School of Psychology, Birkbeck College

March 22, 2007

Course PSYC044U (Psychobiology II.)

EASTER HANDOUT FOR SUMMER-TERM LECTURES (2007)

(This is a largely a re-issue of the Easter Handout from previous years: some updated material will be made available in additional paper handouts and corresponding intranet material next term. The initial pages of the handouts used in the Summer Term in 2006 are available on the intranet at http://tinyurl.com/277d25.)

Week 10 (April 26th) ***Primate Cognition 1 — attempts at "Language" training***

Week 11 (May 3rd) ***Primate Cognition 2 — spatial and social knowledge and reasoning.***

Week 12 (May 10th) ***Learning in Neural networks/Connectionism***

Week 13 (May 17th) ***1st lecture, Machine, animal and human learning + 2nd, Course Review***

(FOR ESSAYS SEE THE LIST DATED MARCH 15TH, 2007)

Primate Cognition — Notes (Weeks 10 & 11)

Because primates are biologically more similar to people than other species, it is often assumed that cognitive processes in primates (especially in our closest living relatives, the great apes) will be noticeably human-like, and distinguishable, quantitatively or quantitatively, from those of non-primate species. It is clearly necessary to assess the behavioural evidence very carefully in order to evaluate the soundness of this assumption.

- Although evidence for language-like communication in apes remains weak (despite Greenfield &Savage-Rumbaugh, 1993 and Bodamer and Gardner, 2002), experimental studies of primate cognition have implied that apes, and to a lesser extent, monkeys, are at least quantitatively superior to other species at various kinds of reasoning task (e.g. Gillan *et al* 1981; Menzel *et al* 1985).
- A possible framework for comparisons of non-linguistic cognitive capacities across species is supplied by Piagetian tests designed to assess developmental changes in human cognition (cf Redshaw, 1978; Premack, 1983; Dore, 1986; ; Pasnak, 1979; Muncer, 1982; Woodruff *et al*, 1978).
- On the other hand, there are many who disagree that primates (other than humans) have more than co-incidental cognitive advantages over other species. In particular Macphail (e.g. 1985, 1996) supports a 'null-hypothesis' of equal intelligence (assessed in terms of associative learning) across all vertebrate species. Others such as Herman (see Shyan and Herman, 1987) would suggest that there are species differences in cognitive ability, but that certain non-primate species (dolphins, or other large-brained mammals) demonstrate primate levels of performance on complex tasks.

Further Notes on Primate cognition and species differences in cognition

> "A third hypothesis proposes that ***there are, in fact, neither quantitative nor qualitative differences among the intellects of non-human vertebrates.*** It is argued that this null hypothesis is currently to be preferred, and that man's intellectual superiority may be due solely to our possession of a species -specific language-acquisition device" (Macphail, 1985; p.37).

> "Our conclusion is that it is possible to identify two processes, use of the outcome of one trial to predict the outcome of another, and ***transfer of this or other rules across a change in physical stimuli***, …..***neither of which is uniformly distributed among vertebrates***." (Mackintosh et al., 1985; p. 62).

1. Theories

The first quotation gives Macphail's (1985, 1987) "null hypothesis" for vertebrate intelligence — the hypothesis that any observed behavioural differences are due to "contextual variables" such as perception or motivation, which are distinguished from intellectual or cognitive mechanisms.

The second quotation gives one alternative theory — that particular mechanisms, such as the transfer of rules to different physical stimuli (as opposed to rote-learning which is closely tied to specific stimuli), may be more available to some species than others.

Material for Weeks 10 and 11 concentrates on data for primates, but it should be noted that many of these issues apply to species differences more generally. For instance Mackintosh *et al* (1985) are concerned with differences between pigeons (rote-learners) and corvids (– crows: rule learners).

Theoretical positions which assume differences in cognitive mechanisms available to different vertebrate species are summarised below.

