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## **Panel COGNITIVE**

# **Cognitive Mechanisms and Machine- Brain Interaction**

# Panel

- **Moderator**  
**Giorgio Bonmassar, Harvard Medical School, USA**
- **Panelists**  
**Charlotte Sennersten, CSIRO, Australia**  
**Xia Lin, Drexel University, USA**  
**Hans M. Dietz, University of Paderborn, Germany**  
**Martin Lochner, CSIRO Computational Informatics (CCI), Australia**

# Brain Maps and Information Retrieval

Cognitive 2014 Panel:  
Cognitive Mechanisms and Machine-brain interaction

Xia Lin

College of Computing and Informatics  
Drexel University  
Philadelphia, PA USA

# Retrieval of information

- Learn from how brain retrieves information
- and apply it to
- Information retrieval in databases, search engines, documents, .....
- Can the brain map help?



# Brainmap.org



**brainmap.org**

[home](#) [forum](#) [software](#) [tools](#) [publications](#) [collaborations](#) [credits](#) [contact](#)

## What is BrainMap?

BrainMap is a database of published functional and structural neuroimaging experiments with coordinate-based results (x,y,z) in Talairach or MNI space. The goal of BrainMap is to develop [software](#) and [tools](#) to share neuroimaging results and enable meta-analysis of studies of human brain function and structure in healthy and diseased subjects.

The BrainMap Project is developed at the [Research Imaging Institute](#) of the [University of Texas Health Science Center San Antonio](#). BrainMap was conceived in 1988 and originally developed as a web-based interface. After more than 20 years of development, BrainMap has evolved into a much broader project whose software and data have been utilized in numerous [publications](#). BrainMap provides not only data for meta-analyses and data mining, but also distributes software and concepts for quantitative integration of neuroimaging data.

## Collaborations

The BrainMap development team welcomes [collaborations](#). We will provide guidance and assistance in the execution of meta-analyses upon request. We encourage collaborations that develop new tools for meta-analysis or use BrainMap data to develop or validate other neuroinformatics tools and strategies.

## BrainMap ICA Results

### Quick Author Search

Want to check if a paper is already in the BrainMap database? Just type in the author's last name below:

### Activation Coordinate Experiment-wise Search (ACES)

Upload a tab-delimited file of locations to find which BrainMap experiments are most similar:

No file selected.

Reference space:  Talairach  MNI  
Find similar experiments:

### Functional Database Status

Papers: 2426  
Experiments: 11545  
Paradigm Classes: 107  
Subjects: 47166  
Locations: 92664

### VBM Database Status

Papers: 978  
Experiments: 3045  
Subjects: 68760  
Locations: 19983



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# Everyone Knows but Uncertain

- How information is organized in memory
  - Organized by clustering or chunking ?
  - Organized by semantic networks ?
  - Self-organization ?
- How information is retrieved from memory
  - Recall -- direct access
  - Recognition --
  - Recollection -- reconstruct through logical structures, partial memories, or clues
  - Relearning –experiencing the same information multiple times



# BrainMap Indexing

- **Content Descriptors**
  - "Coordinates: centre of activity"
  - "Volume of activation"
  - "Percentage signal change"
  - "Published statistical parameter: t-score,"
  - "r-value, z-score and so on"
  - "Standardized statistical parameter: z-score"
  - "Significance level"
  - "Standard anatomical descriptor: Talairach"
  - "Daemon labels"
  - "Functional area terms: V1, V2, area MT/V5,"
  - "supplementary motor area and so on"

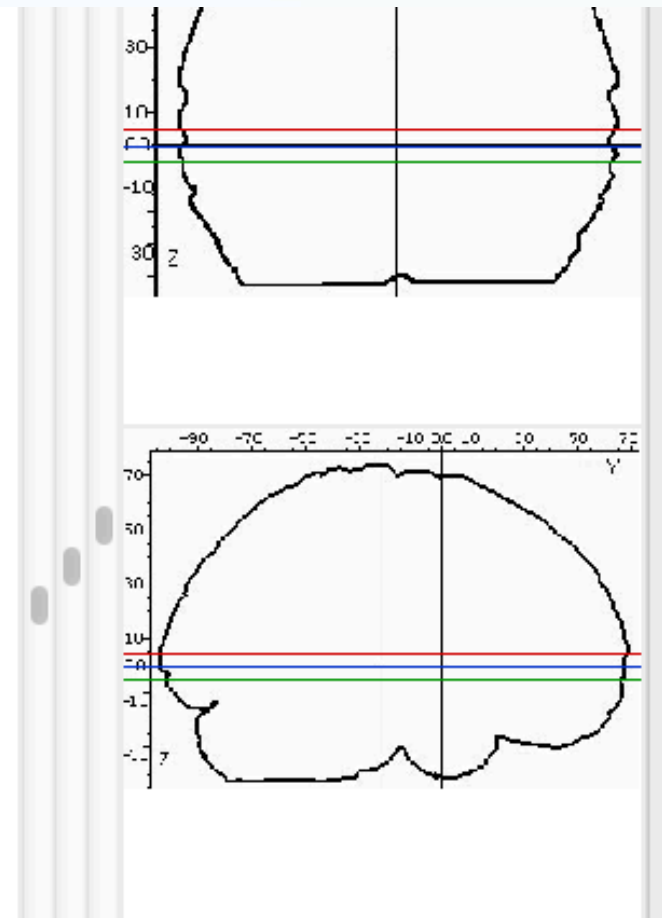
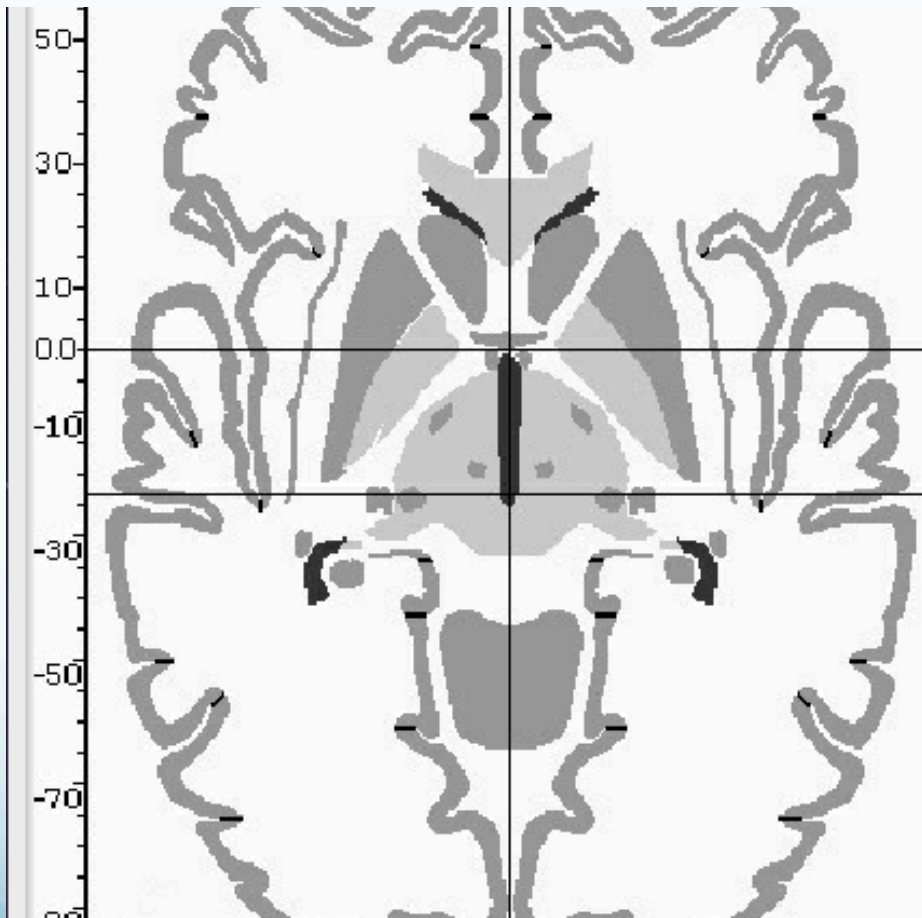


# BrainMap Indexing

- **Context Descriptors**
  - Intent: normative mapping, ageing,
  - development, disease effects and so on
  - Subjects: number, gender, handedness, diseases and so on
  - Behavioural domain: perception, action, cognition, emotion and so on
  - Experimental conditions and contrasts
  - Acquisition modality and methods
  - Analysis software and methods



# BrainMap Sleuth



# Lessons Learned

- The more detailed indexing, the more accuracy in retrieval
- The map can help to cluster and group information based on its relevance to specific functionalities and locations.
- Need more analysis and self-organization?

# Neurolex.org



THE NEUROSCIENCE LEXICON POWERED BY THE NEUROSCIENCE INFORMATION FRAMEWORK

Search this wiki

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- FAQS
- NIFSTD ONTOLOGIES
- HOW TO CONTRIBUTE
- CURATION POLICIES
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- REGISTER A RESOURCE
- REPORT A BUG

Neurons Brain Regions

Main Page

Page Discussion

History More

## Welcome to NeuroLex, the Neuroscience Lexicon.

A dynamic lexicon of 32,943 neuroscience terms, including 747 neurons and 1281 parts of the nervous system supported by The Neuroscience Information Framework and the International Neuroinformatics Coordinating Facility

About • Help • What's new • FAQs • NIFSTD ontologies • How to Contribute • Curation policies • [Subscribe to Neurolex mailing list](#)

Find a Term!

Show me a Random Term!

All Categories A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Enter text into box to create your new page.

