# Consciousness in a Multi-layered Multi-functional Labyrinthine Mind

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This is available at http://www.cs.bham.ac.uk/research/projects/cogaff/talks/#pac07

## This conference is about two streams of thought

- Enactivists: action is integral to consciousness,
- Separatists:
  - sensorimotor control/dorsal functions are ‘unconscious’
  - ventral functions are ‘conscious’
  - are they are in opposition? can they be unified?

## I suggest that both views

(a) fail to do justice to the fact that biological evolution produced many different designs for organisms – with many different kinds of consciousness/awareness/perception/sensing.

(b) fail to accommodate the variety of design problems solved by evolution in producing these designs

(c) focus too closely on a subset of features of (normal, adult) humans.

(d) use ill-defined ordinary language terms as if they had precise meanings (e.g. “consciousness”).

# What did evolution do for us?

Millions of years of evolution produced a huge variety of information-processing systems.

Normal human information-processing systems include many subsystems interacting in a very complex architecture that grows itself from infancy onwards,

– partly under the influence of the genome

– partly through various epigenetic processes

Familiar categorisations are too crude to provide accurate specification of these processes and their results (for scientific or philosophical purposes)

E.g. ‘conscious’, ‘intentionality’, ‘personal’, ‘subpersonal’, ‘explicit’, ‘implicit’, ‘what it’s like to...’, etc.

We need instead to adopt the design stance (Dennett 1978) and make significant use of present and future concepts from information engineering and information science – and test our ideas in working systems.

That will reveal a logical topography [see refs at end] underlying the logical geography of concepts currently in use, pointing at the possibility of new deeper conceptualisations.

Compare what happened to ordinary concepts of kinds of stuff, following discoveries about the architecture of matter, the periodic table of the elements, chemical structures, etc.

To help us think about this we need agreed high level ways of classifying many sets of requirements for mechanisms and representations, within an architecture (for animal or robot).

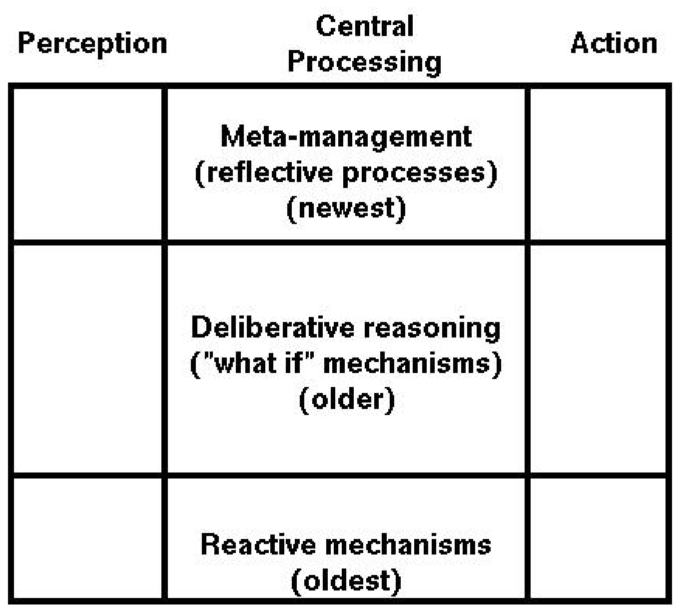
One example is: The CogAff (Cognition and Affect) Schema:

# The CogAff Schema: A first-draft high level ontology

## Biological information-processing systems have many subsystems

These are crudely divisible as shown in the figure (with further subdivisions possible).

Requirements for subsystems can refer to:




- **Types of information handled:** (ontology used: processes, events, objects, relations, causes, functions, affordances, meta-semantic states, goals, questions, plans, rules, etc.)
- **Forms of representation:** (transient, persistent, continuous, discrete, Fregean (e.g. logical), spatial, diagrammatic, distributed, dynamical, compiled, interpreted, neural, symbolic...)
- **Uses of information:** (controlling, modulating, describing, planning, predicting, explaining, executing, teaching, questioning, instructing, communicating...)
- **Types of mechanism:** (many examples have already been explored – there may be lots more, as yet unknown).
- **Ways of putting things together:** in an architecture or sub-architecture: e.g. dynamically, statically, with different forms of communication between sub-systems, and different modes of composition of information (e.g. vectors, graphs, logic, maps, models, ...)

Sub-systems can be concurrently active, e.g. controlling breathing, walking, thinking, seeing, talking.

