inputs become actively associated with response outputs, or have inhibitory associations with response outputs.

Evidence for a separate attentional process

The conditioning/extinction theory does **not** include any attentional processes. Theories such as that of Sutherland and Mackintosh (1971) **do**. In this “the suggestion was that animals might *learn to attend to the relevant stimuli of a discrimination problem*”. There are two main kinds of evidence for attentional processing in discrimination learning: transfer effects; and conditional discriminations. (See Lieberman, 2000; pp. 384-398; Reynolds, 1961). A third strand of evidence comes from visual search: when searching for an “X” among a display of other letters it is usual to assume that human subjects are selectively attending to X's, and similar quantitative evidence can be obtained with animal subjects (e.g. Blough, P.M., 1989; Blough, D.S, 2000; Zentall and Riley, 2000).

1. **Attention and visual search**. In this paradigm, the results of visual search experiments using both naturalistic and artificial stimuli have been interpreted as evidence for attentional mechanisms (e.g. Bond, 1983; Blough, P.M., 1989; Blough and Blough, 1997; Blough, 2000; Blough, 2002). Visual search phenomena have been used as a paradigm for theories of selective attention in human vision (Treisman & Gelade, 1990) and some broadly similar results have been obtained in pigeons. For instance, Blough (1989) found that the reaction times of birds searching for a target letter increased with the number of alternative letters in a display, and decreased if the particular target to be searched for was indicated by a cue preceding the trial; and Cook (1992) found that pigeons were more accurate in searching for single features than for conjunctive mixtures of two features (colour and shape). (See Roberts, 1998, p. 33 and pp. 43-50; also Buracas and Albright, 1999; Bond and Kamil, 2002; Dukas, 2002)

2. **Transfer effects**. The idea here is to show that training with a certain set of stimuli and a particular response output requirement facilitates the learning of a new response task with related stimuli. If this occurs, one conclusion is that the facilitation happens because the initial training “switched in” attention to an appropriate kind of stimulus input. Such transfer effects have been demonstrated in serial reversal learning, transfer from easy to difficult versions of the same problem, transfer to similar problems using the same dimension, and, in the case of “oddity” learning, transfer to similar problems using different stimulus dimensions. (See Lieberman, 2000, pp386-387 or Walker, 1987, pp 260-274 for transfer effects.)

3. **Conditional discriminations**. A very general result is that animals appear to become more sensitive to a particular stimulus modality, or a dimension within a modality, when it is used for discrimination training (e.g. Pavlov, 1927; Jenkins and Harrison, 1960). A basic proposition in attentional theories is that there is in some sense more processing of a stimulus feature when the its inputs have motivational significance: this would explain the above transfer effects (e.g. Sutherland and Mackintosh, 1971). In more elaborate experiments, one stimulus can be used as a cue to signal that attention should be paid to another – that is, the attentional process can be switched on and off

(e.g. Yarczower, 1971: 'pay attention to the tilt of a line when the background is red': Lieberman, 2000; pp. 384-5).

Overall Conclusion

Animal perceptual systems have evolved to do useful things in natural environments. **But** it appears that, at least in higher vertebrates, there are substantial capacities for perceptual recognition of non-natural stimuli. **Categorization and pattern recognition, involving grouping of sets of stimuli in functional relations to responses, appear to be consequences of perceptual learning.**

Further note: Hearing

Most of the evidence to be considered for pattern recognition involves the visual modality, but similar theoretical questions arise also for hearing. For bird species which learn by vocal imitation in the wild, it should be expected that laboratory procedures will reveal a highly sophisticated perceptual learning system (e.g. Chaiken et al., 1997; Hausberger et al., 2000). Other species possess perceptual learning mechanisms which are sufficiently general to apply to complex stimuli of kinds which would not be found in natural environments. Porter and Neuringer (1984) tested the auditory discrimination of different kinds of classical music by pigeons: the data suggested that organ and orchestral music of the same loudness can be differentiated in this relatively unvociferous species, but also that unknown characteristics of Stravinsky's 'Rite of Spring' (orchestral) generalized to a piece of modern organ music. A number of experiments indicate that both non-human primates (e.g. Waters and Wilson, 1976; Hauser et al., 2001; Ramus et al., 2000) and mammals such as rodents and cats (e.g. Kuhl and Miller, 1975; Eggermont, 1995) can readily discriminate human speech sounds.

Main Sources

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VISION

Visual pattern recognition in animals has interest both because of the difficulty of the problem in computational terms, and because it separates visual perception from language.