<input type="text"/>	Create a new cell
<input type="text"/>	Create a new brain region
<input type="text"/>	Create a new resource
<input type="text"/>	Create a new generic

### HIERARCHIES


- Behavioral Activity
- Behavioral Paradigms
- Brain Regions
- Cells
- Neurons
- Diseases
- Imaging protocols
- Molecules
- Nervous System Function
- Subcellular Parts
- Resource Types
- Qualities

### TABLES

- Behavioral Activity
- Behavioral Paradigms
- Brain Regions
- Overlapping Brain Regions
- Brain parcels
- Cell Types
- Diseases
- Molecules
- Nervous System Function
- Neurons
- Neurons by Neurotransmitter
- Organisms
- Resources and Information Entities
- Subcellular Parts
- Techniques
- Qualities
- Tissue banks



# Cognitive Atlas



**cognitive atlas**

a collaborative knowledge base characterizing the state of current thought in Cognitive Science.

**CONCEPTS / 695**   **TASKS / 511**   **DISORDERS / 214**   **COLLECTIONS / 20**   **ABOUT**   **BLOG**

## Welcome to Cognitive Atlas

The Cognitive Atlas is a collaborative knowledge building project that aims to develop a knowledge base (or ontology) that characterizes the state of current thought in cognitive science. The project is led by Russell Poldrack, Professor of Psychology and Neurobiology at the University of Texas at Austin in collaboration with the UCLA Center for Computational Biology (A. Toga, PI) and UCLA Consortium for Neuropsychiatric Phenomics (B. Bilder, PI). It is supported by grant R01MH082705 from the National

### Sign In

Registered users may edit and contribute to the Cognitive Atlas

Keep me logged in



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# BBC: Human Body & Mind

Nature | Wildlife Finder | Science | Prehistoric Life | **Human Body & Mind** | Space

You are here: [BBC Science](#) > [Human Body & Mind](#) > [The Body](#) > [Organs](#)

## Human Brain Map

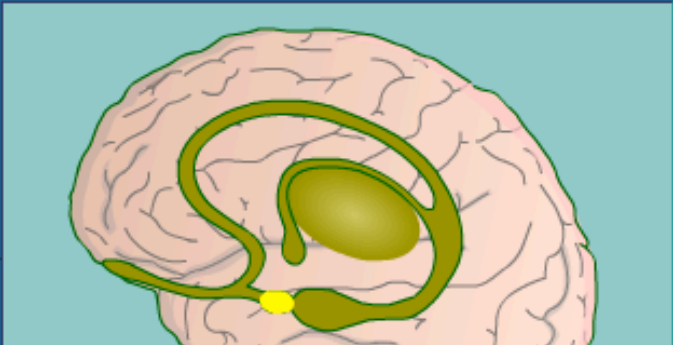
**In Human Body & Mind:**

- The mind
- The body
- Organs**
- Muscles
- Skeleton
- Nervous system
- Puberty
- Brain Sex
- Sleep

**Anger**

Your amygdala (shown in yellow) is responsible for generating negative emotions such as anger, sadness, fear and disgust.

Working on non-emotional mental tasks inhibits the amygdala, which is why keeping yourself busy can take your mind off feeling angry.



Human Brain Map features:

- Anger
- Breathing
- Consciousness
- Coordination
- Disgust
- Fight or flight
- Happiness
- Hearing
- Language understanding
- Long-term episodic memory
- Movement
- Sadness
- Self awareness
- Self control
- Smell
- Speech production
- Taste
- Thirst and hunger
- Touch
- Vision

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# Mapping functions to areas of the Brain

Nature Wildlife Finder Science Prehistoric Life **Human Body & Mind** Space

You are here: [BBC Science](#) > [Human Body & Mind](#) > [The Body](#) > [Organs](#)


## Human Brain Map

Anger	Breathing
Consciousness	Coordination
Disgust	Fight or flight
Happiness	Hearing
● Language understanding	Long-term episodic memory
Movement	Sadness
Self awareness	Self control
Smell	Speech production
Taste	Thirst and hunger
Touch	Vision

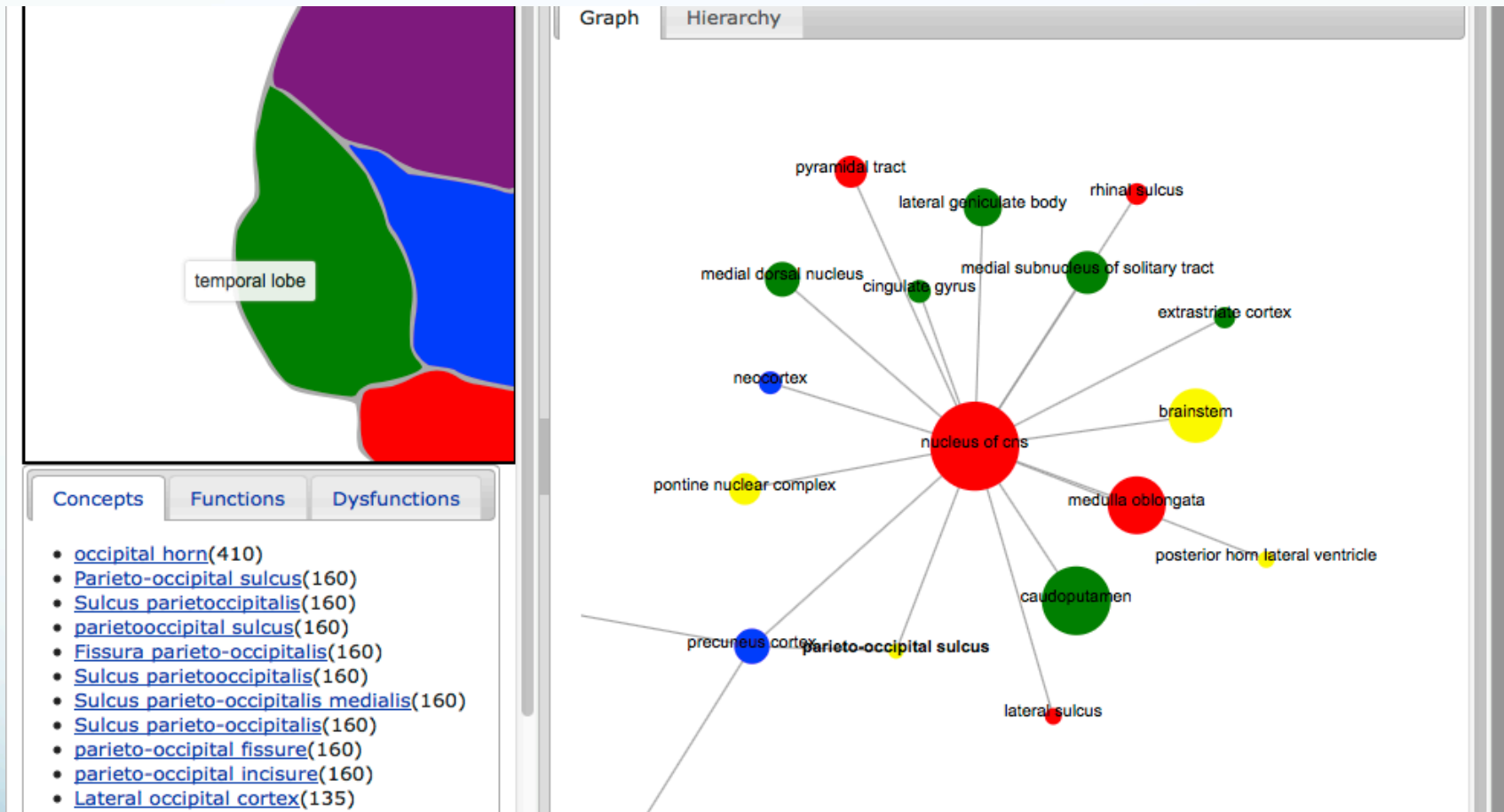
### Language understanding

Wernicke's area (shown in yellow) is located in the temporal lobe near the parietal lobe. It is essential for understanding language.

People who suffer brain damage to this area can't understand what is being said to them and are unable to put together meaningful sentences. They can speak fluently with correct grammar, but what they say is likely to be nonsense.



# Neuroscience Literature Retrieval



# How libraries organize information

## Indexing + Classification

### Dewey Classification System:

#### The Ten Main Classes

- 000 Computer science, information & general works
- 100 Philosophy & psychology
- 200 Religion
- 300 Social sciences
- 400 Language
- 500 Science
- 600 Technology
- 700 Arts & recreation
- 800 Literature
- 900 History & geography