In different types of organism or machine, the ‘boxes’ include different (possibly empty) sets of requirements, met by different mechanisms, with different functions and connectivity, different forms of learning, and different forms of representation using different ontologies, In some organisms, the architecture grows itself after birth.

The CogAff Schema allows many different combinations of requirements for sub-systems, and many different designs for architectures, to be represented — depending on what is in the various boxes and also on what is linked to what and how.

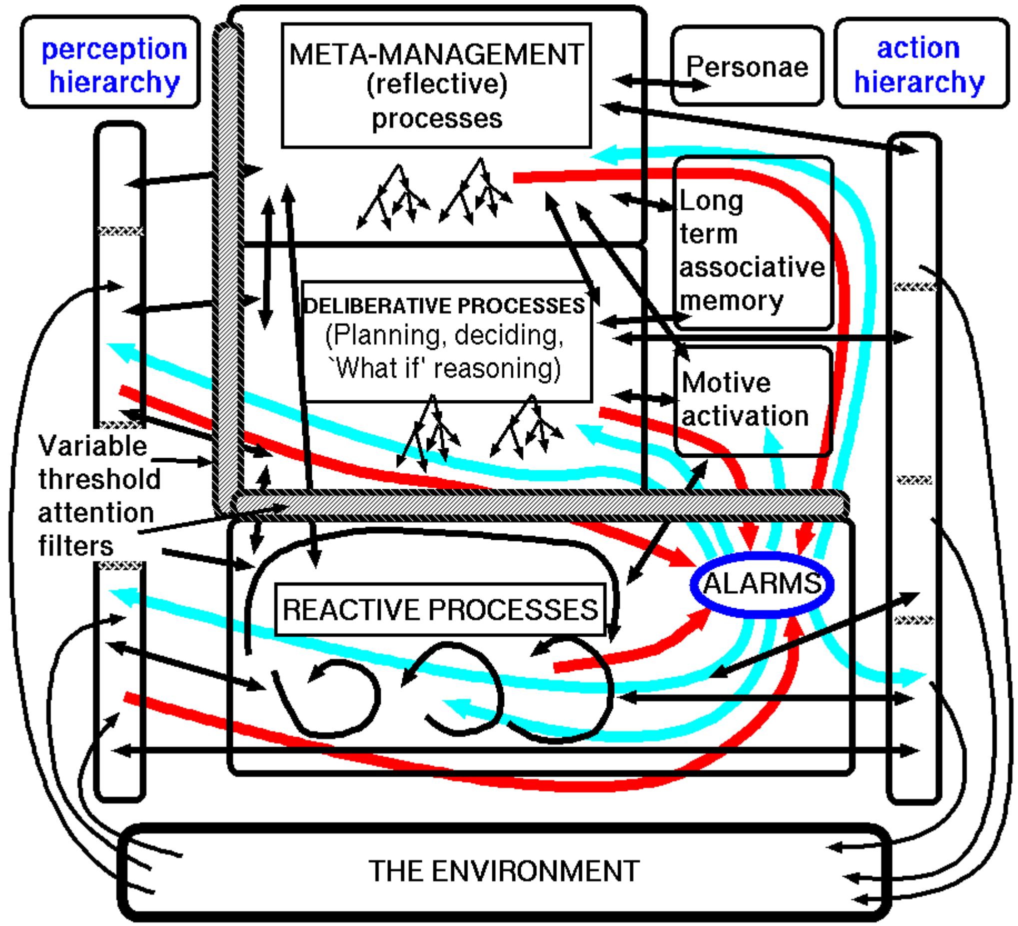
# Sketch of a special case of CogAff: H-CogAff

H-CogAff specifies a sub-class of human-like architectures within the generic “CogAff” schema (“H” = “Human”).

A “labyrinthine” collection of requirements to be met, in a modular but very highly connected architecture

– able to grow new components and new connections.

Perception and action sub-systems have many concurrently active layers of functionality related to the different central layers/mechanisms: e.g. seeing marks, letters, words, phrases, meanings...




## Where could this come from?

Different trajectories for different layers:

- evolutionary,
  precocial competences from the genome
- developmental,
  altricial competences and architectures built while interacting with the environment – including substantive ontology-extension
- adaptive changes, (small adjustments)
- compilation of reactive skills
- social learning, including changing personae, high level motives, etc.

## Much work remains to be done.

Kantian causal understanding and reasoning probably cannot occur in the reactive layers. Why not? Compare mathematical competences.