1.1 Abstraction. Learning may be tied to specific physical stimuli to a greater or lesser extent. This is one way of characterising the position of Mackintosh (1988 and *et al* 1985). Premack (1983) took the position that "only primates have abstract codes" and his 1986 view could be interpreted as an extension of this.

1.2 Piagetian stages. Piagetian theories of mental development can be applied to species differences – although in most cases it is development only during the human sensory-motor period which is relevant. The theoretical content (Piaget, 1971) is less important than the use of Piagetian tests of cognitive attainment, mostly connected with the attainment of different levels of object permanence.

1.3 Social skills. Although there are many other highly social vertebrates primate intelligence in particular has been related to the learning of social skills and strategies (e.g. Humphrey, 1976; Cheney and Seyfarth, 1992). This hypothesis is interesting but especially difficult to test.

1.4 "Theory of Mind" hypotheses. These variants of "social skills" idea suppose that only some species have a functional concept of "self" (Gallup, 1970) or that only particular species (usually only the great apes) are able to make inferences or assumptions about the goals and intentions of conspecifics or human experimenters (Premack and Woodruff, 1978). This has recently attract extra interest because of the hypothesis that human autism is characterised by a lack of this capacity (e.g. Leslie, 1987). The social cognitive features of "shared-reference" (or "shared-attention") and "proto-declarative" communicative acts have been proposed as important pre-conditions both for the development of a "theory of mind" and for the development of human language (Baron-Cohen, 1992; Savage-Rumbaugh *et al*, 1983; Tomasello, 2000)

2. Experimental Evidence

2.1 Learning sets, serial reversal and oddity rules. Evidence using these experimental procedures is reviewed by Mackintosh *et al* (1985) and Mackintosh (1988) and is particular relevant to the "Abstraction" theory. Pigeons trained on matching-to-sample (or "oddity" which involve selecting the choice different from the sample) with a particular pair of colours do not generalize to a new pair of colours, whereas corvids (which include rooks, jackdaws and blue-jays) do, and also transfer the rule to non-coloured shape stimuli. Young chimpanzees are said to sort objects on the basic of matching, or transfer the rule in a matching task, "spontaneously" (Hayes and Nissen, 1971; Oden *et al*, 1988)

Learning sets (Walker, 1987; pp 270-4) appear to test "learning to learn" with a very simple problem, which is to choose one of a pair of objects. Even primates will take half-a-dozen or more trials before they consistently choose the one of a pair of objects under which food is hidden. But after several hundred pairs, only one presentation is needed — there is accurate performance on the second trial (whether the random choice on the first was right or wrong). Chimpanzees and rhesus monkeys show strong learning-set performance, but rats and pigeons hardly any. However corvids tested in a similar way also show good learning sets. (e.g. Hunter and Kamil, 1971). Evidence suggests that learning-set performance is accomplished by the use of a "Win-stay, Lose-shift" strategy which is independent of particular objects, and entails remembering the outcome of trial 1 on trial 2. Successive reversal learning probably also entails the use of such a strategy, but for species such as rats and pigeons is not independent of particular physical stimuli. Goldfish show little evidence of successive reversal learning (Mackintosh *et al*, 1985).

2.2 Piagetian tests. Tests designed to assess the cognitive development of human infants in the first year of life can be used fairly directly for apes, and, with greater modification, for other species. Redshaw (1978) gave the same sequence of standard tests to 4 hand-reared gorilla infants and two human babies. The apes passed the vast majority of tests in the same order as babies did, a few weeks earlier. In Piagetian terms the tests were designed to measure object permanence, achieving desired events, object relations in space, and operational causality. Modified tests suggest that mammalian infants of some species also progress partially up the object permanence scale, (Doré, 1986; Gruber *et al*, 1971; Gagnon and Doré, 1992) with adult apes coming closest to human performance (Premack, 1983; Natale *et al*, 1986).

