PROTO-PROPOSITIONS

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Before the evolution of languages as public conventional communication systems, pre-humans had somewhat complex private mental schemes for representing the external world. What is known about human and some animal vision suggests that proposition-like cognitive structures existed for the mental representation of perceived scenes before the advent of complex language. The structures traditionally adopted by formal Logic can be modified to conform to known constraints on the visual representation of scenes. While this modification slightly reduces the expressive power of representations (in that the meanings of some complex sentences cannot naturally be represented), it provides a unified, ontologically parsimonious, primitive notation for cognitive representations, suitable for later recruitment by complex syntactic language. The most basic semantic elements later mapped onto sentences are all present in the prelinguistic mental representation, which reflects the workings of the visual attention system

1. The Magical Number 4 – How big is a single thought?

First order predicate logic (FOPL), not being an explicitly psychological theory, places no upper bound on the number of entities that can be involved in a simple proposition. Thus, beside natural 1-place, 2-place, and 3-place predicates, in principle 14-place, even million-place predicates are countenanced by the metatheory of FOPL. In practice, however, the examples discussed by logicians hardly ever involve predicates of degree greater than 4. This is in fact a psychologically natural limit, conforming to the limits on subitizing, the fast process of global visual attention which can take in a very limited number of objects at one glance. The limit in humans is around 4.

Cowan (2001) has argued that the real limit on human short-term memory is also "the magical number 4", and not seven plus or minus two, as earlier argued by Miller (1956). The human subitizing limit of 4 is shared by animal species relatively closely related to humans (Dehaene 1997).

If simple clauses in human languages are taken to correspond to propositions describing simple scenes, the typical size and scope of human simple clauses can be explained by this limitation on visual attention and short-term memory, shared with non-linguistic creatures. (The complex sentences of modern languages, with embedding and coordination of simple clauses, are not the issue here. The evolutionary basis for simple clauses is an issue

independent of the evolution of processes which build more complex structures with them.)

2. Predicate-Argument Structure in Animal Brains

Propositions, as theorized by logicians, are structured asymmetrically, consisting of elements of two distinct kinds, a predicate and one or more arguments. The semantic functions of predicate and arguments differ. Predicates are associated with properties and relations, whereas arguments typically refer to individual objects. The combination of a predicate and its arguments results in a formula with a truth value, which depends on whether the property or relation denoted by the predicate holds of the object(s) referred to by the arguments. As argued in Hurford (2003), neural correlates can be found in human and animal visual (and auditory) systems of these two logical types. One visual mechanism, the so-called 'dorsal stream' (or the 'where stream') pre-attentionally picks out objects (up to about four at a time) and assigns mental indices to them, for the purposes of tracking them in the scene. The dorsal stream, apart from thus indexing objects in the scene, does not categorize them in any way. Once visually indexed, objects can be the targets of focal attention, and at this stage properties are assigned to them by processes in the ventral stream (or 'what stream'). Thus one brain mechanism picks out objects – this corresponds to the referring function of logical arguments. Another, separate, mechanism, assigns properties to objects. This division of labour by the visual system is shared by many mammals. The visual representation of a scene is the overall complex of neural activity delivered by the interacting dorsal and ventral streams. The represented scene is composed by a process delivering objects as arguments and a process delivering predicate-like judgements about the properties of those objects. This visual system forms a natural evolutionary platform for representations of meanings, subsequently expressed by human sentences. This whole argument is presented in detail in Hurford (2003).

3. Local and Global Attention to Objects and Scenes

Humans and some animals are capable of parallel attention to whole scenes (global attention) and to the objects within scenes (local or focal attention). And humans and some animals (e.g. pigeons) can shift back and forth rapidly between local and global attention. This activity exhibits a kind of two-level representation. For instance, a pattern of dots forming a rectangle can be

simultaneously represented as both a rectangle and a collection of dots. In a pathological condition known as simultanagnosia, patients 'cannot see more than one object at a time'. Such a patient cannot simultaneously see both a rectangle formed with dots and the individual dots (for example not being able to count the dots), and cannot see the relations between multiple objects in a scene. This is a failure in the normal coordination of global and local attention. Normal humans can simultaneously categorize a scene by its global properties, and assign properties to the constituent objects. It seems likely that other primates, and many other vertebrates, have visual attention organized in this way, with a division between global and local attention and an ability to shift between them and combine their outputs into a single representation. This, as will be seen in a later section, suggests a parallel with current event-based semantics, and can lead the way to a re-thinking of traditional logical representations.