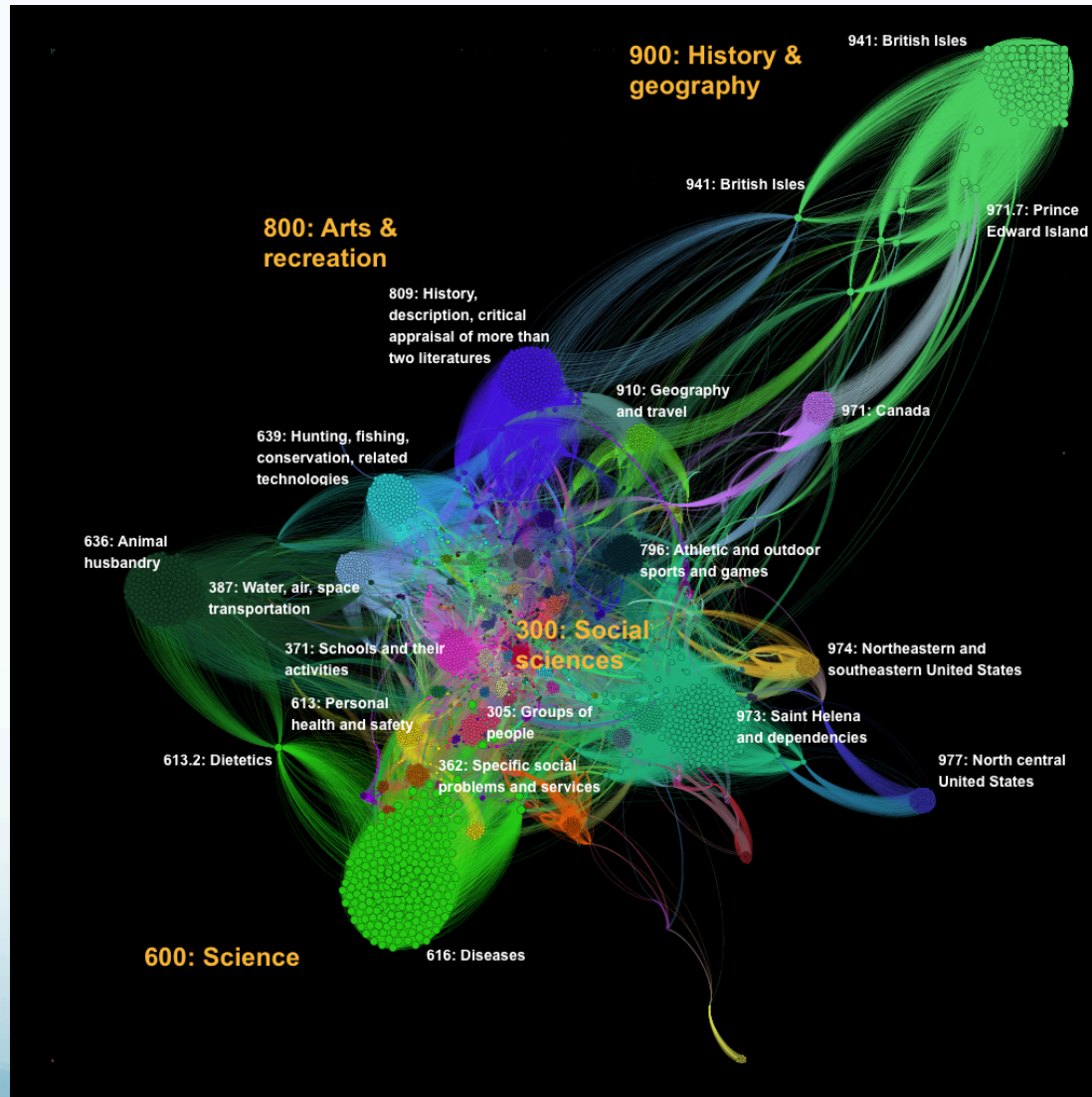
#### Second Summary

#### The Hundred Divisions

000 Computer science, knowledge & systems  
010 Bibliographies  
020 Library & information sciences  
030 Encyclopedias & books of facts  
040 [Unassigned]  
050 Magazines, journals & serials  
060 Associations, organizations & museums  
070 News media, journalism & publishing  
080 Quotations

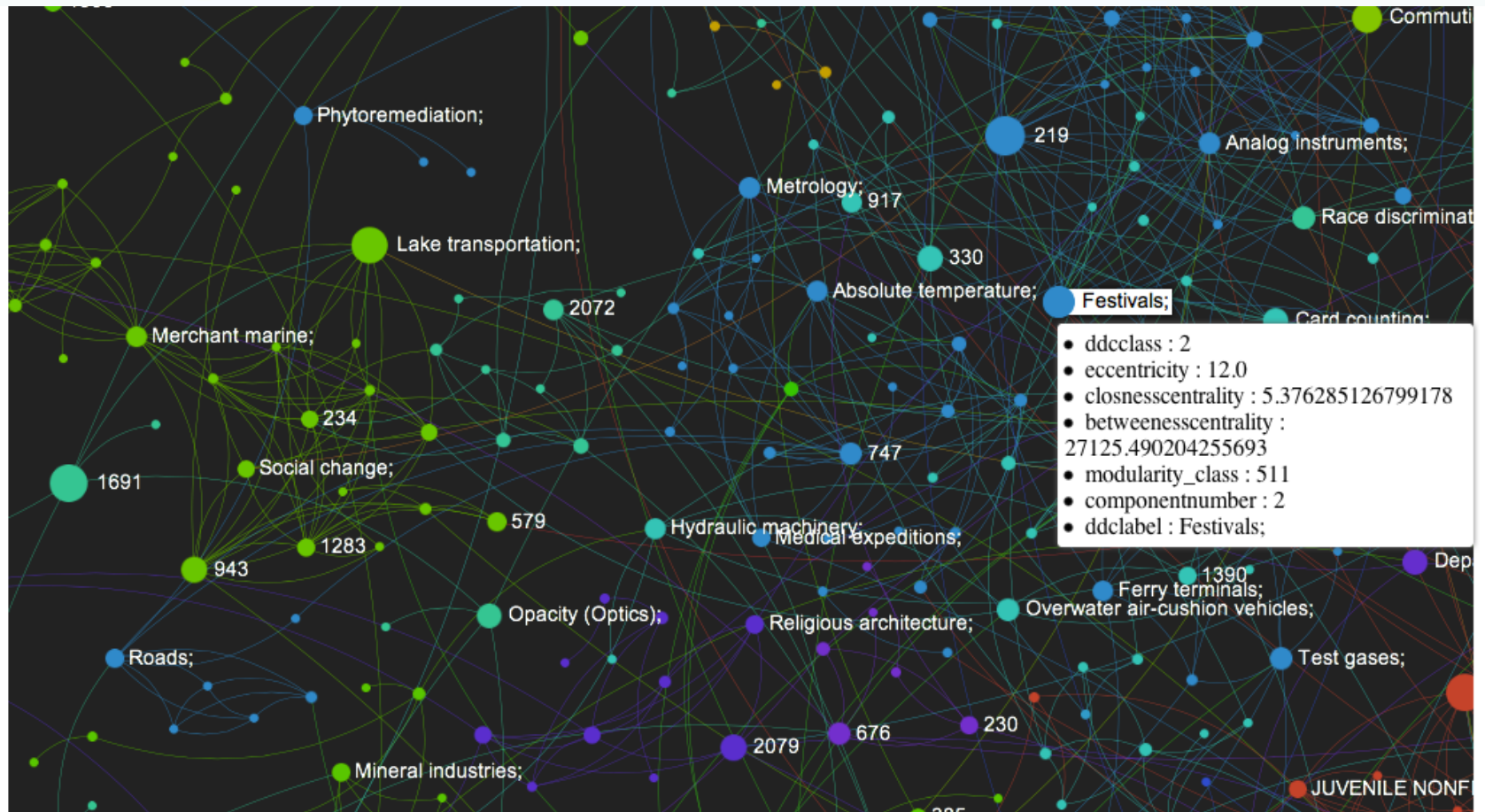
500 Science  
510 Mathematics  
520 Astronomy  
530 Physics  
540 Chemistry  
550 Earth sciences & geology  
560 Fossils & prehistoric life  
570 Life sciences; biology  
580 Plants (Botany)

# Classification + self-organization





# Zoom-in and Interaction



# Another Example

How should the concept “brain” be represented?



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# A Classification View

## MeSH Tree Structures

[Nervous System \[A08\]](#)

[Central Nervous System \[A08.186\]](#)

▶ [Brain \[A08.186.211\]](#)

[Blood-Brain Barrier \[A08.186.211.035\]](#)

[Brain Stem \[A08.186.211.132\]](#) +

[Cerebellum \[A08.186.211.212\]](#)

[Cerebral Ventricles \[A08.186.211.276\]](#) +

[Limbic System \[A08.186.211.577\]](#) +

[Prosencephalon \[A08.186.211.730\]](#) +

[Meninges \[A08.186.566\]](#) +

[Neural Analyzers \[A08.186.667\]](#)