This suggests there may be differences between species in the types of cognitive processes available forming perceptual representations of objects in space. Questions may also be asked about rudimentary forms of reasoning about quantity, number and causality. Conservation-like performance has been measured in monkeys and apes (Woodruff *et al*, 1978; Pasnak, 1979; Muncer, 1982). Many species can learn some simple forms of number discrimination and more sophisticated assessment of number has been claimed for some specially trained chimps (Boysen and Berntson, 1989; Rumbaugh *et al*, 1987; Matsuzawa, 1985). Premack (1983) compares the "natural reasoning" performance of chimpanzees (requiring object permanence and the distinction between one and two objects) with that of 4- or 5- year old children.

2.3 Artificial reasoning experiments with chimpanzees. Gillan (1981) suggested that one highly trained chimp could perform transitive inference, and Gillan *et al* (1981) that Sarah, with 10 years of experience using plastic tokens to indicate "sameness" and "difference", could perform well on a variety of analogical reasoning tasks (Walker, 1987; pp 344-348).

2.4 Self-recognition, and interpretation of the behaviour of others. Naturalistic observation of groups of chimpanzees (De Waal, 1982/9; Goodall, 1991) and vervet monkeys (Cheney and Seyfarth, 1992) suggests that individual animals come to possess a rich representation of their own social relationships to others in the group, and of the intentions and perspectives of other individuals. Laboratory tests indicate that chimpanzees, but no other non-human species yet tested except orang-utans, recognise their own images in mirrors and video displays (Gallup, 1970; Menzel *et al*, 1985; Povinelli, 1989, Povinelli *et al*, 1993). It is suggested (e.g. Povinelli *et al*, 1990) that this ability may be related to a capacity for understanding how objects and events appear from another's perspective, the "mind-reading" (Whiten and Byrne, 1988) of another animal's (or a human experimenter's) intentions and the ability for deception or pretence about one's own intentions (Woodruff and Premack, 1979). However, these forms of social cognition may be interpreted as special purpose, species-specific adaptations for social organization, rather than aspects of general-purpose learning. (Cheney and Seyfarth, 1992). Some authors (e.g. Heyes, 1994, 1996, 1998) argue that there is no satisfactory evidence that primates have any special abilities in the area of social learning and imitation, or self-recognition, whereas primatologists typically believe the cognitive capacities of the great apes can be regarded as the precursors of human cognition (Whiten *et al*, 1999; Tomasello and Call, 1997; Call, 2001)

Main Sources— Primate Cognition

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Animal Learning and Learning in Connectionist (Neural Network) Simulations (WEEK 12)

Notes

(All page references are to chapters in the two volumes of "Parallel Distributed Processing edited by Rumelhart and McClelland in 1986, briefly referred to as "PDP1" and "PDP2", except where otherwise indicated)

In the last 15 years or so a new approach to answering questions about cognitive psychology has attracted a great deal of attention. It goes under various names, including "Parallel Distributed Processing", "PDP", "Connectionism" and "Neural Networks".

The "neural networks" are not real ones. The basic idea is to set up conventional computers to mimic or simulate "brain-style" information processes. The characteristics of brain-style information processing which are taken most seriously are as follows —

Neurons are slow, but numerous, and highly interconnected – they can typically operate only about 100 times per second; but since there are millions of them, each one having thousands of connections with others, it is assumed that the brain can do complicated things quickly by widespread sharing out of jobs across neurons working collectively — "parallel distributed processing"

Learning takes place when the connections between neurons are modified – an important theme is that artificial neural networks can be trained. Typically a network is connected at random to start with, but learns by somehow internalising regularities imposed on it by presenting it with a series of inputs and desired outputs.

Since there is such an emphasis on learning, and the learning is supposed to be done by neuron-like units, there are some obvious similarities with old-fashioned "Stimulus-response" theories of animal learning (Thorndike, 1949, called himself a connectionist.). But the new connectionists are mainly interested in specifically human expertise. For instance, it has been claimed that an artificial neural network connected up at random to begin with can be trained to produce the correct past-tense versions of the roots of both regular and irregular English verbs (Rumelhart and McClelland, 1986b)

A) Similarities of new connectionism with associative theories of animal learning.