4. Animal Truth and Reference

Truth and reference are paradigmatic qualities of human propositions. Can the prelinguistic mental representations of animals refer, or be true? Yes. Some non-human animals have mental categories. This is most obviously shown by their systematic behaviour in relation to various coherent classes of input stimuli from the environment. Most neuroscientists would talk of patterns of neural activity, rather than mental categories; but if these patterns of neural activity are categorially distinct (which they usually are, with a little fuzziness at the edges), this is only a terminological difference. While some philosophers have been reluctant to attribute concepts to non-humans, ethologists have usually had no such qualms where it can be shown that the relevant behaviour cannot be accounted for in terms of simple triggering mechanisms. Herrnstein (1991) defined a scale with five points, and labelled the fourth point on the scale 'concepts'. He concluded that many animals showed evidence of having concepts, but that only humans reach his fifth point, the level of abstract relations. More recent work indicates that some non-humans can sustain representations long after the triggering stimulus has faded (e.g. Zuberbühler et al. 1999), and can represent abstract relations. In some cases, animals have been shown to control complexities beyond simple recognition of the concrete properties of objects. Thus, there is evidence in some animals for primitive versions of metacognition (sensitivity to ones own mental states), and control over more abstract relational concepts, such as 'same-colour-as'.

An animal can hold an object in (focal) attention. The relationship between the external object and the brain mechanism directing and controlling attention to it is the basis for the later evolution of deictic reference in communicative

acts, like that involved with the English demonstrative pronouns *this* and *that*. When such pronouns are successfully used in conversation about concrete things, as when one says "This is hot!", both speaker and hearer attend to the same external object. It seems reasonable to call the relation between the brain mechanism of a non-linguistic creature attending to an object a relation of **proto-reference** to the object in question. What is lacking in proto-reference, as opposed to deictic reference in language, is an accompanying communicative signal. Ballard et al. (1997) use the term *deictic* for the relation between mental variables tracking objects and the objects themselves. More complexly, humans can perform parallel "attentive tracking" of a limited number of objects in a scene. Theoretical models of this capacity describe it as involving the mental assignment of spatial tags to targets; see Culham et al. (1998). Here again it is appropriate to call the relation between the mental tags and the external objects 'proto-reference'. Neuroscientists sometimes apply the term *refer* to this relation between a mental process and an external object. Pylyshyn (2000:205), for example, writes "... the visual system ... needs a special kind of direct reference mechanism to refer to objects without having to encode their properties."

The properties assigned to an attended-to object, combined with the mental index of the object in the scene, constitute a proposition-like representation, in which the evolutionary beginnings of **truth** can be discerned. The truth of human linguistic utterances depend on conventionally coordinated assignments of denotations to predicates. If I point to an object and say "That is a mouse", the truth of my utterance depends on what class of objects is normally associated in this society with the word *mouse*. Uncommunicative creatures have no such shared conventions, but it is possible to appeal to the idea of a single adult creature's usual patterns of behaviour in relation to classes of objects which we human researchers can identify as nondisjunctive natural classes. If such a move can be justified, we can maintain that non-human animals can have true or false beliefs. The cat that chases a wind-blown leaf may well be mentally categorizing the leaf as a mouse. That is, the neural activity normally reserved for mouse-like things gets 'wrongly' triggered by the wind-blown leaf. In this case, it seems reasonable to say that the representation in the cat's brain is false.

In claiming that an animal acts as if X were true, or that it believes X, two points must be acknowledged: firstly, no linguistic representation of X is present in the animal's mind, and secondly, it follows that whatever form of words we choose to describe X is only an approximation to the conditions influencing the animal's behaviour. Only an impossibly omniscient external agent can infallibly judge the truth or falsity of propositions in creatures' minds. We scientists can approach the fact of the matter whether animals have
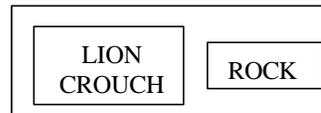
true or false beliefs on particular occasions, based on our systematic observations of their normal responses to categories of objects which we have reason to believe they perceive more or less as we do. See Dennett (1996)'s section on 'The Misguided Goal of Propositional Precision' for concurring arguments.

5.   A parsimonious *Begriffschrift* for proto-propositions

Frege introduced a notation for the representation of concepts. His graphically baroque notation has since been translated (without loss or increment) into the more familiar representations of FOPL.   For Frege, concepts were not psychological, due to a phobia of 'psychologizing', understandable at a time when so little was known about the brain. However, given modern knowledge of the workings of the visual system, we are now in a position to devise a notation for the mental representation of visual scenes, comparable to Fregean FOPL. The notation proposed is comparable, preserving what is apt about the Fregean conception, but rejecting what is psychologically implausible.

It is useful to adopt a minimal element of iconicity in the proposed notation. The central idea is to replace any individual variable by a box, and to write predicates applying to that variable inside the box. Thus, the following two representations are equivalent, both translatable as *There's a crouching lion and a rock.*

$\exists x \, \exists y \, \text{LION}(x) \, \& \, \text{CROUCH}(x) \, \& \, \text{ROCK}(y)$

LION CROUCH	ROCK

The outer box represents the whole scene, the object of global attention. As will be seen shortly, predicates can be applied to the whole scene as well as to the individual objects in it.

