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Entry: Insight and relational mechanisms

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Relational mechanisms lie at the core of human cognitive organisation, expressed in everyday language by terms such as ‘bigger than’ and ‘smaller than’ and in formal symbolic systems by logical arguments such as A> B. Ordered as a series A>B> C furthermore, such relationally based mechanisms support transitive inferences of the sort that, given A>B and B>C, A must be bigger than C - an important deductive form of reasoning believed to be the cornerstone of rational choice behaviour. Relations are also central to the human ability to classify objects and events using rules of group membership. Reflected in linguistic acts of reference such as ‘that is a canary’, our further ability to denote the canary as (also) a bird reflects hierarchical principles which crucially underwrite our ability to combine and recombine words into sentences and communicate propositions about the world.

But what of non-humans? Historically, it was held by many that such relational competences were unavailable to ‘the brute mind’, a view offered by the father of American psychology, William James, and reinforced by the work of his student Thorndike, whose classic studies of problem solving behaviour with cats at Columbia University based on ‘blind’ trial and error mechanisms led to a characterisation of non-human intelligence, retaining a powerful influence over many comparative psychologists to this day. Designed ostensibly to evaluate the extent to which cats locked in a box would immediately connect a successful response such as pressing on the door panel with escape and inducing in turn a sort of ‘aha’ response, Thorndike found instead that cats only gradually acquired the successful response, selecting it with progressive frequency from a range of competing response within their repertoire. Thorndike concluded that the connection between response and outcome was forged as the result of blind trial and error processes rather than the outcome of strategic planning and a perception of the causal relationship between action and success.

For Kohler, on the other hand, such trial and error characterisations were the result of bad experimenter practice that disabled the subject from seeing the problem ‘in the round', rather than a reflection of normative mechanisms. In the early part of the twentieth century, Kohler presented apes with problems that were meaningful 'at first sight' and without having to make any overt response at all. For example, confronted with alluring bananas out of reach, they could recruit sticks to augment their reach, or boxes when stacked to gain height and recover the prize. In contrast to Thorndike, Kohler found that apes would often make sudden solutions without requiring trial and error when they were in a position to perceive the putative relationships between the different components of a problem, instead of seeing the task piecemeal as in the case of Thorndike's cats.

This disparity between Thorndike's and Kohler's characterisations of animal intelligence provoked the philosopher Bertrand Russell to comment dryly that American rats learn by trial and error, while European rats learn by insight! For Kohler, however, 'insight' was a pale reflection of what humans might consider as thinking regarding it as the result of a sudden (involuntary) perceptual re-organisation. Since then, augmented by a new and burgeoning interest in comparative and evolutionary precursors to thought and language, a range of new paradigms has been evolved, often based on intensive learning procedures to parallel the life history and deep cultural immersion of humans. Critically too, some of these have been designed to eschew manipulation constraints which have long embargoed the deployment of free classification and other object based tests so effective in charting human cognitive growth. As a consequence, contemporary comparative research reveals that non-human primates (at the very least) share some core conceptual representations arguably the precursors of human propositional thought, reasoning transitively, classifying hierarchically, and exhibiting flexible executive skills in serial ordering tasks. Of great significance for the issues of evolutionary origins and continuity, these ordering competences, moreover, based also on temporal relations, suggest significant evolutionary precursors for the highest forms of human achievements including language.

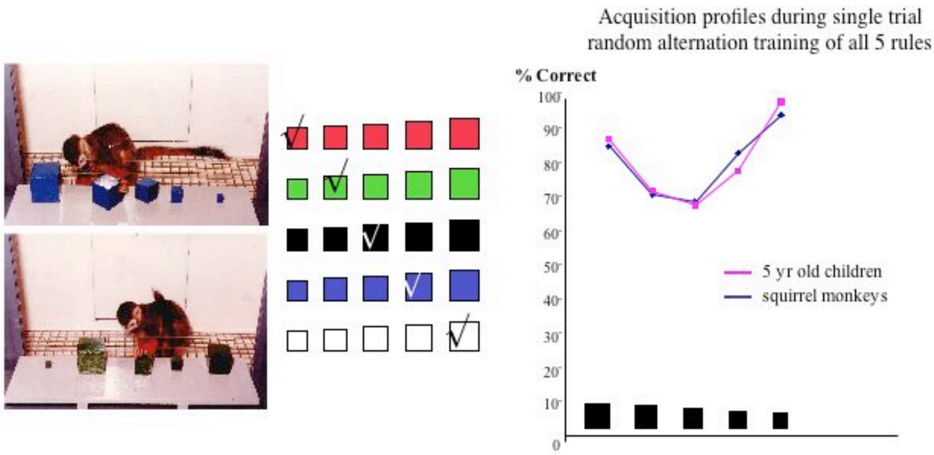
We illustrate some of these key building blocks of evolutionary cognitive growth based on relational competence in the sections below:

Systematic relational competences

For Kohler, 'insight' in apes is driven by relationally based perceptual laws of organisation derived (as he put it) from ' silent physiological operations' not accessible to conscious scrutiny. Yet humans, at least, are well aware of object relationships *per se* (and not merely the objects themselves). In language, for example, simple declaratives such as 'Jane is bigger than Henry' reflect an explicit grasp of the material (size) relationship in question. Humans also compute the inverse relation 'smaller than' from the declarative, as in 'Henry is smaller than John'. Whilst contemporary evidence for relational learning by non-humans is strong, it is not systematic in this sense, one of the major problems being that the choice of relational tests used with animals has been somewhat *a la carte*, based on the isolation of a single relation such as 'brighter than', using choice methods which conventionally requires the subject to choose an object either as ' brighter than' or 'darker than' its neighbour. Figure 1 shows an important evolution of the conventional procedure. Here, the subject learns a 'language' of conditional signs where each sign signals which relational rule (within as set of five) must be chosen. Thus if all objects which vary in size are black, for example, the subject must select the larger/largest object (irrespective of its absolute size); if all white by contrast, then the subject must choose the smaller/smallest object. As illustrated in Figure 1, this method has revealed that squirrel monkeys can acquire five related size rules, operating them systematically in ways very similar to that of four year old children (McGonigle and Chalmers 2002). In showing that rules are both systematic and available to non-verbal animals (at least primates), and that the type of relation itself can be linked with an arbitrary sign, we can conclude that core relational competences are reflected in language but not determined directly by language *pe se*.

Figure 1. Systematic relational learning: the acquisition of five size rules

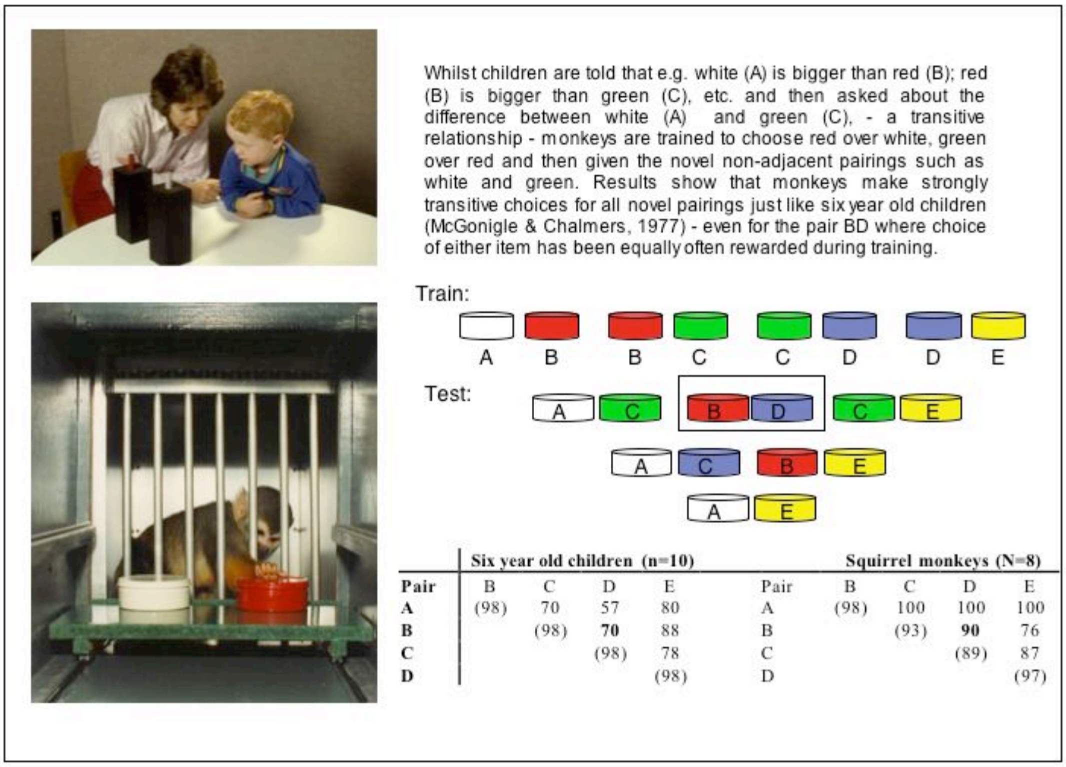
Squirrel monkeys (left) being trained on a series of 5 conditional rules of relation such that e.g. 'if all blocks are red' then choose the smallest one, 'if all blocks are green', choose the second smallest, etc until all 5 rules can be operated concurrently and in random order. The array changes randomly from trial to trial so that the rewarded item cannot be identified by a unique location. Performance on five rule training as depicted followed training on smaller numbers of rules. Five year old children were given similar training and showed highly similar acquisition profiles to monkeys during the final single random alternation phase as the graph illustrates (McGonigle and Chalmers, 2002).