Letter discrimination. One well replicated result (Morgan *et al.*, 1976; Blough, 1982) is that pigeons reliably discriminate alphanumeric stimuli and show human like patterns of generalization between letters, and across typefaces. This may seem odd, but it should be remembered that the human visual system did not evolve in environments where literacy was widespread. Macaque monkeys similarly can discriminate alphanumeric stimuli in different typefaces (Schrier *et al.*, 1984) and can use configural cues in 3-letter groups (Gaffan, 1977). This is an artificial rather than a natural task for humans as well as animal subjects (Polk *et al.* 2002)

Picture discrimination. Pigeons (e.g. Herrnstein, 1985) and non-human primates (e.g. Hayes and Hayes, 1953; Schrier *et al.*, 1984) appear to classify large sets of stimuli according to the presence or absence of complex object categories: e.g. whether or not a picture contains a person. Theoretical questions arising from these data map on to traditional issues in concept learning and categorization (cf Smith and Medin, 1981; Freedman *et al.*, 2001). In many cases it is clear that there is **no** single “common feature” which could define an apparent stimulus category. Some authors appeal to abstract processes of categorization or rule-forming (Herrnstein, 1984; Mackintosh, 1988; Bhatt *et al.*, 1988; Fagot *et al.*, 2001). However, there is evidence that classification performance, at least in pigeons, can sometimes be due to the rote learning of large numbers of specific visual patterns (Vaughan and Greene, 1984). An intermediate theoretical position is that categorization in many species is based on the use of **lists of specific examples**, which do not necessarily all share common features. (What Smith and Medin, 1981, Lieberman, 2000, and Roberts, 1998 call “**the exemplar view**” and what Kirkpatrick-Steger *et al.*, 1998 refer to as “**template models**”). A variation of this view emphasises that a large variety of features, in different combinations are involved in the internal representation of a category (a “**polymorphous concept**” in Morgan *et al.*, 1976 and Roberts, 1998. Another version of this last kind of theory “Recognition-by-components” was put forward in the context of human image recognition by Biederman (1987) and a number of results published since then suggest that a not dissimilar kind of theory applies to image recognition in pigeons (e.g. Van Hamme *et al.*, 1992; Wasserman *et al.*, 1996; Kirkpatrick-Steger *et al.* 1996; Kirkpatrick-Steger *et al.* 1998, Peissig *et al.* 2000; Young *et al.*, 2001).

Comparative anatomy and physiology of the visual system (e.g. Walker, 1985 pp 267ff)

- Vertebrate eye displays more uniformity of structure than any other organ.
- Fish and amphibians focus by moving the lens backwards and forwards. Higher vertebrates thicken lens by tightening or relaxing muscles.
- Rats (Leonard and McNaughton, 1990) are widely believed to have poor vision (especially albinos which can resolve 0.38 cycles per degree; pigmented rats 1.2 cycles per degree of visual angle – humans about 60 cycles per degree). This allows us to detect sharp edges, but natural scenes have low spatial frequencies, where contrast sensitivity is **better** in rats than in primates. Rats’ visual cortex is less comparable to that of primates (Girman *et al.*, 1999) than is the equivalent forebrain area in birds (Shimizu & Bowers, 1999).
- Rats are also good at sound localization and odour recognition
- Human retina has 1M ganglion cells and 125M rods and cones. (but in fovea almost every receptor represented in optic nerve
- “area” is high concentration of cones: “fovea” is a depression with a similar high concentration
- Pigeon and sparrow have only one fovea, but (e.g.) eagles hawks, swallows and terns have two
- Hawk *Buteo buteo* has fovea with 8 times the density of cones in human fovea. Even the non-foveal parts of retina should have twice the resolving power of human vision. Many birds have ultra-violet vision (Hunt *et al.*, 1998). However color sensitivity and visual acuity in pigeons is roughly similar to the human equivalents (Hodos *et al.*, 1985; Roberts (1998, p32)
- on p 256 of Walker (1987) I said pigeons have 5 different colours of oil droplet filters for their cones, and 3 different visual pigments (red, green, blue). BUT more accurate to say at least 5 types of oil droplet and 4 pigments (Bowmaker *et al.*, 1997, Bowmaker, 1998:)

After Morgan et al., (1976)