6.   Getting Rid of Individual Constants

As argued elsewhere (Hurford 1999, 2001, 2003), individual constants, logical terms corresponding (roughly) to proper names in languages, such as *Queen Elizabeth II* and *Saul Kripke*, are psychologically implausible. In Logic, such individual constants are assumed to have an absolutely rigid designation, recovered by users with absolute reliability. This demands an impossible

omniscience on the part of users. Even animals who can 'recognize' other individuals with impressive reliability can be easily fooled by experimenters. The alternative is to treat proper names as predicates. Thus MARY and JOHN, for example, have the same status in prelinguistic mental representations as WOMAN and MAN, but are more specific as a matter of degree, not of kind. In extensional terms, MARY picks out members of a subset of the set picked out by WOMAN. MARY does not necessarily identify a singleton set; it would include her identical twin as well.

7. Getting Rid of Ordered Arguments and Role Markers

Logic sequentially orders the arguments of a predicate, as a device for making it clear what roles the denoted individuals play in asymmetric relations. But the individuals in a visual scene are simultaneously present, not ordered in any sequential way. Linguists indicate 'who did what to whom' by Thematic role labels such as AGENT and PATIENT. This obviates the need for notational ordering of the arguments of a predicate. It is, further, common practice in event-based semantics (e.g. Parsons (1990)) to treat these Thematic role markers as predicates, and to label a whole event with a separate predicate, often corresponding to a verb in language. Translating a typical event-semantic representation into our box notation, we get the following equivalents.

$\exists e$ STAB(e) & AGENT(brutus, e) & PATIENT(caesar, e)

STAB	BRUTUS AGENT	CAESAR PATIENT

In a common way of paraphrasing, these would represent a scene describable by *There was a stabbing event in which Brutus was the Agent and Caesar the Patient*, or just plain *Brutus stabbed Caesar.* Note the ontological parsimony of the box representations, with only boxes, corresponding to individuals and the single whole scene, and one-place predicates, corresponding to the attributes assigned to the individuals and to the scene. In particular, in the box notation, the property of AGENThood is attributed to Brutus, within the scope of the overall stabbing scene.
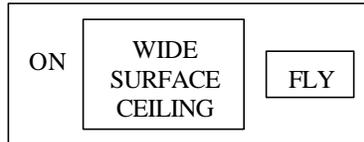
AGENT here is our shorthand for a bundle of perceptual features distinctive of animate objects in vigorous action, including 'biological motion'. Biological motion is recognized by human infants (Johansson, 1973), and by day-old chicks (Vallortigara et al., 2005). All that is claimed in using the term

AGENT is that the observer of a scene can tell which of the participants is "doing something".
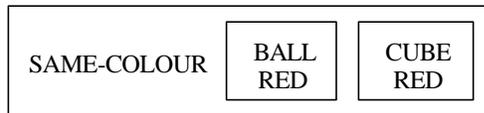
A claim made here, the most radical departure from FOPL, is that **all** prelinguistic predicates were one-place. Some justification for this is given in the next section.

8. One-Place Predicates over Scenes and Objects

Predicates traditionally treated as two-place or three-place can be treated as one-place, given an implicit **relativizing function** of the outer scene-representing box. Only a few examples can be given here. The following diagram represents a scene consisting of a fly on a ceiling.

```
+----------------------------------------+
|       +----------------+               |
|       |     WIDE       |  +--------+    |
|  ON   |   SURFACE      |  |  FLY   |    |
|       |   CEILING      |  +--------+    |
|       +----------------+               |
+----------------------------------------+
```

Here is a diagram representing a scene of which it is judged that two objects are of the same colour.

```
+------------------------------------------------+
|                   +--------+   +--------+       |
|                   |  BALL  |   |  CUBE  |       |
|  SAME-COLOUR      |  RED   |   |  RED   |       |
|                   +--------+   +--------+       |
+------------------------------------------------+
```

It is hypothesized that predicates appearing in the outer box are delivered by global attention.

The ordering of elements within all boxes is immaterial. It will be seen that the proposal that all predicates are one-place is, though strictly true, not as radical a departure from tradition as may be thought. Some predicates, though applying to single scenes (thus technically one-place) only apply to scenes which contain a specified number of objects. Thus, for example, the judgement represented by SAME-COLOUR cannot be arrived at with a scene containing less than two objects. Some predicates, often corresponding to those to which an emerging syntax will associate transitive verbs and prepositions, only apply to scenes with more than one object. But there is no exact correspondence between later-emerging syntactic categories and particular types of prelinguistic predicates. When public labels get attached to such internal private representations, for purposes of communication, other purely public

considerations, such as Topic and Comment, play a part in the structuring of sentences.

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