Relational competences and reasoning

Humans operate relations at a number of different 'levels'. First, they can detect these perceptually, as in the examples given above. However, a significant evolutionary advance centres on the human ability to reason symbolically as in situations where no direct perceptual information is present. Given several connected logical arguments, such as 'Jane is bigger than Henry' and 'Henry is bigger than John', human adults can order these items at a conceptual level and make the transitive inference that 'Jane is (therefore) bigger than John'. A key issue is the extent to which more abstract procedures of this sort are available to non-humans. While the long-standing lack of positive evidence might suggest they are not, one of the key difficulties here has been to present such tasks in a meaningful way to non-verbal subjects. With procedures that eschew language, we illustrate ways this can be done (see Figure 2). In an adaptation of a reasoning paradigm designed for use with very young children (McGonigle and Chalmers 1977), squirrel monkeys were trained on four connected pairs of tins varying in colour and weight; each pair was either heavy or light, but (crucially) the weight relation could not be perceived directly. The outcome showed that all six novel pairs (of the ten pairs that derive permutatively from the term series as illustrated in Figure 2) were discriminated on the basis of a transitivity rule without further training. This was the first demonstration of 'reasoning' by non-humans under the most stringent conditions which developmental and experimental psychologists have been able to devise, now replicated extensively with a variety of species. However, significant variation in the procedures used since the first demonstration may support simpler solutions in certain cases.