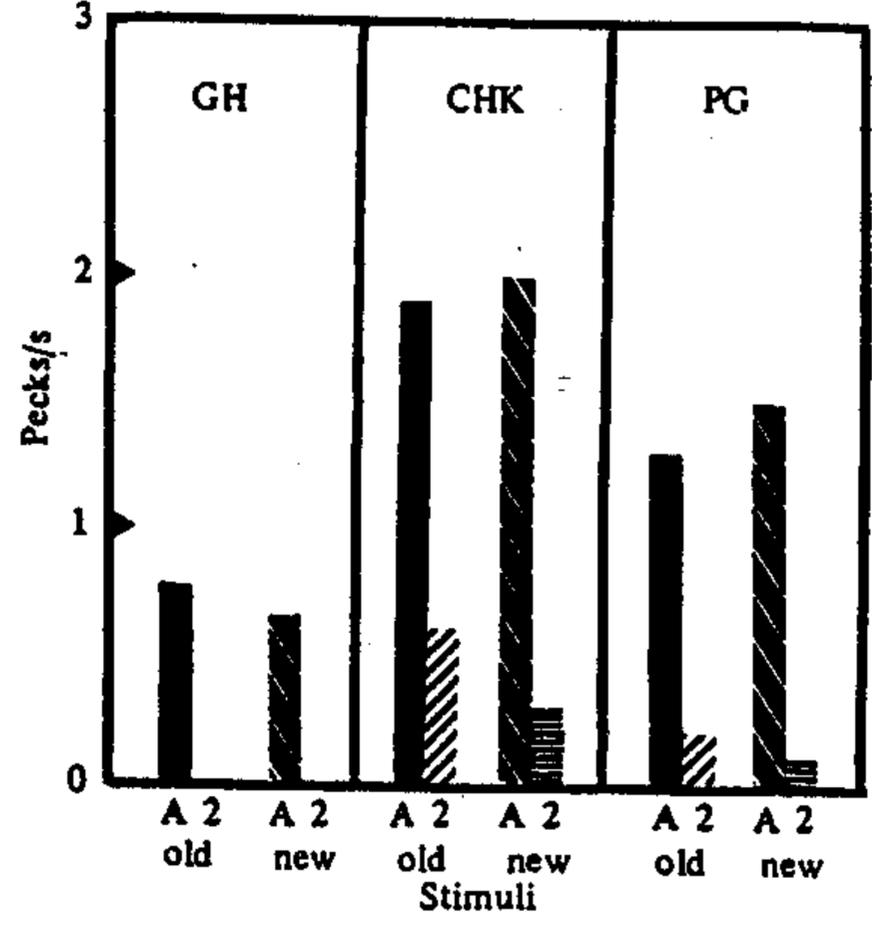
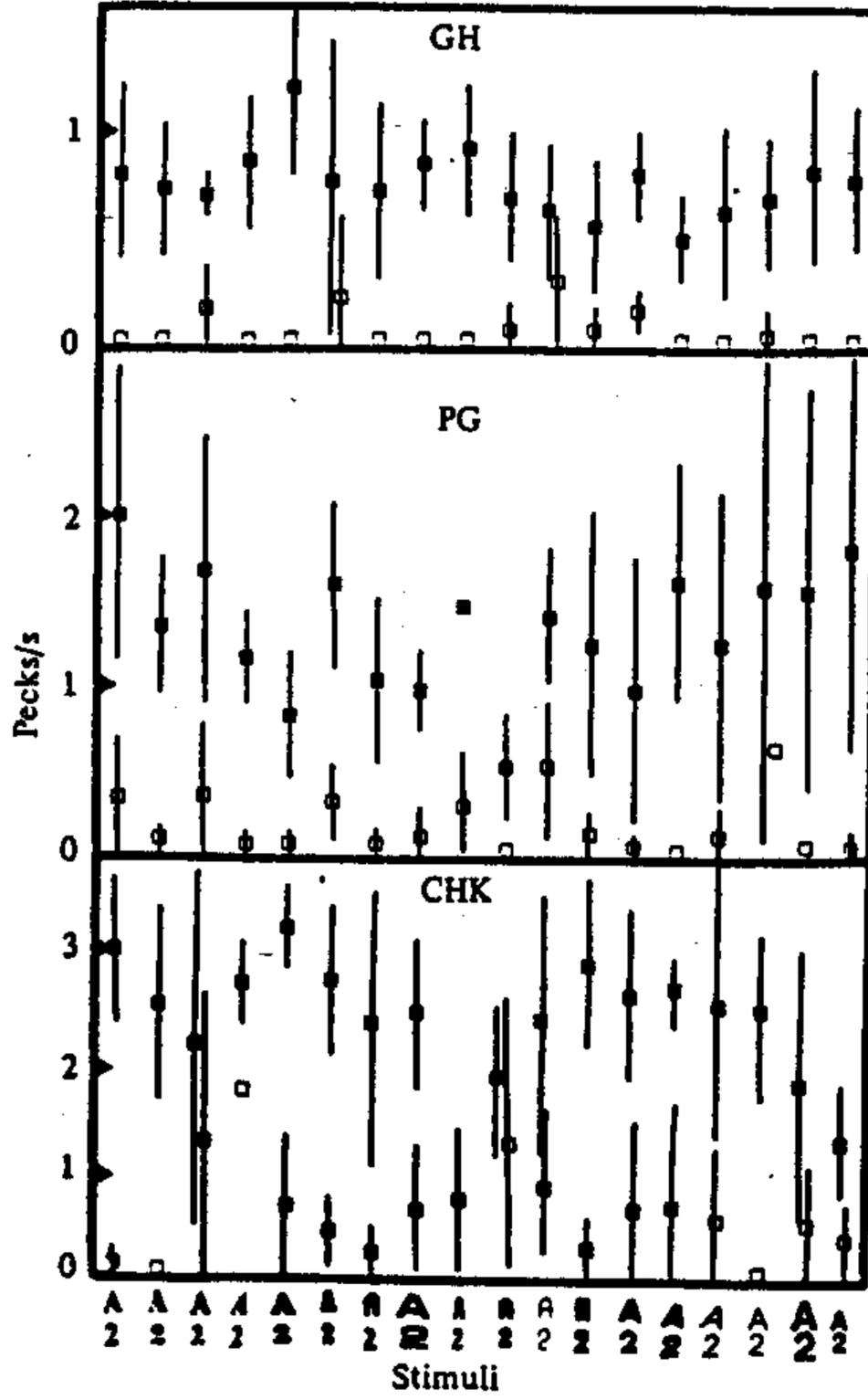


Figure 1. Mean rates of response to each training stimulus for each subject. Filled squares are for 'A's (positive stimuli); open squares are for '2's. The vertical bars indicate standard deviations. The points are based on from one to four observations.