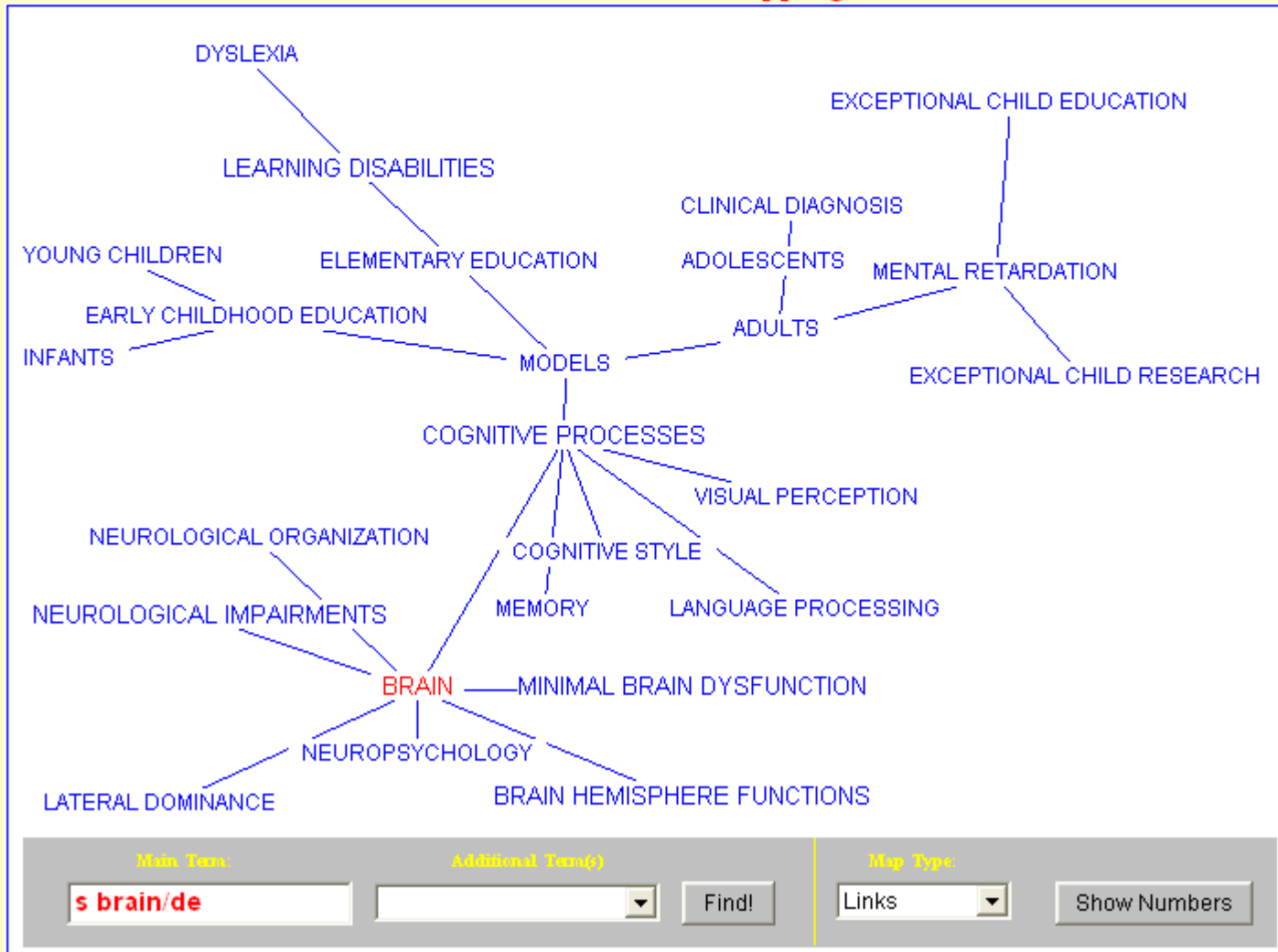
[Spinal Cord \[A08.186.854\]](#) +





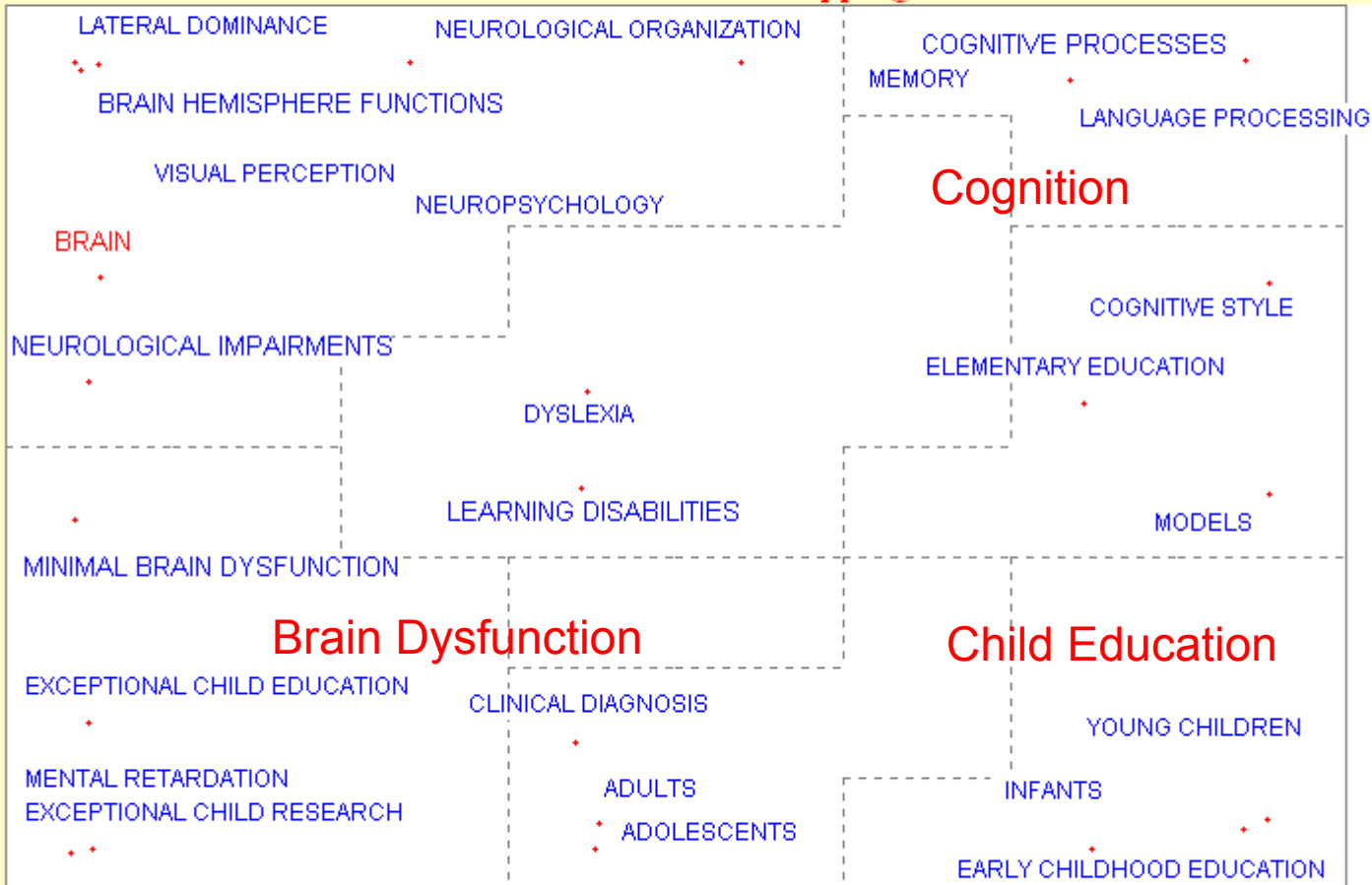
# A Dynamic View

## Instant Literature Mapping

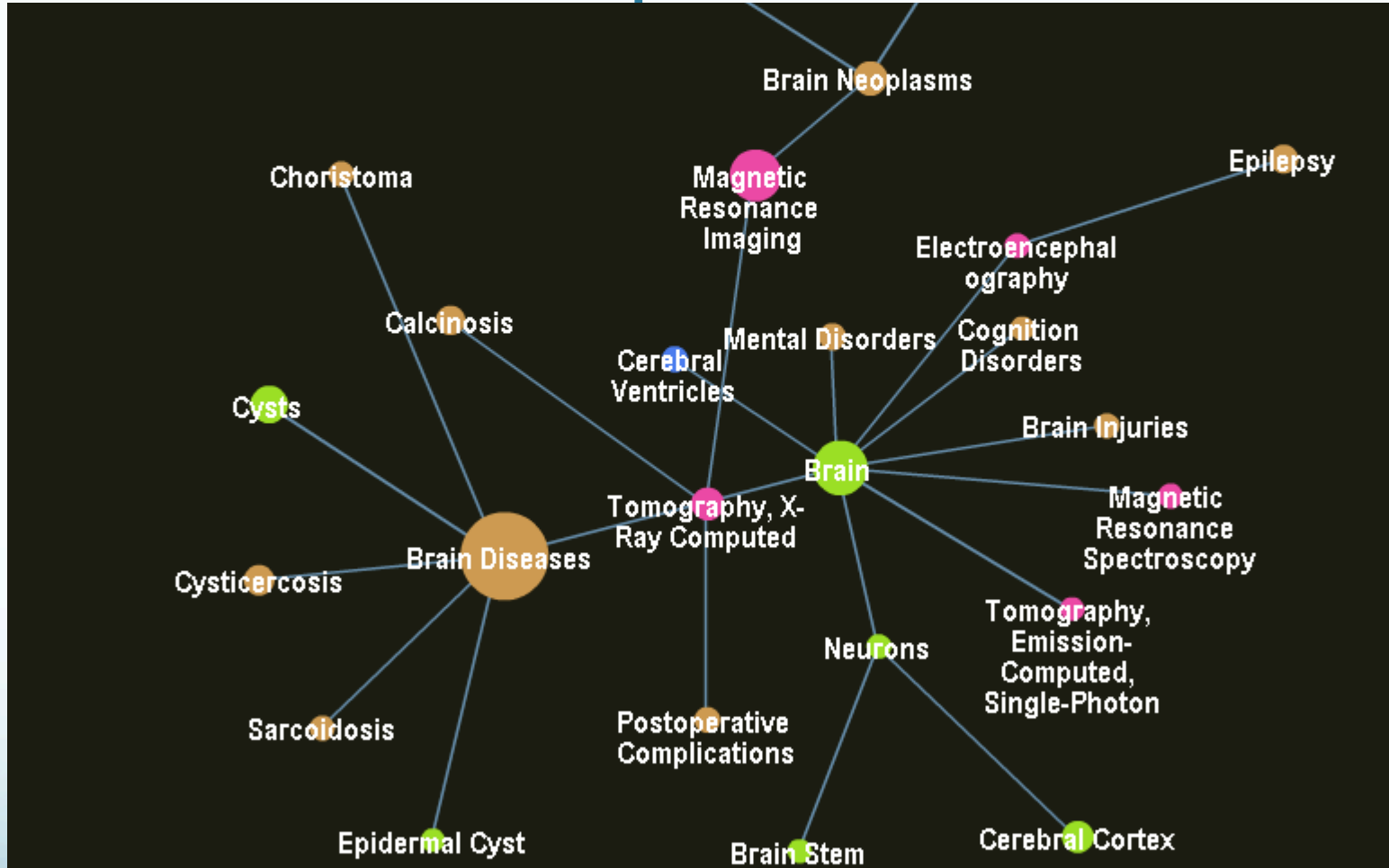


# A Self-Organizing View

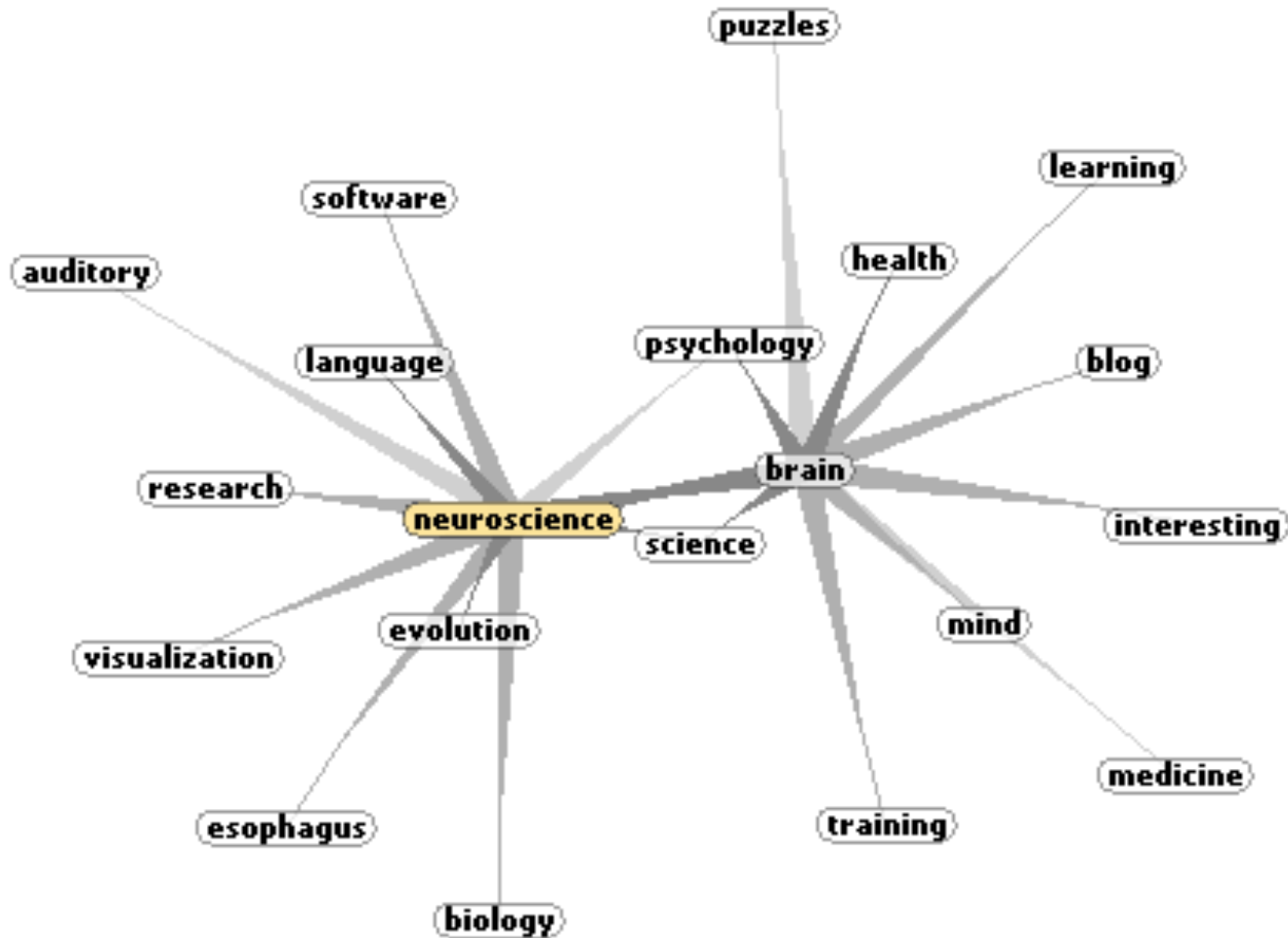
## Instant Literature Mapping



# A “Brain” Map based on ...



# A Social Classification View



# Conclusions

- There is so much we should learn from the brain for
  - indexing, clustering, and classifying
  - mapping and organizing knowledge based on locations and regions
  - using self-organizing maps to represent concepts dynamically
  - enhancing associative retrieval and recollection.

**Panel COGNITIVE 2014**

# **Cognitive Mechanisms and Machine Brain Interaction**

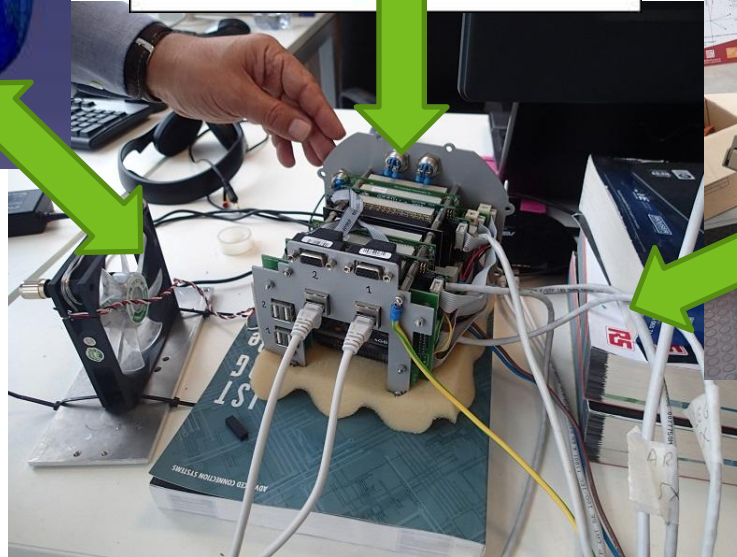
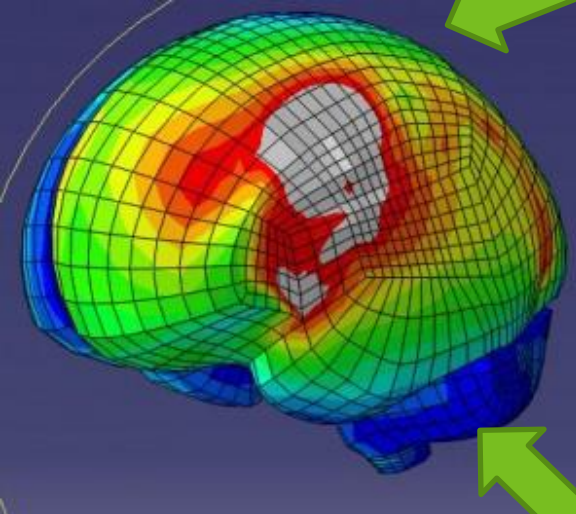
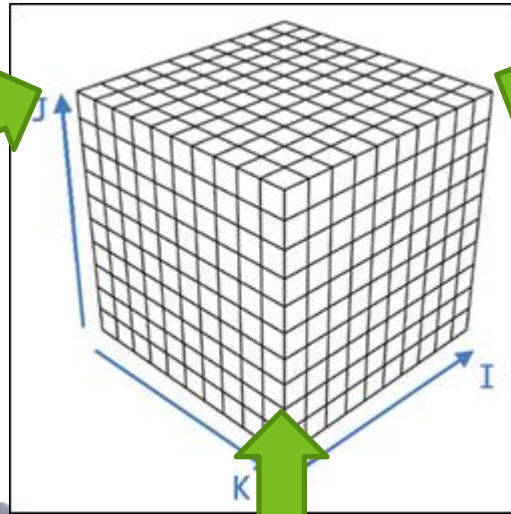
**-volume brain –volume world, adjectives, irrationality and 3D glasses**

**Dr. Charlotte Sennersten**

[www.csiro.au](http://www.csiro.au)



# The volumetric world



# The volumetric brain

# Action in volume

Computational brain\_ volumetric and dynamic comprehension

**Is human memory representing past events as 2D representation(s) in the brain?  
Is human memory representing future events as 3D representation(s) in the brain?  
Does it matter?**



## Cognitive Mechanisms

[Explanations](#) > [Behaviors](#) > [Coping](#) > Cognitive Mechanisms  
[Description](#) | [Example](#) | [Discussion](#) | [So what?](#)

We cope with difficulties in various ways. Some are more positive than others. Here are various mental mechanisms that help us cope.

[Aim Inhibition](#): lowering sights to what seems more achievable.

[Altruism](#): Helping others to help self.