# Colours and sensorimotor/exosomatic contingencies

**Conjecture:** In microbes, insects, etc., all information-processing is linked to sensing and acting, and all or most information about the current environment is available only in transient activation states, whereas for more sophisticated organisms, evolution discovered the massive advantages of enduring re-usable representations of exosomatic, amodally represented, ontologies, allowing external, future, past, unobserved, and hypothetical processes, events and causal relations to be represented independently of sensorimotor details, e.g. in deliberative and meta-management sub-architectures.

So perhaps “mirror” neurones – should be called “exosomatic abstraction” neurons?

## O’Regan on colour perception

At the conference Kevin O’Regan presented what he called a sensorimotor theory of colour.

It turned out that the key fact was that colour of a surface is a property of the surface that can be defined in terms of how light impinging on the surface is transformed on reflection from the surface.

So instead of the key ‘contingencies’ being sensory inputs and motor outputs of perceivers they are input-output contingencies for portions of surfaces of objects.

Humans, other animals and sophisticated robots can learn to classify objects according their colour (or hardness, softness, elasticity, plasticity, rigidity, etc.) thus defined and in so doing they may use a mixture of sensory criteria and more complex experiment-based criteria (e.g. testing a substance for water solubility by inserting into water and stirring).

But for many such tests (not all) it makes no difference who or what does the test.

A person without arms or legs can see that some things are rigid and some are not by seeing the results of other people’s actions on those things, or even the results of wind, rain, etc., on various objects etc.

This all needs to be made precise and tested in working systems: as is being done by people who explore the notion that many affordances used by robots have to be recognised on the basis of explicit testing.

# Different notions of consciousness

## What's the connection with consciousness (in the everyday sense)?

- The noun 'consciousness' is often wrongly taken to refer to some thing that is a clear object of scientific or philosophical investigation:

  It is better to focus on the adjective 'conscious', which usually goes with 'of' and an object, or, which in contrast with 'unconscious', indicates a state in which it is possible to be conscious of things.
  Actual usage of these expressions leads to inconsistencies such as "being asleep implies being unconscious" whereas "being terrified in a nightmare implies being conscious".
  People also give inconsistent answers to questions about consciousness in other animals (including microbes, insects...) Using "what it's like to be ..." doesn't help: that's just another ill-defined expression.

- All organisms have some form of consciousness or awareness, in the pre-theoretical (somewhat confused) sense of these words, especially animals that can hunt food, escape from sensed danger, follow routes, return to nests, etc.
- In that "ordinary" sense, many information-processing subsystems within humans may also be conscious e.g. a posture-control system may be conscious of optical flow. See D.Lee's work.
- But Inward directed self consciousness requires both meta-semantic representational apparatus and architectural mechanisms to support self-monitoring, of both external actions and internal states and processes (probably in very few organisms.)
- This accounts for much of what philosophers say about 'qualia'. Sloman and Chrisley, JCS 2003, 'Virtual machines and consciousness': `http://www.cs.bham.ac.uk/research/projects/cogaff/03.html#200302`

It's the architecture of X, not the content of Y that determines whether X can be conscious of Y: e.g. Y=a current sensory state, a current efferent signal, the changed appearance of a circle viewed obliquely, what X wants, what X believes, what X remembers, etc.

# The role of embodiment

## Many now emphasise the role of embodiment in determining mental states.

But the information processing architecture matters more than the precise bodily form.

Human brain mechanisms that originally evolved to interact with a particular type of body, including particular sensors and effectors, may still be available and able to perform many of their original information-processing functions in individuals who, as a result of genetic abnormalities or injury or illness, lack some sensory or motor capabilities, such as people born blind or limbless.

(E.g. Thalidomide babies, congenitally blind people, conjoined Hensel twins, ...)
See Alison Lapper's web site `http://www.alisonlapper.com/`

## So, having had embodied ancestors is more important for human intelligence, than having any particular form of embodiment.

Likewise design of information processing mechanisms in artificially intelligent systems may be far more important than the specific bodily forms – if they are to have human-like minds – though of course bodily forms limit what actions (including sensing actions) are possible.

The processes of developing normal adult human cognition may be different in humans born with different physical shapes or sensing organs, but many end results (e.g. ability to enjoy gossip, ability to enjoy mathematics and think about infinite sets, ability to watch a tennis game) may be very similar.

This can include having human emotions such as jealousy, excited anticipation, obsessive ambition, intense patriotism, hate, pity, etc. `http://www.cs.bham.ac.uk/research/projects/cogaff/talks/#cafe04`

These ideas can be related to results of empirical research on humans and other animals.