Figure 2. Mean rates of response to training and transfer of stimuli during the test of transfer to new typefaces. 'Old' refers to typefaces which the pigeons had been trained to discriminate, and 'new' indicates typefaces which the pigeons were seeing for the first time.

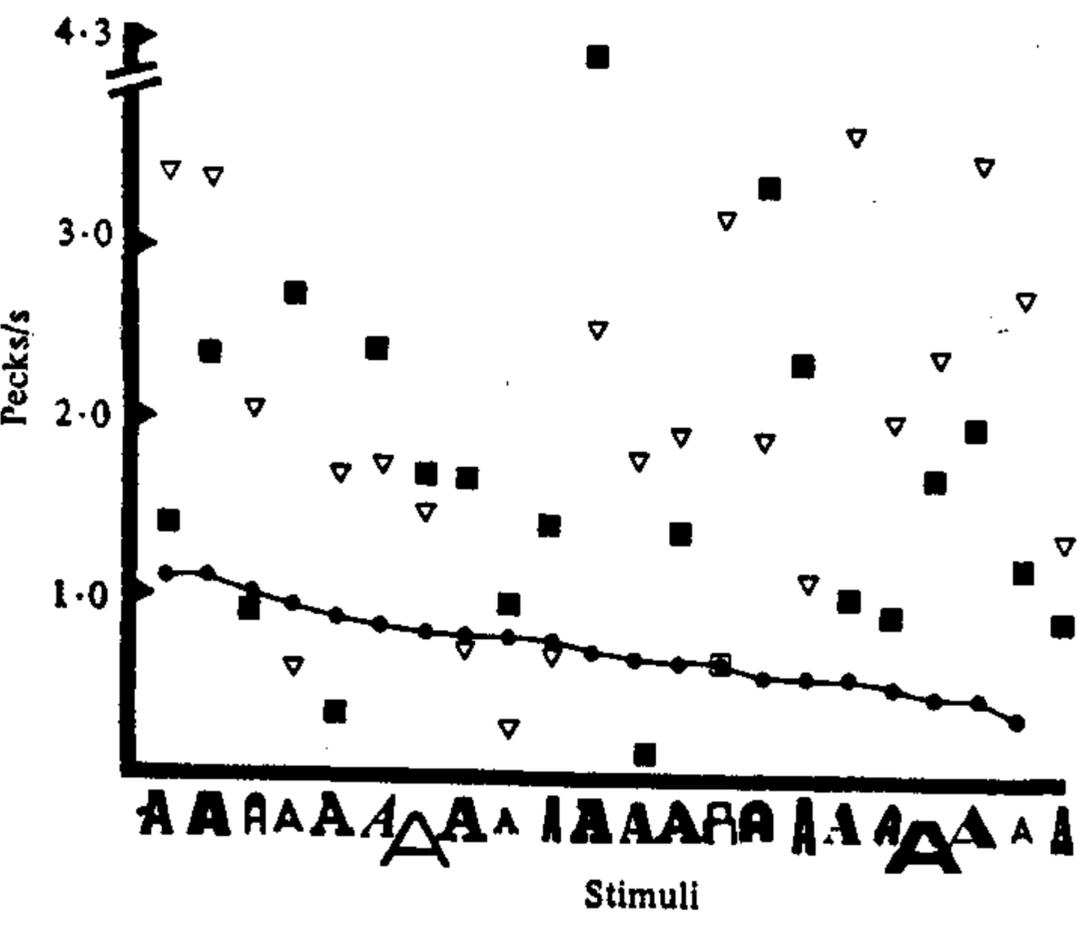


Figure 3. Response rates to 'A's in the twenty-two new typefaces used in the test of transfer to new typefaces. The stimuli are placed on the abscissa in the order of GH's response rates, plotted as circles. Data from CHK and PG are plotted as triangles and squares respectively.

Visual object recognition in primates

The ability of human participants and rhesus monkeys to correctly categorise large numbers of visual images has been examined in several recent experiments..

The abstracts of the papers are given below, and also some brief notes about the experimental procedures in each case.

Fabre-Thorpe, M. (2003). Visual categorization: accessing abstraction in non-human primates. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences*, 358(1435), 1215-1223.

Evolution might have set the basic foundations for abstract mental representation long ago. Because of language, mental abilities would have reached different degrees of sophistication in mammals and in humans but would be, essentially, of the same nature. Thus, humans and animals might rely on the same basic mechanisms that could be masked in humans by the use of sophisticated strategies. In this paper, monkey and human abilities are compared in a variety of perceptual tasks including visual categorization to assess behavioural similarities and dissimilarities, and to determine the level of abstraction of monkeys' mental representations. The question of how these abstract representations might be encoded in the brain is then addressed. A comparative study of the neural processing underlying abstract cognitive operations in animals and humans might help to understand when abstraction emerged in the phylogenetic scale, and how it increased in complexity.

Brief notes: The **Fabre-Thorpe protocol** (see the Delorme paper.) had images projected onto touch screen 30 cm away for only 32 ms. There was a random interval 1.5-3.0 sec between image trials. Subjects had to touch a key below the screen to begin a trial, then they had 1 sec to transfer their hand to touch the screen if they detected a target (animal or food), otherwise they had to keep their hand on the key below the screen. At end of the 1 sec there was a beep for correct, and a drop of orange juice for the monkeys. If the response made was wrong there was a 3-4 sec display of the wrongly classified picture. Monkeys sat in a primate chair and worked daily for as long as they wished (1-3 hours) 5 days per week.