[Avoidance](#): mentally or physically avoiding something that causes distress.

[Compartmentalization](#): separating conflicting thoughts into separated compartments.

[Conversion](#): subconscious conversion of stress into physical symptoms.

[Denial](#): refusing to acknowledge that an event has occurred.

[Displacement](#): shifting of intended action to a safer target.

[Dissociation](#): separating oneself from parts of your life.

**[Fantasy](#): escaping reality into a world of possibility.**

[http://changingminds.org/explanations/behaviors/coping/cognitive\\_mechanisms.htm](http://changingminds.org/explanations/behaviors/coping/cognitive_mechanisms.htm)

# Rationality versus irrationality in system interaction, do we design for this?

ir•ra•tion•al•i•ty (ɪ, ræf ə 'næl ɪ ti)

*n., pl. -ties.*

1. the quality or condition of being irrational.
2. an irrational action, thought, etc.

<http://www.thefreedictionary.com/irrationality>

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How to take FIVE YEARS off your  
Now One Direction faces race storm:  
'Pings' were not from missing  
George Michael rushed to hospital  
Billionaire Manchester United  
Rory McIlroy 'broke up with Caroline  
Food WEB

## The smallest spectacles in the world: Scientists craft 3D glasses for a PRAYING MANTIS to better understand sight

- The specs measure just five millimetres wide and are attached with beeswax to the insects
- Scientists from Newcastle University created the tiny glasses to investigate the 3D vision of the praying mantis
- Insects will be shown 3D films of flies to see if they strike at them accurately, hinting they have similar sight to humans

Site Web Search

Hai bisogno di nuovi pneumatici?