Figure 2. Transitivity: Rational choice without direct perceptual support

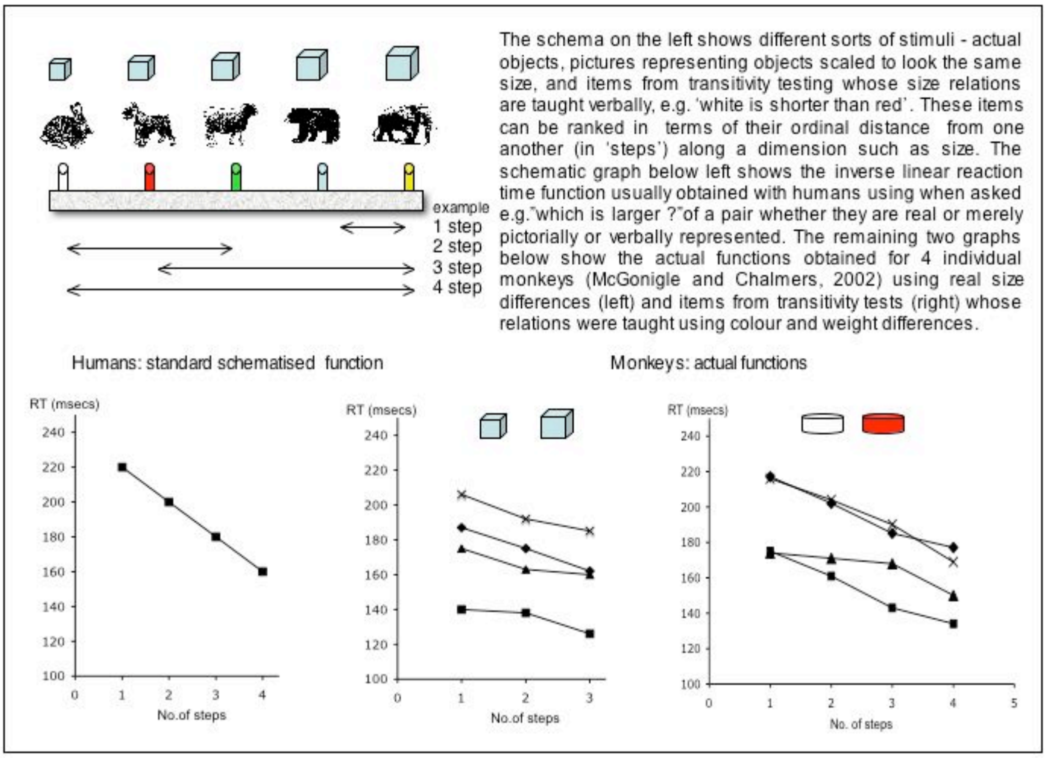


	Six year old children (n=10)					Squirrel monkeys (N=8)			
Pair	B	C	D	E	Pair	B	C	D	E
A	(98)	70	57	80	A	(98)	100	100	100
B		(98)	**70**	88	B		(93)	**90**	76
C			(98)	78	C			(89)	87
D				(98)	D				(97)

'In the minds eye'

Of course, no one source of evidence is definitive in this most difficult area. Instead, evidence is needed from tests assessing cognate cognitive competences. In linear transitive reasoning with human adult subjects, for example, subjects often report the use of a mental image where test items are aligned along an imaginary spatial vector (usually a vertical one) with e.g. Jane at the top, Henry in the middle and John at the bottom of it. Coinciding with subjects' reports of this imaginal process, it has also been found that decision times are often faster for transitive inference tests. That is, it takes longer to retrieve the pairwise information as given, than to generate the inferences that derive from it, and this is known as the Symbolic Distance Effect (SDE). Explained conventionally as due to the fact that inference items are more remote on a spatial representation and less likely to be confused in a spatially based read-off, this phenomenon is also found in other tests of the mental representation of orders by humans when asked to compare a range of familiar objects conveyed as pictures or words ‘in the minds’ eye’. Once again, decision times are inversely related to ordinal distance, and the mode of presentation is also important, with lexical representations of objects providing the slowest (absolute) decision times overall-although the psychophysical functions are similar. Whilst we cannot hope to extract ‘think aloud’ data from non-verbal subjects, we can assess their decision time profiles obtained under similar conditions of test. As Figure 3 shows, squirrel monkeys show a significant SDE for both perceptual and ‘symbolic’ modes of test, recording also, as with humans, slower decision times overall with the ‘symbolic’ mode - although the psychophysical functions are similar. This pattern of results based on decision time data points further in the direction of a ‘symbolic’ competence in non-humans.

Figure 3. The symbolic distance effect: Reaction–time measures of represented linear orders



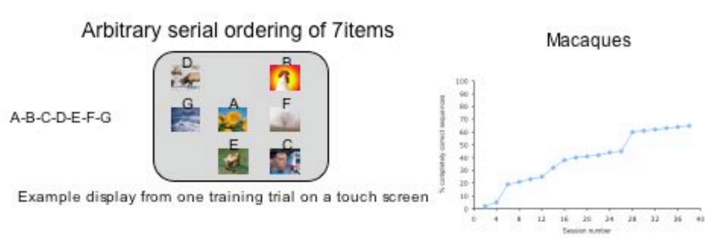
Serial ordering and executive control

Humans exhibit impressive feats of ordering as a core adaptive feature, controlling actions and words in extended productions that exhibit flexibility, capable of substantive recombinations. During human cognitive development, moreover, both the length of the child's utterance and the scope and extent of their ordering – as measured by the classic size seriation task - is a significant index of their cognitive growth. In the case of non-humans by contrast, ordering mechanisms must be inferred from data conventionally based on binary choice paradigms, thus leaving a huge disparity between human and non-human behaviour in this domain.