NB: All theories in this area need to be tested in designs and implementations for working artificial systems, since what appears workable to armchair theorists very rarely can actually work as imagined.

# Example: Multiple perceptual routes

H-CogAff specifies multi-window perception and multi-window action, whereas many architectures assume peephole perception and action.

The visual and action sub-systems have architectural layers (evolved or developed) that concurrently handle ontologies at different levels of abstraction (including in some cases mental states of oneself and others), and have multiple connections to different sorts of central sub-systems, as well as to other sensory and motor subsystems.

So, instead of one or two routes from vision, we have multiple routes,

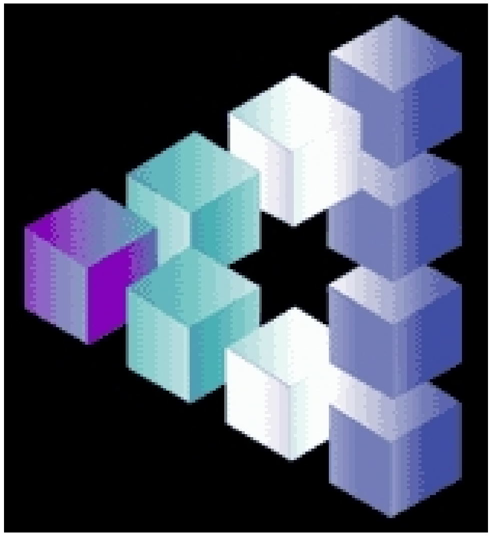
e.g. to blinking reflexes, saccade generators, posture control subsystems, visual servoing mechanisms, motive generators, question answering mechanisms, planning mechanisms, prediction mechanisms, explanation constructors, plan execution mechanisms, learning mechanisms (in several different architectural layers), alarm subsystems, communication mechanisms, social mechanisms.

SIMILAR COMMENTS APPLY TO CONNECTIONS WITH ACTION SUB-SYSTEMS.

## High level percepts can be inconsistent

(Picture by Reutersvard – before Penrose)

This tells us important things about the visual system – and some of the contents of visual consciousness.



What you see is not only what exists, but multiple affordances.
Think of all the things you can do with or between the little cubes.
**Collections of affordances can be inconsistent: but not models of a scene.**
If the picture were huge, you might never discover the impossibility (like a 2 year old). Compare Escher's pictures, e.g. the Waterfall.

For more on visual processing see

http://www.cs.bham.ac.uk/research/projects/cogaff/talks/sloman-cospal-slides.pdf

# Evolution invented "discovery through creative play"

**Cognitive epigenesis:** Multiple routes from DNA to competences, some via the environment

Pre-configured competences:

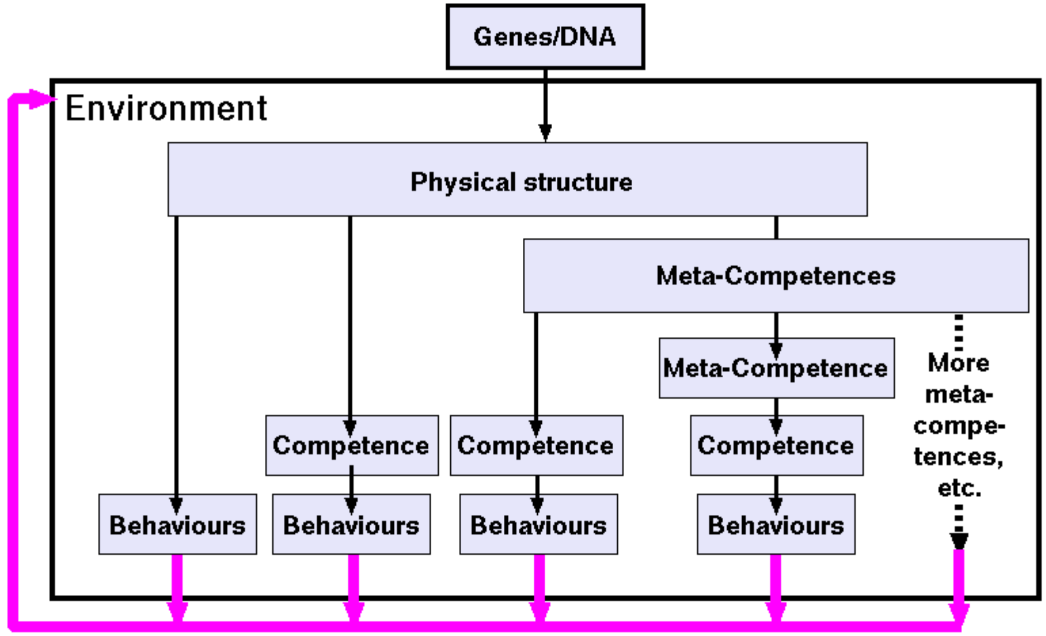
are genetically pre-determined, though they may be inactive till long after birth (e.g. sexual competences), and their growth may depend on standard, predictable, features of the environment, as well as on DNA.