Freedman, D. J., Riesenhuber, M., Poggio, T., & Miller, E. K. (2001). Categorical representation of visual stimuli in the primate prefrontal cortex. *Science*, 291(5502), 312-316.

The ability to group stimuli into meaningful categories is a fundamental cognitive process. To explore its neural basis, we trained monkeys to categorize computer-generated stimuli as "cats" and "dogs." A morphing system was used to systematically vary stimulus shape and precisely define the category boundary. Neural activity in the lateral prefrontal cortex reflected the category of visual stimuli, even when a monkey was retrained with the stimuli assigned to new categories.

The **Freedman et al** paper using morphed stimuli involved a matching procedure with pictures presented successively. To start a trial the monkey had to grasp metal bar and fixate the centre of the screen for 500 ms. The a sample picture (either "dog" or "cat") was presented for 600 ms, follow by a 1 sec delay the choice image. If the choice image was the *same* category as the sample 1 second previous then the monkey needed to release the lever within the 600 ms display time in order to be rewarded with juice. If choice image was in the *different* category then the animal was required to keep gripping its lever for the 600 ms and then a stimulus would appear which was in the *same* category and the monkey could then release the bar to be rewarded with juice. There were intervals of 2 to 3 secs between trials. For an error an additional 3 second time- out occurred. The animals typically achieved about 700 correct trials per day and were more that 90% correct. Training started with just the 6 "prototypes" and the choice stimuli being identical to the sample. During the training more than 1000 stimuli were used from all over the morph space. But for the purpose recording from the prefrontal neurons only 54 sample images were used and for the choice stimuli 6 levels of blend between cat and dog were in 100 images otherwise chosen at random.

Sigala, N., Gabbiani, F., & Logothetis, N. K. (2002). Visual categorization and object representation in monkeys and humans. *Journal of Cognitive Neuroscience*, 14(2), 187-198.

We investigated the influence of a categorization task on the extraction and representation of perceptual features in humans and monkeys. The use of parameterized stimuli (schematic faces and fish) with fixed diagnostic features in combination with a similarity-rating task allowed us to demonstrate perceptual sensitization to the diagnostic dimensions of the categorization task for the monkeys. Moreover, our results reveal important similarities between human and monkey visual subordinate categorization strategies. Neither the humans nor the monkeys compared the new stimuli to class prototypes or based their decisions on conditional probabilities along stimulus dimensions. Instead, they classified each object according to its similarity to familiar members of the alternative category.

The **Sigala, Gaibbiana and Logothetis** paper used 12 humans and 3 monkeys. The monkeys got juice rewards. They had two levers and had to pull one or the other according to the category of the presented image. Low and high tones provided feedback. After learning to be 75% correct they got blocks of trials with juice only after 5 consecutive correct responses. After 85% correct with the 10 exemplars, new exemplars were tested with no feedback given. For each subject there were 15 classifications per stimulus. They also did similarity testing. For the Bruswick faces the Eye Height and Eye Separation were relevant, Nose Length and Mouth Height not. For the Fish, Dorsal Fin and Tail were relevant, and Mouth and Ventral Fin not. All dimensions had 3 possible values

Bovet, D., Vauclair, J., & Blaye, A. (2005). Categorization and abstraction abilities in 3-year-old children: a comparison with monkey data. *Animal Cognition*, 8(1), 53-59.

Three-year-old children were tested on three categorization tasks of increasing levels of abstraction (used with adult baboons in an earlier study): the first was a conceptual categorization task (food vs toys), the second a perceptual matching task (same vs different objects), and the third a relational matching task in which the children had to sort pairs according to whether or not the two items belonged to the same or different categories. The children were tested using two different procedures, the first a replication of the procedure used with the baboons (pulling one rope for a category or a relationship between two objects, and another rope for the other category or relationship), the second a task based upon children's prior experiences with sorting objects (putting in the same box objects belonging to the same category or a pair of objects exemplifying the same relation). The children were able to solve the first task (conceptual categorization) when tested with the sorting into boxes procedure, and the second task (perceptual matching) when tested with both procedures. The children were able to master the third task (relational matching) only when the rules were clearly explained to them, but not when they could only watch sorting examples. In fact, the relational matching task without explanation requires analogy abilities that do not seem to be fully developed at 3 years of age. The discrepancies in performances between children tested with the two procedures, with the task explained or not, and the discrepancies observed between children and baboons are discussed in relation to differences between species and/or problem-solving strategies.

This paper compares the performance of 3 year old children with the findings previously obtained with adult baboons (Bovet & Vauclair, 2001). The baboons were tested with an apparatus attached to their home enclosure. Two objects were presented, and the task for the animal was to pull at a rope at one side if the objects were the *same*, but to pull a second rope on the other side if the two objects were *different*. Small food rewards were delivered for correct responses. The baboons were able to learn to detect if the two objects were in the same category, using the categories of "food" and "non-food". The 3-year old children found this difficult to learn unless the experimenter explained to the child that he/she should place pictures of pairs of things that go well together in one box, because they are both for eating or both for playing, and in the other box, pictures of pairs of things that do not go well together, because one is for playing and the other is for eating.