1) Learning involves modifying connection strengths –'*knowledge is* ***in the connections'***

2) The currency of the system is ***excitation and inhibition***, *not symbols*.

3) Learning procedures work ***'simply and incrementally'***. The incremental process can be formalized mathematically, and more complex knowledge acquisition is supposed to *emerge from these simpler processes*. (points 1-3 all on p.132).

4) There is ***no central executive*** (p.134)

5) Biased towards ***empiricism*** (random self-organizing networks) although there is no reason why connections could not start off innately organized. (p.139)

6) The question "Why are people smarter than rats?" is answered initially in terms of 'more cortex' with emphasis on the potential for "**forming connections**" that are useful for language.(p.143). Linguistically and culturally determined schema or "tools for thought" are entertained speculatively. (e.g Rumelhart *et al*, 1986, Chap 14 in *PDP2*)

7) The initial position minimizes serial process and specializations e.g. attention, language, the central executive.

8) ***Learning paradigms*** include single stimulus presentation, stimulus pairings, classification and regularity detection (p. 159-161).

9) ***Learning rules*** are a major issue, with degree of error correction a primary question (p. 46, 54, 162). This bears some similarity to Thordikean trial and error learning, **BUT** there is a difference in that the major principle of instrumental learning is a change in some sort of association at the point of a successful response, where-as error-correction corresponds more to "learning from mistakes".

10) A particular learning rule, simple association by contiguity, provides a link between old and new connectionism. McClelland *et al* explicitly trace this back as far as Hebb (1949) by calling their formulation the 'Hebb rule' (p.36) In their wording the rule is

*Adjust the **strength of the connection** between units A and B in proportion to the product of their simultaneous activation. (p.36)*

Originally it was that if an axon of neuron A repeatedly took part in firing neuron B, A's efficiency in firing B increased (Hebb, 1949; p.62). There are versions of this in Thorndike (e.g. 1905) and many earlier sources, in particular James (1890/1985, p 534) – "*When two elementary brain-processes have been active together or in immediate succession, one of them, on recurring, tends to propagate its excitement into the other."* The concept of local increases in connection strength is thus an old one, but some of the best known version of old connectionism (Thorndike, Hull) strongly emphasised a supervisory influence of motivational events selectively stamping-in connections.

A further similarity here is that *the basic Hebbian principle of* ***contiguity*** *has been rejected* as the sole basis some of the most obvious empirical evidence for associations, in the case of analyses of classical conditioning, and for neoconnectionists "it turns out that ***the Hebb rule... has some serious limitations***" (p.37), and more sophisticated rules of association formation have had to be developed for neural networks, some of which have more in common with modern theories of classical conditioning (Sutton and Barto, 1981)

11) Finally, both new and old connectionism are open to the criticism of over-simplification, and have particular difficulties in their simplest forms. It was shown that a "one layer perceptron", a network of direct connections between a set of inputs and a set of outputs, can add little to the information in the input (Minksy and Papert, 1969; p 112-3) and thus PDP models are now multilayered and include 'hidden units' to remap connections between input and output. There is a rough analogy with the efforts of early stimulus-response theorists to elaborate their theories with 'mediating responses' 'pure stimulus acts' etc, which were internal sources of associations between measurable input and output

B) Differences between neoconnectionism and associative theories of animal learning.

1) Old connectionism concentrated in the first instance on ***single reflex paths***, whereas the essence of new connectionism is emphasis on the potential of ***numerous reflex paths organized in a network and operating in parallel* —** hence "Parallel Distributed Processing". However, there were primitive versions of this idea in Spencer and James, in Pavlov's "analysis and synthesis", and in stimulus-response theory.

2) Wholistic processes (e.g. Gestalt perceptual processes) tended to be contradicted by old connectionism, but emerge more naturally in new connectionism.