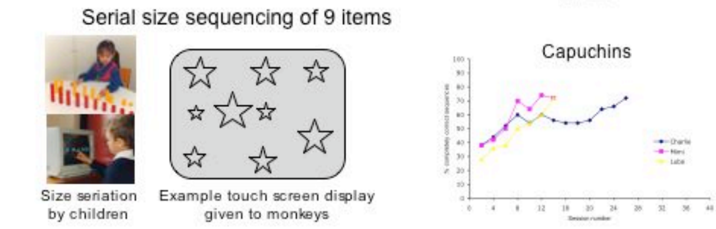
Based on touch screens, new technology, however, has enabled investigators to assess the serial ordering competences of non-humans without requiring the high levels of manipulation required to place objects in a neat row, or to sort them into collections and classes. With touch screen procedures, the response requirements to each item is low cost - a simple touch registered by the computer. Figure 4 illustrates this contrast, first showing sequences achieved by primates required to nest cups in a manipulative test of principled seriation (Johnson-Pynn, Fragaszy et al. 1999). As can be seen, the number of objects seriated is small. In contrast, touch screen based seriation is limited more by the size of the screen than the primates' competence to seriate. This is illustrated both by the sequencing of a fixed arbitrary list by rhesus macaques where the elements have no material connection, one to the other (Terrace 2005) and also by size based seriation by capuchin monkeys (McGonigle, Chalmers et al. 2003), using an iterative size rule (choose bigger). The monkey's size seriation performance converges on that of six year old children, both in terms of the length of the production and in its style (to count as successful, each production must be without error).

Figure 4. Linear ordering: serial nesting of real objects, arbitrary list learning and ordering of elements according to a (size) relational rule

Spontaneous cup nesting behaviour by primates shows evidence of primitive linear ordering (Johnson-Pynn et al, 1999). The bar graph shows the extent to which 2 primate species will nest cups serially during free play compared with young children.



Training monkeys to order items on a computer-driven touch screen reveals their potential for linear ordering. The graph (left) depicts the group learning functions for 4 rhesus macaques across sessions of 60 trials to a criterion of 65% completely correct trials within a session (Terrace, 2005).