SELEZIONA LA MARCA DELLA TUA AUTO

- |              |            |
|--------------|------------|
| ▶ ALFA ROMEO | ▶ FIAT     |
| ▶ AUDI       | ▶ MERCEDES |
| ▶ BMW        | ▶ PEUGEOT  |
| ▶ CITROEN    | ▶ ALTRO    |

Specs appeal: British scientists have made the world's smallest pair of 3D glasses (pictured) for praying mantises to wear



<http://www.dailymail.co.uk/sciencetech/article-2612169/The-praying-mantis-specs-appeal-Scientists-craft-worlds-smallest-pair-3D-glasses-carnivorous-insects.html>

# Can Human Cognition Benefit from Machine Cognition?

Hans M. Dietz

[dietz@upb.de](mailto:dietz@upb.de)

University of Paderborn  
Institute of Mathematics

May 29, 2014  
IARIA Cognitive 2014 –  
Panel Discussion

## Several layers of the question:

- Can the "*cognition of the human society*" benefit from artificial cognition?
  - ▷ Certainly YES
  - ▷ ANY RISKS???
- Can (*individual*) *human cognition + AI* together perform better?
  - ▷ Certainly YES
  - ▷ ANY RISKS???
- Can (*individual*) *human cognition (alone)* benefit from machine cognition?
  - ▷ ???

Recall: Starting point of my talk about "CAT"\* this morning:

(\* "CAT - a Semiformal Concept-building Procedure for Teaching Mathematics")

Cognitive sciences	Teaching:
understand, model (!), replicate**, ...	understand, model (?), support, ...
... human's cognitive activities	

\*\* e.g. by AI, "thinking machines"

Open questions in teaching:

- (A) support error avoidance
- (B) support of abstraction
- (C) ...

Today: Focus on error avoidance.

*Recall: CAT supports "reading maths"*

- from processing symbols, signs and words
- up to a valid mental concept

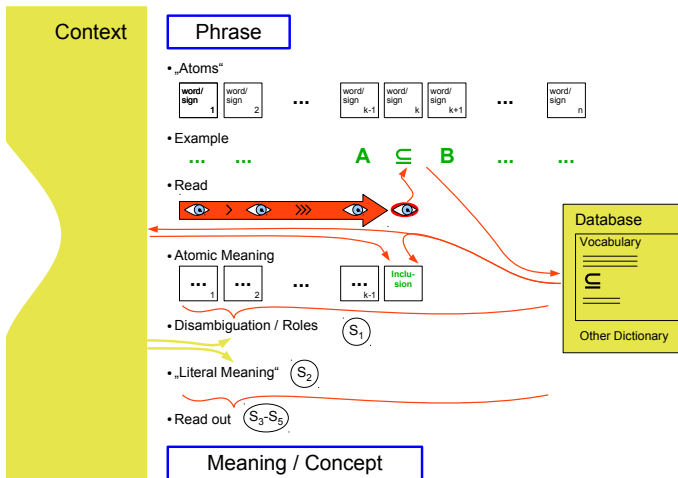
**Example:** Consider the following piece of text:

*Let  $A$  denote an arbitrary set and*

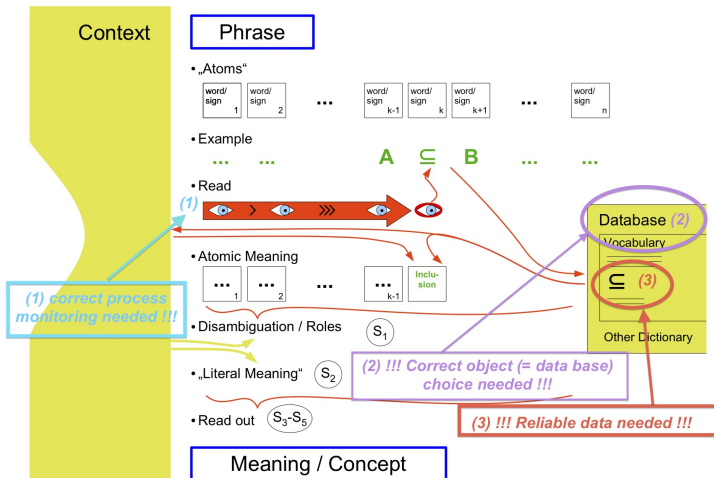
$$H := \{ A \mid A \subseteq B \} \dots$$



Recall: CAT's reading procedure:



## CAT's correctness requirements:



*A correct translation result is "guaranteed", given correct ...*

- ... metacognitive process (level) organization
- ... object classification and choice
- ... data memorization
- ... ...

*Neither of these is guaranteed in human cognition!*

## Some error examples:

(from interviews conducted by J. Rohde under the author's supervision)

### Task example 1:

(Fictious) **Definition:** A natural number is called "nice", if the series of its digits contains a "2", or if it contains the factor "2". **The task:**

Decide whether the following statement is true (W) or false (F). (Mark the correct answer with a cross and provide a written justification of your choice.)

- ii) 13794 is nice.
- iii) 0 is nice.
- iv) A natural number is nice, if exactly two of its digits are equal to "2".

### Example answers (wrong!) :

- (ii) is wrong, as "there is no 2 in the digits", as "a number is nice, if its digits contain a 2" (*neglects 2nd part of the definition*)
- (iii) "0 can be divided by two and thus, 0 is nice" (*neglects context: 0 is not a natural number.*)

**Task example 2:** Let  $A$  and  $B$  be given non-empty subsets of  $\mathbb{R}$ .  
Exemplify

$$A + B := \{ a + b \mid a \in A \wedge b \in B \}.$$

**"Solution"** (wrong):

The image shows handwritten mathematical work on a chalkboard. At the top right, two small circles represent sets  $A$  and  $B$ . Set  $A$  contains an element  $a$ , and set  $B$  contains an element  $b$ . Below this, a large Venn diagram shows two overlapping circles, also labeled  $A$  and  $B$ , with vertical lines drawn inside them. To the left of the Venn diagram, the following equations are written:

$$a = 2k \subseteq A$$
$$b = 2k + 1 \subseteq B$$
$$A \oplus B = a + b$$

Two arrows point from the expression  $A \oplus B = a + b$  to the result  $\Rightarrow 2k + (2k + 1)$ . A red arrow points from the top of the page down to the first equation. A blue arrow points from the left side of the equation to the result, and a pink arrow points from the left side of the equation to the result.

*OBSERVATION:* High complexity of error structures!  
*QUESTION:* How to construct error avoidance strategies?  
*HYPOTHESIS:* Much can be gained by ...

- ... making thinking processes transparent to the thinking persons
- ... supporting memorization of indispensable basics

## *CAT's transparency advice: Use*

- checklists to monitor regular working steps
- conscious knowledge management
- "toolboxes" to support problem solving
- ...



*CAT's memorization advice: Develop a basic vocabulary*

*Example entry for "set inclusion":*

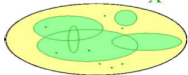
Vocabulary:	
key word:	$\subseteq$
definition:	$A \subseteq B :\Leftrightarrow (x \in A \Rightarrow x \in B)$
	syntax: $A, B$ sets
description:	set inclusion symbol
"read out"	" $A$ is a subset of $B$ "

*(black parts: recommended categories)*

*(blue parts: to be inserted in by the students)*

## CAT's concept advice: Extend the vocabulary entry to a concept base

Example entry for "power set":