Van Hamme, L.J., Wasserman, E.A. and Biederman, I. (1992)

This was a modification of an experimental paradigm originally used to assess the role of very local features in human object recognition.

Pigeons were trained with 12 copies of each of 4 modified line drawings: an elephant, a mushroom, a chair and a telephone. The modification was that half of the original outline was deleted. 4 birds were used, each being shown 48 stimuli each session.

The birds had to peck a small viewing screen (7x7 cm) when the drawings were projected on it. After 30 pecks, choice keys outside each of the 4 corners of the viewing screen were illuminated. Only one of the 4 choice keys was correct for each of the stimulus categories. If the correct choice was made the pigeon received 2.5 sec access to grain. After an incorrect choice no grain was presented.

After training (60 days) there was a test phase in which the modified drawings used were sometimes replaced by the other half of the full line drawing (see next page for examples).

The result was that all 4 birds were significantly better than chance at making the correct response to these new versions of the drawings, the precise details of which they had never seen before. The mean percent correct during the test phase was 77% correct for the drawings used in training and 67% correct for the new drawings. (Chance is 25% correct).

There was thus substantial generalization to the new drawings. In further experiments, scrambled versions of the stimuli, were less well discriminated.

The authors **conclude** that a particular theory of object recognition in humans – “*Recognition by components*” applies to some extent also to pigeons.

Watanabe et al 1995

Pigeons discrimination of paintings by Monet and Picasso

Journal of the Experimental Analysis of Behavior, 1995, Vol.63, No.2, Pp.165-174

Pigeons successfully learned to discriminate color slides of paintings by Monet and Picasso.

Following this training, they discriminated novel paintings by Monet and Picasso that had never been presented during the discrimination training. Furthermore, they showed generalization from Monet's to Cezanne's and Renoir's paintings or from Picasso's to Braque's and Matisse's paintings. These results suggest that pigeons' behavior can be controlled by complex visual stimuli in ways that suggest categorization. Upside-down images of Monet's paintings disrupted the discrimination, whereas inverted images of Picasso's did not. This result may indicate that the pigeons' behavior was controlled by objects depicted in impressionists' paintings but was not controlled by objects in cubists' paintings.

Expt 1 8 naive pigeons and 2 chambers, one with video, one with slides

They used 10 Monet's and 10 Picasso's as training, and selected “typical” pictures

After training, used 3 new Picassos, and 3 each also of new Monet, Cezanne, Braque, and Delacroix an earlier “Romantic” history painter whose use of color influenced both the impressionists, and Picasso.)

Then tests

Test 1 was monochrome of all training pictures; **Test 2** was out of focus (to examine the role of contour); **Test 3** all the training S were used by 3 S+ and 3 S- were upside down and 3 similarly were left-right reversed. plus six normal stimuli were presented; **Test 4** was the new pictures.

Results: all birds maintained discrimination of black and white versions, but with reduced accuracy and similarly they discriminated coloured, but out of focus familiar pictures. In test 4, birds trained to respond to Monet showed high rates to new Monets and to Renoir and Cezanne. Birds trained to Picasso's did not generalize quite as much to Braque and Matisse and may therefore have been memorizing individual pictures.

Kimberly Kirkpatrick has a long online chapter on "Object Recognition" which deals mainly with pigeon experiments at <http://www.pigeon.psy.tufts.edu/avc/kirkpatrick/>

Some links to the most relevant diagrams showing the scrambled drawing of a watering can, iron, desk lamp and boat are [available here](#).