They are represented towards the left side of the diagram.

Meta-configured competences:

are produced through the interaction of pre-configured or previously produced meta-configured competences with the environment (internal or external).

New competences make new experiences possible (e.g. new ways of 'seeing as'.)




(Chris Miall and Jackie Chappell helped with the diagram.)

Evolution 'discovered' that speed of learning is increased by active intervention: some animal species discover many facts about the environment, and about themselves, through creative exploration and play, using not just general learning mechanisms but processes designed for a 3-D physical environment like ours, allowing specific kinds of ontologies, theories and strategies are developed, tested and debugged. This often uses Kantian causal models.

PHYSICALLY DISADVANTAGED, PARTLY PHYSICALLY DISCONNECTED, INDIVIDUALS CAN STILL LEARN.

Vicarious learning may be slower, but it works, nevertheless.

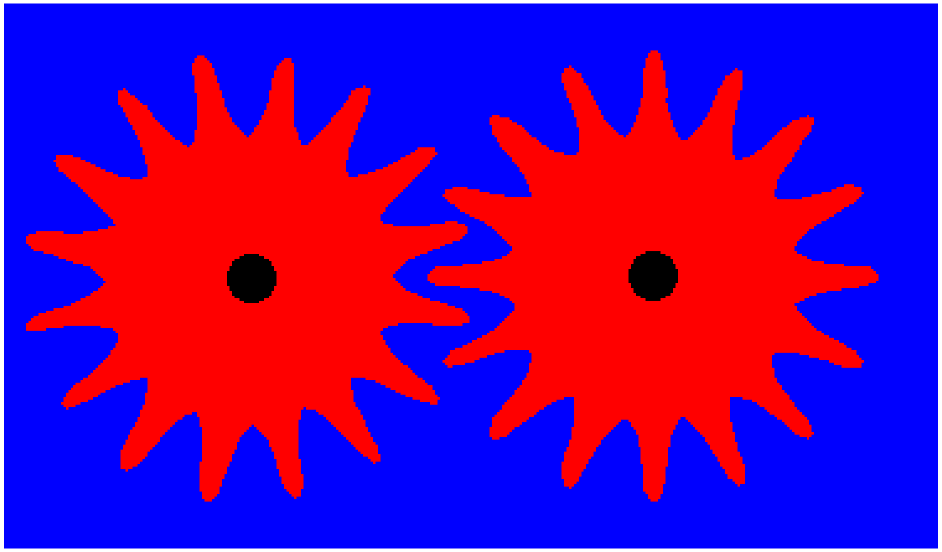
For more on cognitive epigenesis see papers by Chappell and Sloman:

http://www.cs.bham.ac.uk/research/projects/cosy/papers/

# Experiencing Kantian Causation in Meshed Gears

When gears are not meshed, you cannot tell if turning one will affect another, except by experimenting: using 'Humean' causation (e.g. Bayes nets).

But if they are meshed:
You (and some children) can tell, by looking, how rotation of one wheel will affect the other. How? You can simulate rotations in a virtual machine.



## What you can see includes this:

As a tooth near the centre of the picture moves up or down it will come into contact with a tooth from the other wheel.
If both wheels have fixed axles, and are rigid and impenetrable, then if the first tooth continues moving, it will push the other in the same direction, causing its wheel to rotate.

NB: The simulations that you run can make use of not just perceived shape, but also unperceived constraints: in this case rigidity and impenetrability.

These need to be part of the perceiver's exosomatic (not sensorimotor) ontology and integrated into the simulations, for the simulation to be deterministic.

Constraints and processes using them need not be conscious, or expressed in linguistic or logical form.