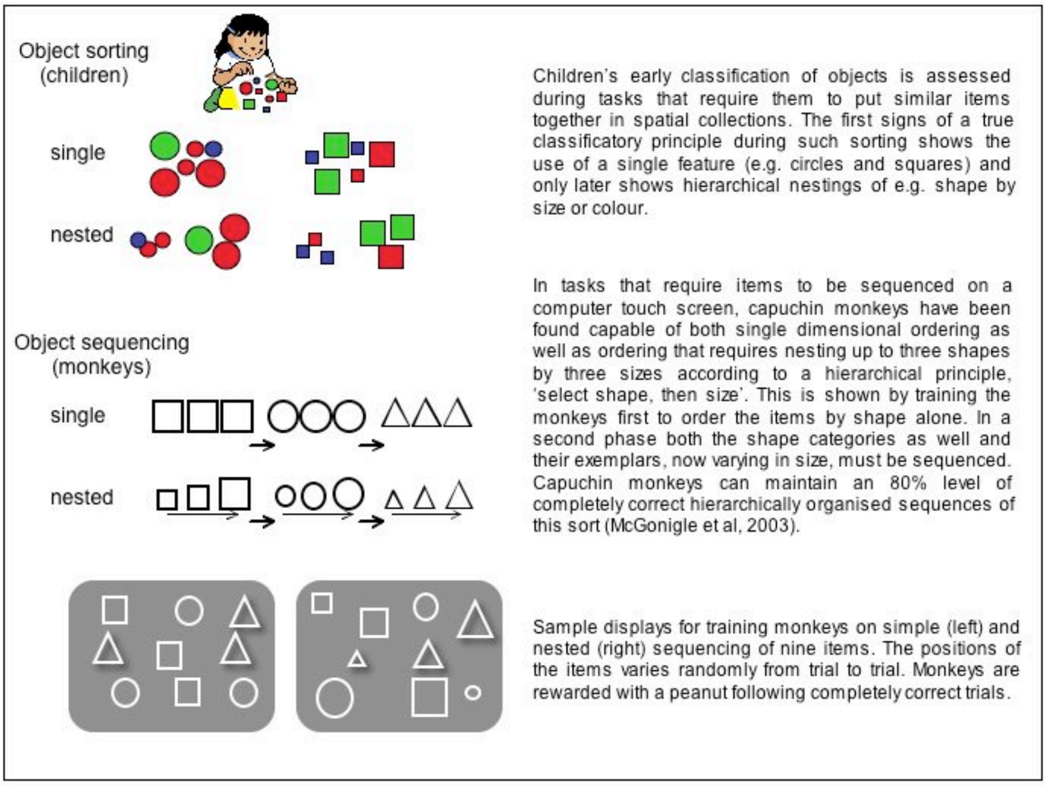


Using touch screens, capuchin monkeys have been shown capable of seriating 9 sizes. The graph depicts learning functions for 4 individual monkeys across sessions of 30 trials, trained to a criterion of 70% completely correct sequences within a session (McGonigle et al, 2003).

Categories and hierarchical organisation

Humans deploy both linear and hierarchical structures in language and thought. The latter are revealed in the ‘all/some’ relationship and in the asymmetry between the use of the superordinate such as ‘animal’, and subordinate such as ‘monkey’. Without such structures, Darwin’s taxonomy would have been impossible. Based on a complex of equivalence and difference relations, the only option available to assess such high-level, adaptive competences in non-verbal subjects is to require them to sort objects into groups and collections (see Figure 5). However, the high manipulatory demands entailed when using such conventional methods may be responsible for their meagre returns - a persistent result is that only one class can be identified from a group of objects - the rest left scattered and ungrouped. Given however, that (even) non-human primates are relatively poor at object manipulation, conventional tests may have underspecified their competences in this regard. Figure 5, shows by contrast how sequencing on a touch screen can reveal substantial classificatory skills in monkeys where capuchin monkeys (*Cebus apella*) classify nine test icons - presented in a randomized array on each trial - into three separate collections based on shape (McGonigle, Chalmers et al. 2003). In the first phase of tests, the exemplars within each category are identical; the monkey must interrogate all the exemplars from the category which must be sequenced first, then all the exemplars from the second category, then the final one, before the production is complete. In the second phase, the exemplars from each category vary in terms of their relative size. In this condition, the monkey has to order each exemplar as well as each category. As there are only three sizes of exemplar common to all categories, the monkey can only seriate accurately by coordinating the ordinal position of each exemplar with the ordinal position of the category from which it is derived, and this requires a hierarchical form of control. These data show that monkeys can organise information hierarchically, now regarded as a vital precondition for the evolution of language itself.

Figure 5. Classification: hierarchical classification capabilities revealed in non-human primates



Conclusions

From the classic work of Kohler deriving from the early part of the twentieth century, insight and relational competences have evolved as new paradigms and new technology empower the investigator to ask more focussed question and eschew many of the linguistic and manipulative constraints on the expression of animal cognition that have traditionally left it underspecified. Now, insight and the ‘suddenness’ of a solution as emphasised by Kohler, is less important that the unearthing of mechanisms for principled solution which can underwrite planning and goal directed behaviour in a non-reactive, intelligent way. Based on studies of ordering and executive functioning in particular, comparative research is beginning to reveal important evolutionary precursors to human cognition and language alike.

Further reading

Johnson-Pynn, J., D. M. Fragaszy, et al. (1999). "Strategies used to combine seriated cups by chimpanzees (*Pan troglodytes*), Bonobos (*Pan paniscus*) and capuchins (*Cebus apella*)." Journal of Comparative Psychology **113**(2): 137-148.

McGonigle, B. and M. Chalmers (1977). "Are monkeys logical?" Nature **267**: 694-697.

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McGonigle, B., M. Chalmers, et al. (2003). "Concurrent disjoint and reciprocal classification by *Cebus apella* in serial ordering tasks: evidence for hierarchical organization." Animal Cognition **6**(3): 185-197.

Terrace, H. S. (2005). "The simultaneous: A new approach to serial learning." Trends in cognitive sciences **9**(4): 202-210.

Figure captions