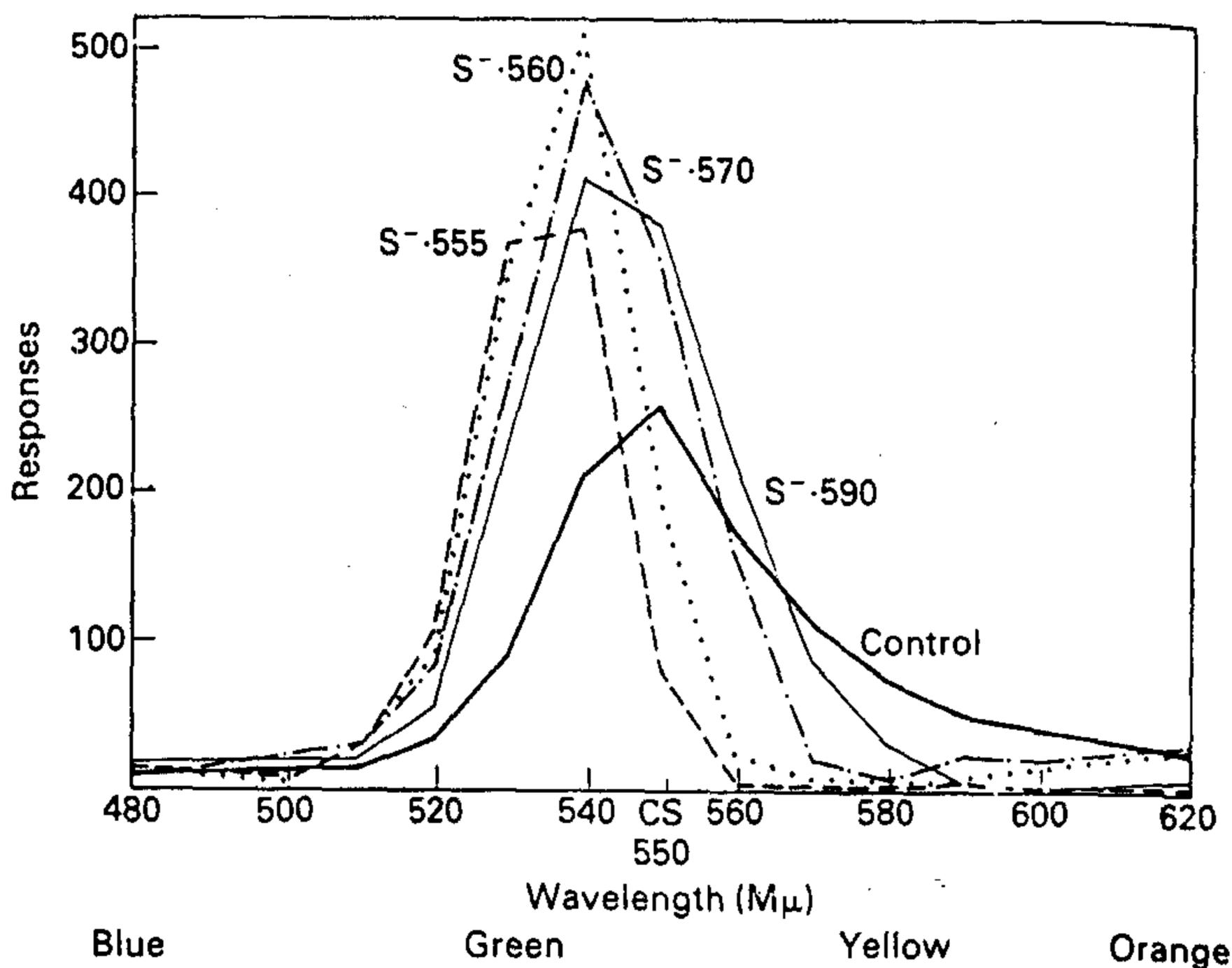


Figure 8.1 *Generalization gradients and peak shift.*

Number of responses to a range of coloured stimuli, by pigeons only ever rewarded for pecking at a stimulus of wavelength 550. Various groups had previous experience of a specific non-rewarded stimulus (S-) of the wavelength value indicated. See text. After Hanson (1959).

symmetrical and bell-shaped distribution about the stimulus value previously experienced. Smooth curves were obtained by Hanson (1959) and easily replicated subsequently, which show the generalization of the pigeons' key-pecking response to other hues after being trained with a green of a particular wavelength, and serve to demonstrate the smoothness and cohesiveness of that species's internal scale of wavelength, which begins peripherally with five different colours of oil-droplets in the retina, functioning as cut-off filters, plus the three different types of visual pigment (absorbing maximally 'red', 'green' or 'blue' light) in the retinal cone cells, which are more reminiscent of the primate system (see Figure 8.1).

The heavy line in Figure 8.1 shows data from birds which were trained on a variable interval schedule to peck a key illuminated with light at a wavelength of 550 nm, which

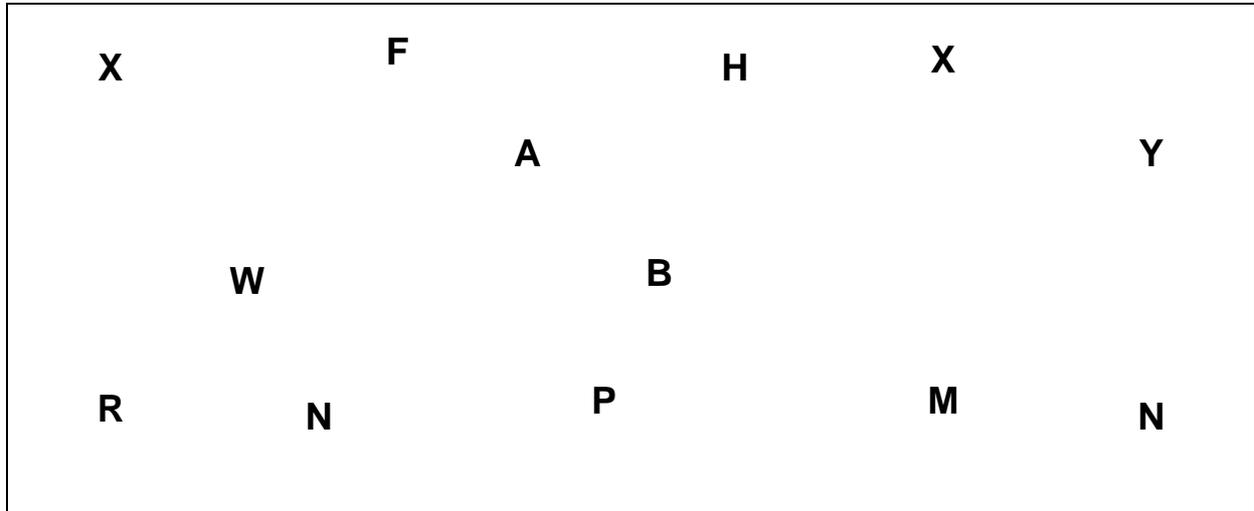
Patricia Blough has a long online chapter on "Cognitive Strategies and Foraging in Pigeons" at <http://www.pigeon.psy.tufts.edu/avc/pblough/>.