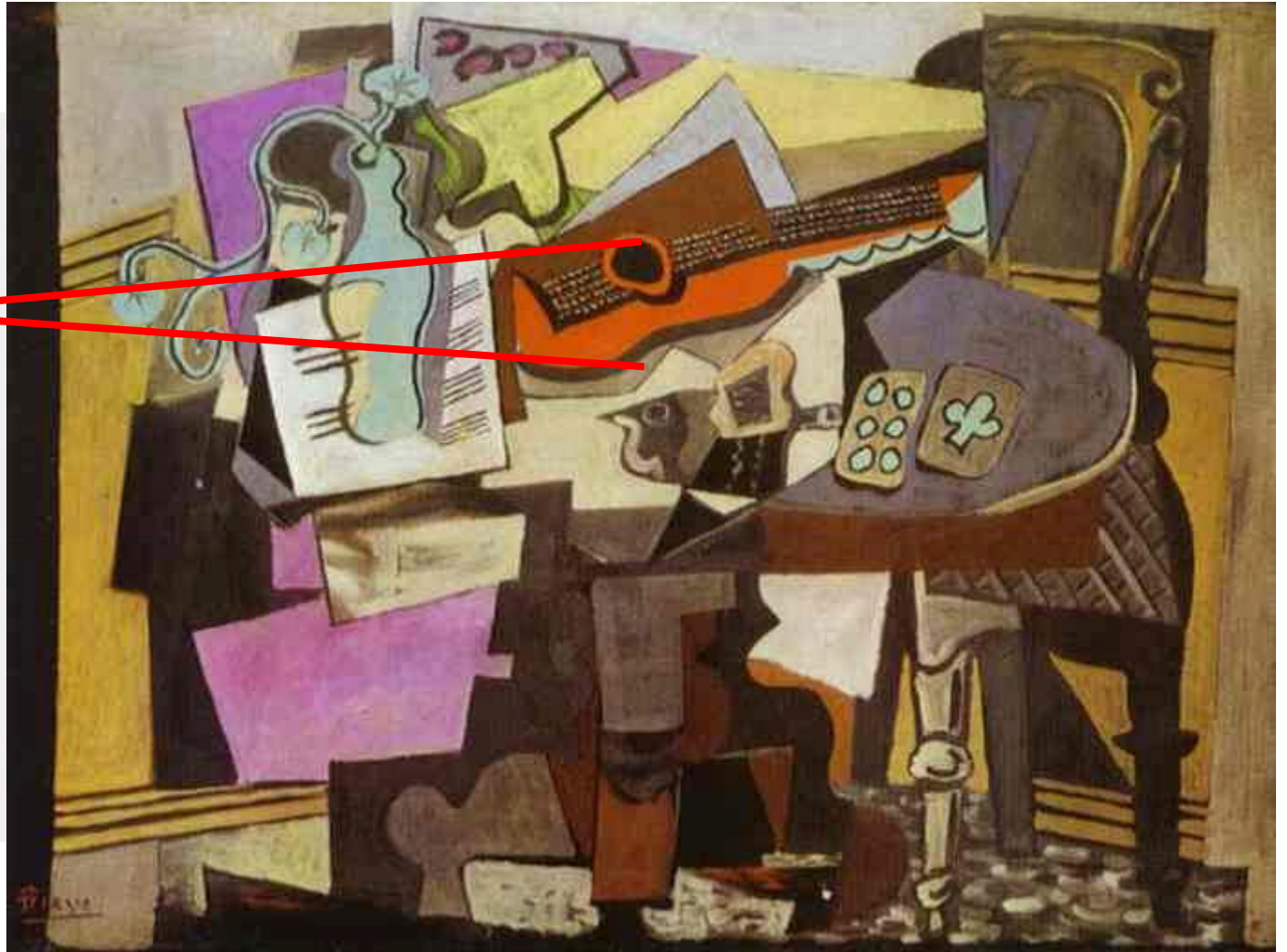
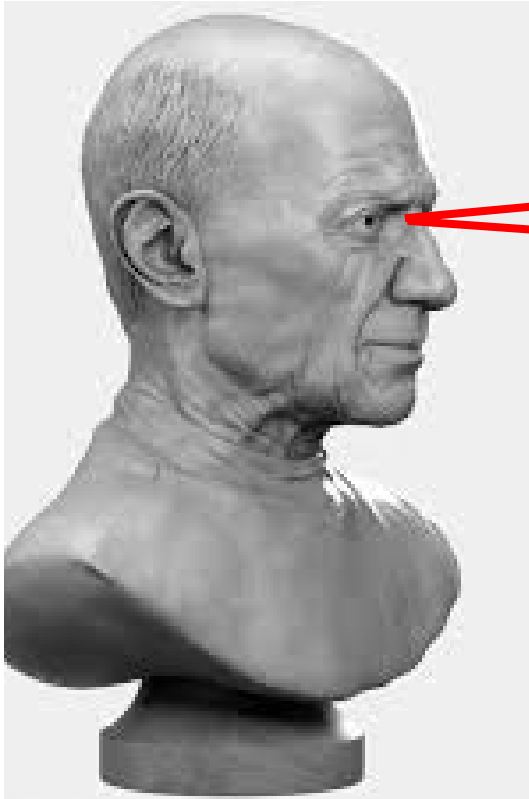
<b>Vocabulary:</b>	
...	
<b>Extensions:</b>	
<b>examples:</b>	$\mathcal{P}(\emptyset) := \{\emptyset\}, \mathcal{P}(\{1\}) := \{\emptyset, \{1\}\},$ $\mathcal{P}(\{1, 2\}) := \{\emptyset, \{1\}, \{2\}, \{1, 2\}\}, \dots$
"non-examples":	<b>Attention:</b> $\mathcal{P}(\emptyset) \neq \emptyset$
<b>visualisation:</b>	$\mathcal{P}(M)$ is the set of <i>all</i> possible $A$ like this:  M
<b>important statements:</b> (conjectured)	(a) <i>If <math>M</math> is a finite set with <math>n</math> elements then <math>\mathcal{P}(M)</math> has <math>2^n</math> elements</i> (b) $A \subseteq B \Rightarrow \mathcal{P}(A) \subseteq \mathcal{P}(B)$ ...
<b>applications:</b>	(to follow later in the course)

recommended categories | content to be provided by the students

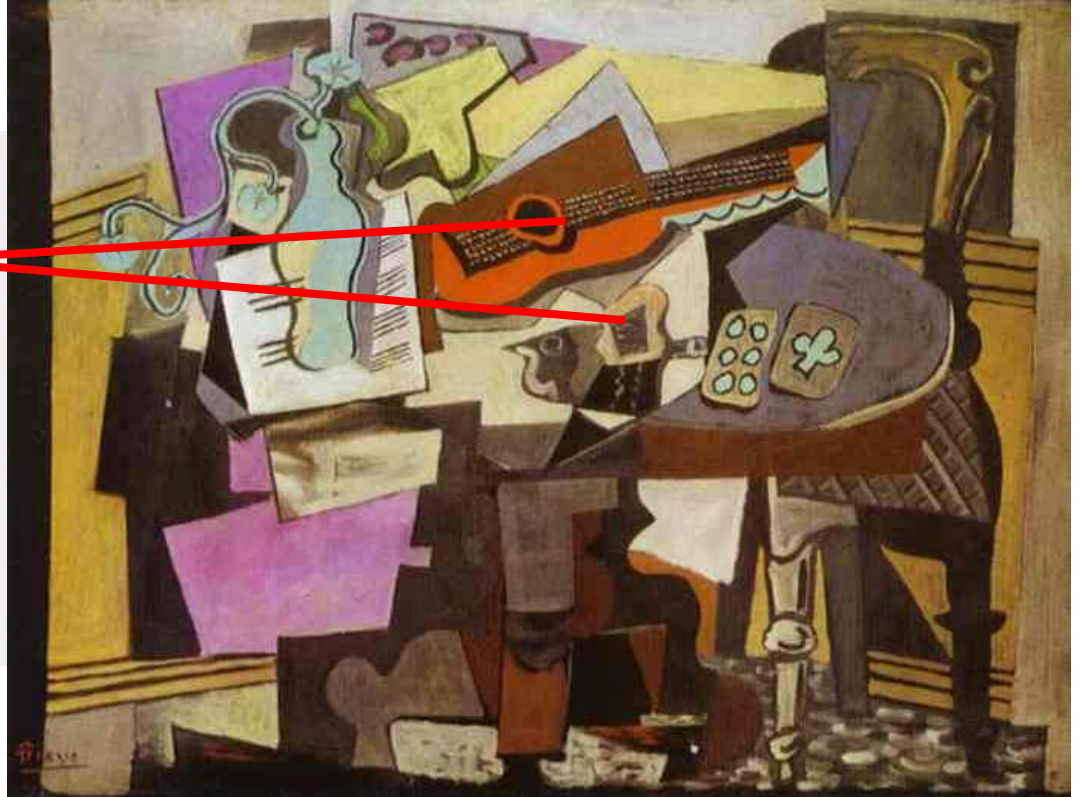
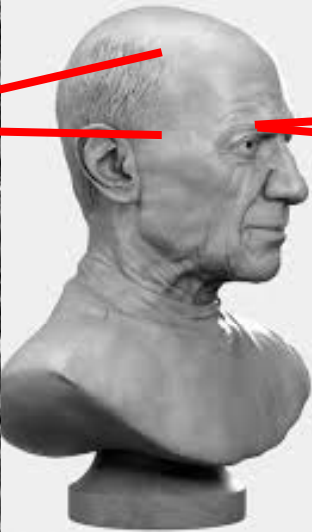
## References

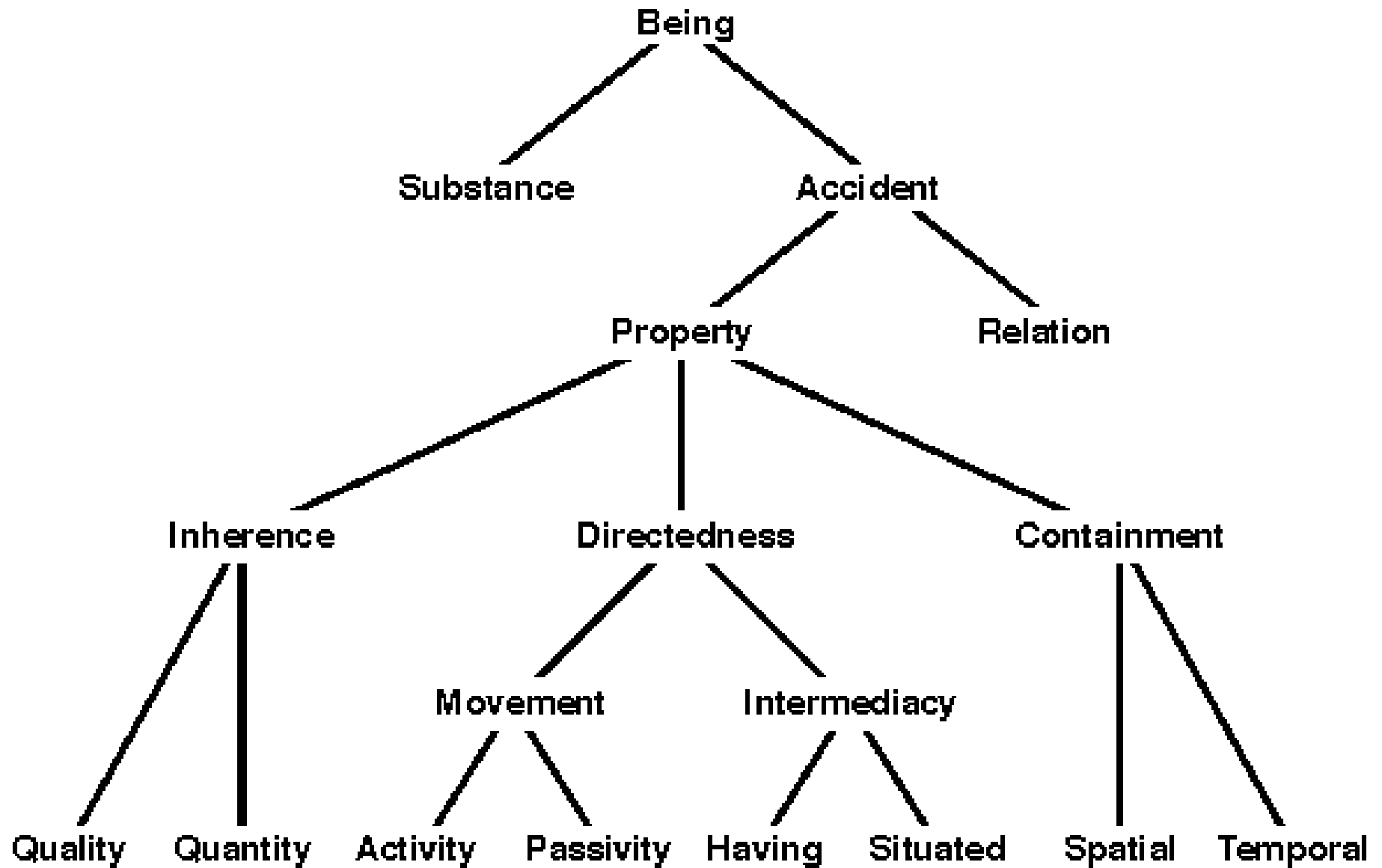
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- Tall, D. and Vinner, S.: *Concept Image and Concept Definition in Mathematics with Particular Reference to Limits and Continuity*. Educational Studies in Mathematics 12 (1981) 151-169.