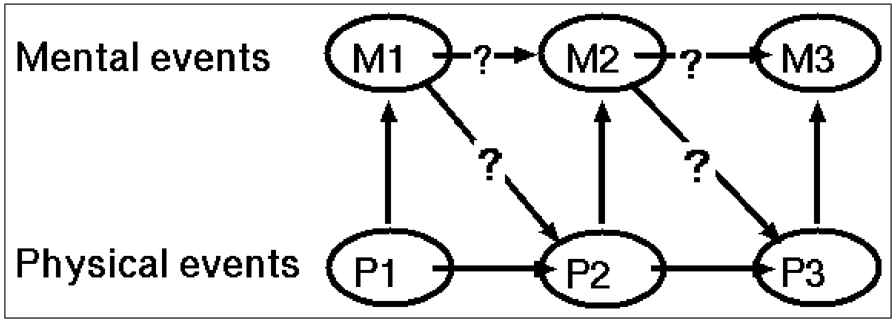
There is no suggestion that a child can do all this from birth.

**How this competence develops, and what information processing is involved, remains to be explained. It is also not known which other animals can do such things.**

# Virtual machine events can also be causes

We now know that relations depicted in the figure can exist in computers, though there are people who dispute the causal links marked with '?'s.

Events in virtual (mental) machines, like inserting a character in a line, or a spelling checker correcting a typing mistake, or a chess program deciding to attack your queen, are like mental events in many ways: e.g. such events have no physical location, cannot be observed using physical sensors, and are describable only by using concepts not definable in terms of the concepts of the physical sciences.




Understanding all that is important for scientists (and philosophers) trying to understand minds, brains, and what they do and how they do it.

People who challenge the links marked "?" (especially downward links) regard events in minds and computer virtual machines as **epiphenomenal** – i.e. as effects but not causes.

This denial is based on a false theory of causation (e.g. if causation is thought of as a kind of "conserved fluid" flowing through the universe).

If instead we regard causal talk as merely a way of expressing which of a (rather complex) set of counterfactual conditionals are true and which false, then virtual machine events can be causes.

We need to understand this to understand the variety of types of mental phenomena that can occur and the variety of types of consciousness, e.g. some more concerned with control, others more with description (e.g. of reality or of possibilities).

Not only can seeing a tree have effects, so also can the internal process of monitoring seeing a tree (using the meta-management architectural layer).

See `http://www.cs.bham.ac.uk/research/projects/cogaff/talks/#inf`

# John McCarthy on The Well Designed Child

Quotes from his unpublished online paper: 'The well designed child',

`http://www-formal.stanford.edu/jmc/child.html`

> **"Evolution solved a different problem than that of starting a baby with no a priori assumptions."**
>
> ...
>
> "Animal behavior, including human intelligence, evolved to survive and succeed in this complex, partially observable and very slightly controllable world.
> The main features of this world have existed for several billion years and should not have to be learned anew by each person or animal."

Biological facts support McCarthy:

Most animals start life with most of the competences they need – e.g. deer that run with the herd soon after birth. For them, there's no blooming, buzzing confusion (William James)
So why not humans and other primates, hunting mammals, nest building birds, ...?
Perhaps we have not been asking the right questions about learning.

We need to understand the nature/nurture tradeoffs, much better than we currently do, and that includes understanding what resources, opportunities and selection pressures existed during the evolution of our precursors, and how evolution responded to them.

See the papers and presentations by Chappell and Sloman here
`http://www.cs.bham.ac.uk/research/projects/cosy/papers/` starting with:

The Altricial-Precocial Spectrum for Robots, in *Proceedings IJCAI'05*

# Related papers and presentations
## (some with colleagues)

**ASSC10 Poster**

**How an animal or robot with 3-D manipulation skills experiences the world**

http://eprints.assc.caltech.edu/112/

http://www.cs.bham.ac.uk/research/projects/cosy/papers/#pr0602

**The Computer Revolution in Philosophy**

http://eprints.assc.caltech.edu/247/

**Understanding causation in humans, animals and robots**

http://www.cs.bham.ac.uk/research/projects/cogaff/talks/wonac/

**What is information? Meaning? Semantic content?**

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/whats-information.html

**Orthogonal Recombinable Competences Acquired by Altricial Species**

http://www.cs.bham.ac.uk/research/projects/cosy/papers/#dp0601

**Two Notions Contrasted: 'Logical Geography' and 'Logical Topography'**

Variations on a theme by Gilbert Ryle: The logical topography of 'Logical Geography'.

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/logical-geography.html

**More general collections**

http://www.cs.bham.ac.uk/research/projects/cogaff/talks/

http://www.cs.bham.ac.uk/research/projects/cosy/papers/

http://www.cs.bham.ac.uk/research/projects/cogaff/

NOTE: This document may be too terse to be easily understood. The above links and references in the text may help people who wish to follow up these ideas.