3) Old connectionism was heavily involved with animal learning as a model, whereas new connectionism uses mathematical models and/or computer simulations (of parallel processes, PDP being explicitly an alternative to computer-like fast serial mechanisms)

4) Many versions of old connectionism included emphasis on ***motivational factors*** in learning rules (Thorndike, Hull) or otherwise for performance rules: New connectionism tends to ignore motivation and emotion. (but see Grossberg and Gutowski, 1987). Goals in the limited sense of error correction (e.g. the 'delta rule' or back-propagation; p.53) are used very often, but the bias is towards automatic learning by exposure to input or by externally imposed "teaching" that uses little that could correspond to a motivational state, or internal goal anticipation, in a neural

network. It is a principle that “Learning... amounts to a very simple process that can be implemented locally at each connection without any need for overall supervision” (p.37).

5) Related to this is the fact that there is not much in current simulations that corresponds closely to ***instrumental learning***. Hinton (1989) notes this, but suggests that it would not be difficult to implement “Reinforcement learning procedures” in which local decisions are assigned credit if they correlate with a global reinforcement signal, some work having been done on the problem of delays between the global motivational outcome and previous associations. Hinton (1989) also mentions the possibility of using “relative pay-off procedures” in which connection probabilities are altered so as to maximise expected reward.

6) Another related point is that ***error-reduction*** is the dominant focus of current connectionist learning algorithms: learning only occurs when errors are made, and compared with an imposed correct output. More traditional principles of instrumental learning suggest that learning occurs on the occasions of successful responses, and that learning can take place (and indeed may be optimal) when no errors are made at all.

7) Old connectionism became dominated by ***Behaviourism***: an attempt was made to tie everything to explicit observable stimulus input and motor output. New connectionism is in one sense the opposite of this. Although the attempt to simulate observed human performance is one of the basic strategies these attempts are in the nature of demonstrations of the powers of neural networks, not the testing of particular models against experimental data. Similarly, old connectionists were interested in ***practical methods of training and therapy*** (e.g. Watson, Thorndike, Skinner), but this is not so far a feature of neo-connectionism.

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1. Human Cultural Learning

Critics of connectionism, and some treatments of human learning, stress the "high-level" abilities involved in systematic thought and **self-regulation of learning strategies**. It has recently been proposed that human learning involves unique forms of social cognition which allow for the imitation of adults by infants, the instruction of infants by adults, and collaborative learning by peers, and hence the cultural transmission of acquired knowledge (Tomasello, Kruger and Ratner, 1993).

Summary of Tomasello et al (1993)

Tomasello et al stress that human learning is unique because it involves cultural products such as social traditions, systems of education and scientific theories which accumulate over time. This accumulation of knowledge is termed the "ratchet-effect". They propose that cultural learning is made possible because the human species has uniquely powerful forms of social cognition which enable them to understand and take the perspective of others. They suggest that there are three stages of social-cognitive ability in human development, as in the table below.

Table 1 Major features of the three types of cultural learning.

Cultural learning process	Social-Cognitive ability	Concept of person	Cognitive Representation
Imitative 9 months	Perspective-taking (e.g. joint attention, social referencing.	Intentional agents (0 order)	Simple (other's perspective)
Instructed (4 years)	Intersubjectivity (e.g. false-belief task, intentional deception).	Mental agent (1st order)	Alternating/ coordinated (other's and own perspective)
Collaborative (6 years)	Recursive intersubjectivity (e.g. embedded mental-state language	Reflective agent (2nd order)	Integrated (dyadic intersubjectivity).