She includes a description of the experiment by Bond (1983) on the proportions taken of two different food items as they varied in relative availability. A link for the relevant graph is [available here](#).

Example from Blough (1989) –

search for the 'A' or the 'L'

(The target letter could be either A or L, in any one of 24 positions, and either 6, 12 or 18 other letters would be 'distractors' in the other 23 positions.)



Results

- Reaction times varied according the number of other letters present.
- When cues before each trial indicated which of the targets would present, reaction times were faster than when a different cue could be followed by either of the targets.

Patricia Blough has a long online chapter on "Cognitive Strategies and Foraging in Pigeons" at <http://www.pigeon.psy.tufts.edu/avc/pblough/>.

Some links to the most relevant diagrams showing the effect of display size on visual search times is [available here](#).

Pattern recognition and theories of categorization (Walker, 1987 pp 287-301; Pearce, 1997 pp 118-124; Lieberman, 1993, pp. 509-511; Lieberman, 2000, pp. 502-511; Roberts 1998 pp 338-345. cf Freedman *et al.* 2001; Reisenbuber & Poggio, 2002; Miller et al, 2003.)

1. Feature theory

Membership of a category is determined by whether or not an item possesses some necessary set of defining features. The simplest version of feature theory involves just one feature common to all items in a category, but in practice the theory has to be extended to include “polymorphous” concepts (see Morgan et al’s expt with A’s and 2’s, 1976)

2. Exemplar theory (=Template theory)

Subjects memorise each instance or example in the category separately. Generalization to novel instances then has to be explained by ‘generalization along certain physical dimensions’.

3. Prototype theory

For this subjects are supposed to combine or accumulate instances to form a composite or average representation. This involves more cognitive processing or abstracting of information to form a representation that may not correspond exactly to experienced stimuli.

The theories are difficult to separate, but they all have to account for experimental results which show substantial amounts of extrapolation or generalization so that perceptual performance has to be explained by something more complicated than direct stimulus-response, input-output connections. The results also demonstrate that vertebrate perceptual systems are often capable of learning to discriminate a wide range of novel stimuli not typical of natural environments.

Several current theories which attempt to design neural network models (see week 12 and Lieberman, 2000; Chapter 12) in the light of neuroscience data from human and other primates, include a large element of the “**Exemplar theory**” idea —

“According to this model, categorization and identification are based on similarity to memories for previously encountered exemplars. Evidence for a particular categorization is based on the summed similarity to category exemplars, whereas evidence for a particular identification is based on the similarity to a specific exemplar; a categorization or identification decision is based on the relative evidence across alternatives.” (p R282, Gauthier and Palmeri, 2002).

“The key idea here is that interpolation and generalization can be obtained by simple networks that learn to combine the output of cells, each broadly tuned to the features of an example image. Simple learning networks of this type can learn to identify an object across different view-points and illuminations, as well as **categorizing objects across exemplars of a class.**” (p. 164, Reisenhuber and Poggio, 2002).

“The experiments presented here reveal many similarities between the strategies used by monkeys and humans in a subordinate categorization task. In both species, exemplar and boundary models clearly and consistently outperformed prototype and probability models in accounting for their categorization performance. Thus, it appears unlikely that either monkeys or humans abstracted a prototype to categorize face or fish objects, or used a strategy based on conditional probabilities along each stimulus dimension, as postulated by probability models.” (Sigala et al, 2002)

“These new studies of categorization in monkeys demonstrate once again the power of the **exemplar-based framework** for understanding visual object recognition. This should not come as a surprise: image-based, viewpoint-dependent theories of object recognition are essentially exemplar-based accounts, and have received support from neuro-physiology.” (Gauthier and Palmeri, 2002; page R284).

Ohzawa, I. (1999). Do animals see what we see? *Nature Neuroscience*, 2(7), 586-588.

Do animals experience visual illusions? Nieder and Wagner show that owls perceive, and their neurons respond to, illusory contours that are not physically present.

[www version of figure 1](#)

(Birkbeck Library does not subscribe to the online version of this journal, and so you will not be able to return to the full article by closing the browser window, but you may be able to access the figure by clicking on the link above. It shows a Kanisza triangle and an illusory line defined by interleaved line endings. Alternatively you could try the links below to pdf files provided on Dr Nieder's homepages.)

[http://homepages.uni-tuebingen.de/andreas.nieder/Ohzawa\(1999\)NatNeurosci.pdf](http://homepages.uni-tuebingen.de/andreas.nieder/Ohzawa(1999)NatNeurosci.pdf)

[http://homepages.uni-tuebingen.de/andreas.nieder/Nieder,Wagner\(1999\)NatNeurosci.pdf](http://homepages.uni-tuebingen.de/andreas.nieder/Nieder,Wagner(1999)NatNeurosci.pdf)