Chimpanzees. One line of evidence examined by Tomasello et al (1993) is provided by chimpanzees, which can be compared with material given in weeks 12 & 13. They refer to the animals given training by human intervention as "enculturated chimpanzees". They claim that neither wild nor enculturated chimpanzees learn collaboratively from other chimpanzees of humans, because "they do not conceive of others as reflective agents" (p. 505). Although they stress that chimpanzees cannot internalize instruction and use it to regulate their own behaviour, they are sympathetic to the view that chimpanzees enculturated by humans seem to show "sophisticated skills of perspective taking" (p.506). The argument is that chimpanzees raised with human care-givers develops the animals' skills in joint attention, which is one of the skills involved in social cognition, and that their enhanced social cognition makes enculturated chimpanzees more capable of social learning.

2. Computer-Aided Learning (CAL)

Another area in which interest in theories of human learning has been maintained is that of *computer-aided instruction* or *Computer-Aided Learning* (CAL). Here the concept of practice by doing is still important. "Proceduralization" is another concept, and is rather like habit formation operating unconsciously. Goal structures and sub-goals are also important, so the formula **"learning is a function of goal achievement and results in habits"** would apply at least to some theories (e.g. Anderson, 1987a, 1987b). Immediate feedback and error minimization are practical recommendations common to traditional learning theory and some theories of learning in CAL. Clearly learning which takes place by interacting with a computer programme does not involve social cognition in the ways emphasized by Tomasello et al (1993).

The main reference here is Glaser (1990), who reviews the work of Anderson (e.g. 1987b) and other contrasting theories of human learning. Glaser's paper reviews cognitive analyses of human performance in various domains — and computer-aided instructional programs that aim to produce competence in these domains. The sorts of domains (tasks) studied include —

- medical diagnosis
- trouble shooting of electrical circuits
- reading comprehension
- algebraic equations
- geometric proofs
- computer programming

Detailed analysis of assumptions about learning that underlie these programs indicates **implicit theories of learning**

Programs are for **the acquisition of proceduralized knowledge**, and the development of self-regulatory strategies. Glaser suggests that instructional experimentation is of increasing value to the interactive growth of learning theory and its applications.

It is pointed out that over the last 20 years, work in Cognitive Science (and cognitive psychology) has tended on the structure and organization of human performance, at the expense of the investigation of the mechanisms of learning which underlie human cognition: Newell and Simon (1972) for instance explicitly de-emphasized the study of learning.

But Glaser says "Now learning theory is re-emerging in investigations spawned by different disciplines that contribute to cognitive science. This essay examines the articulation of theoretical issues in learning that is taking place through studies of instruction that are grounded in descriptions of competence."

A common factor in the several approaches he discusses is "**an explicit cognitive task analysis**; that is, the objectives of instruction are based on current knowledge of the characteristics of competent performance on a task [cf **comparisons of experts with novices**].
There are **three major aspects of competence**

A. 'Compiled' automatized, functional and proceduralized knowledge

B. Internalized self-regulatory control strategies.

C. The structuring of knowledge for explanation and problem solving.

{**NB**: A. is a common factor in all kinds of learning. B. and C. are clearly more characteristic of human than animal and machine learning)

GLASER'S COMMENTARY (Glaser, 1990; p. 36)

Various rather different instructional programs have been discussed. They teach different categories of human performance, deal with different subject matters, and derive from different traditions. No completely general view of learning is apparent, but Glaser suggests that attempts to integrate the various approaches promise to provide a more all-encompassing theory of learning. There are several commonalities between the approaches, and one major dichotomy.

Commonalities – certain major principles are shared

- all advocate learning in the context of working on specific problems.
- most recommend explication of the appropriate problem-solving structure.
- most believe that **strengthening knowledge results from error-free practice**.
- but apart from knowledge compilation failure or conflict may trigger new learning.
- Guidance and feedback is recommended
- help with problem-solving structures cross-cuts approaches.

A dichotomy – progressive mastery or no structured transitions.

- In the mastery approach there is a specific transition path: a progressive sequence of skills is carefully fostered.
- In contrast, in non-structured approaches, the learners may be given tools or strategies to apply on their own: the tutor only gives assistance if it is needed.
- However, these different methods may suit different kinds of task.

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