Aristotle's Categories

<http://www.jfsowa.com/ontology/ontoshar.htm>



# Ontology (1)

“the philosophical study of the nature of being, becoming, existence, or reality, as well as the basic categories of being and their relations. “

- "What can be said to exist?"
- "Into what categories, if any, can we sort existing things?"
- "What are the meanings of being?"
- "What are the various modes of being of entities?"

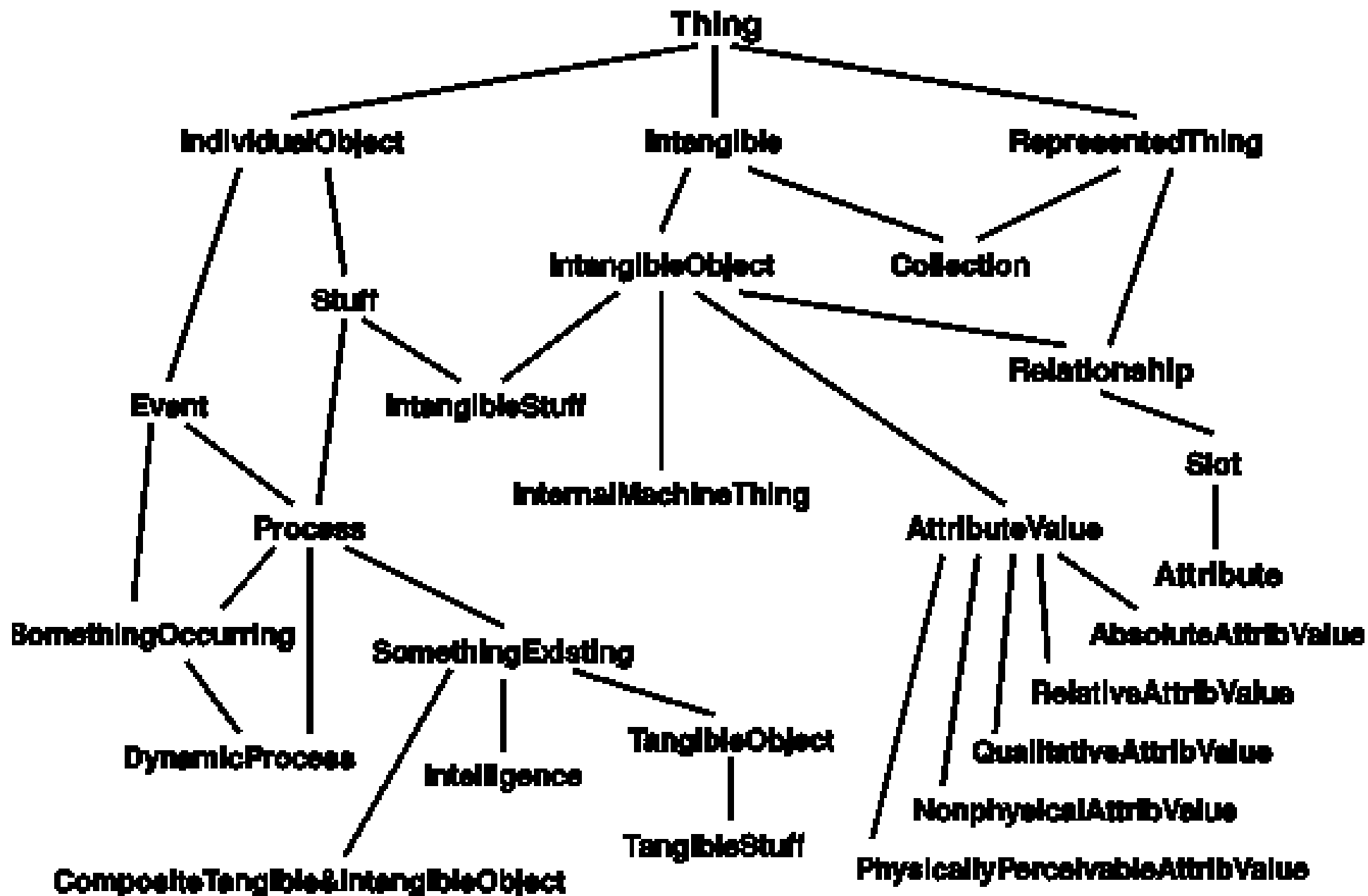
Wikipedia definition

<http://en.wikipedia.org/wiki/Ontology>

# Ontology (2)

“explicit specification of a conceptualization.” - Gruber

- |   |  |
|---|--|
| <ul style="list-style-type: none"><li>• <b>Individuals</b></li><li>• <b>Attributes</b></li><li>• <b>Relations</b></li><li>• <b>Function Terms</b></li></ul> | <ul style="list-style-type: none"><li>• <b>Restrictions</b></li><li>• <b>Rules</b></li><li>• <b>Axioms</b></li><li>• <b>Events</b></li><li>• ...</li></ul> |
|---|--|



Cyc Ontology top level categories  
<http://www.jfsowa.com/ontology/ontoshar.htm>

(S),  
 Hobart

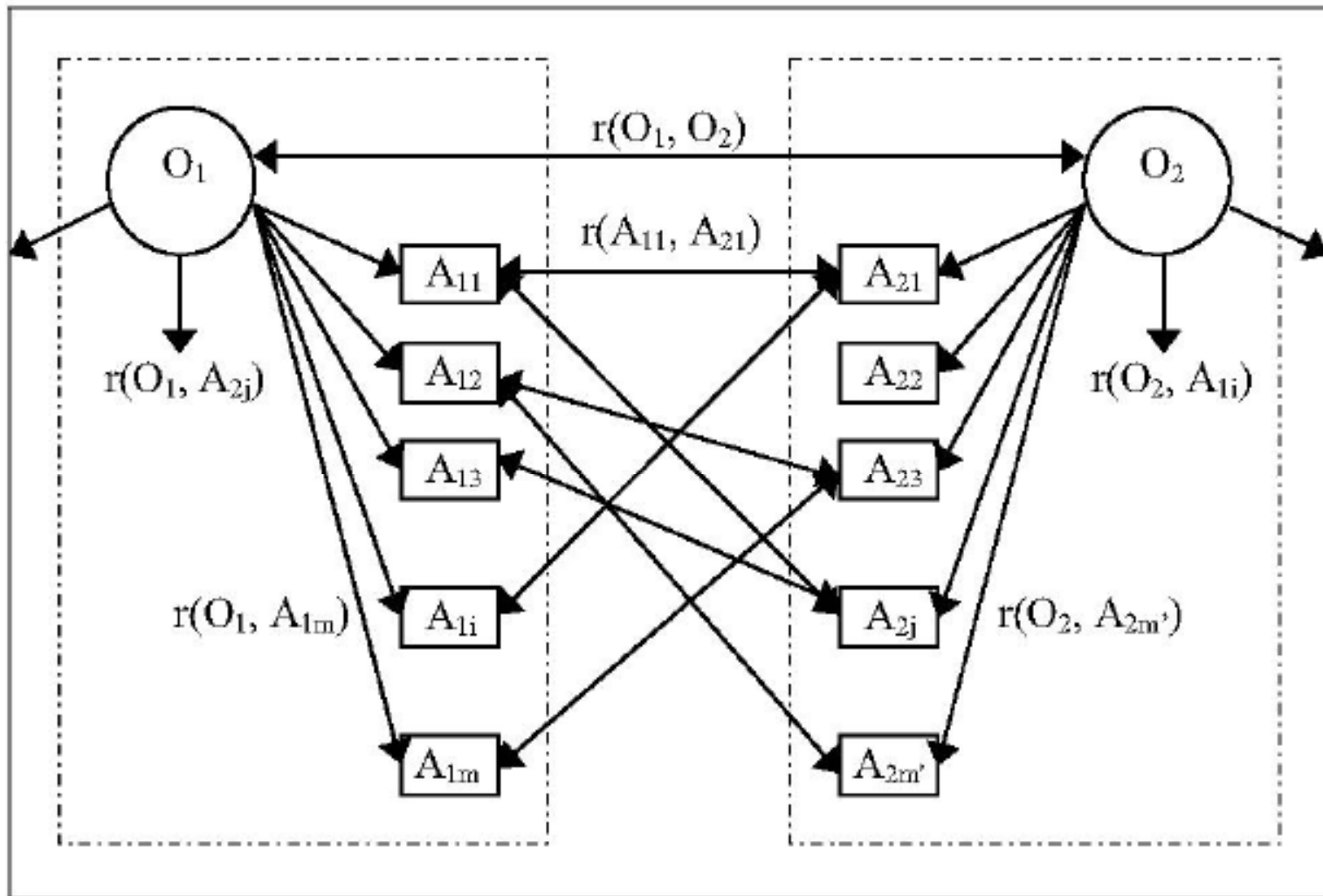
# Relation between ontological representation and a cognitive model

OAR Model	Ontology Components
Object(s) Attribute(s) Relation(s)	Class Properties Relationship(s)

OAR Model of Neural Informatics for Knowledge Representation in the Brain, Wang 2007

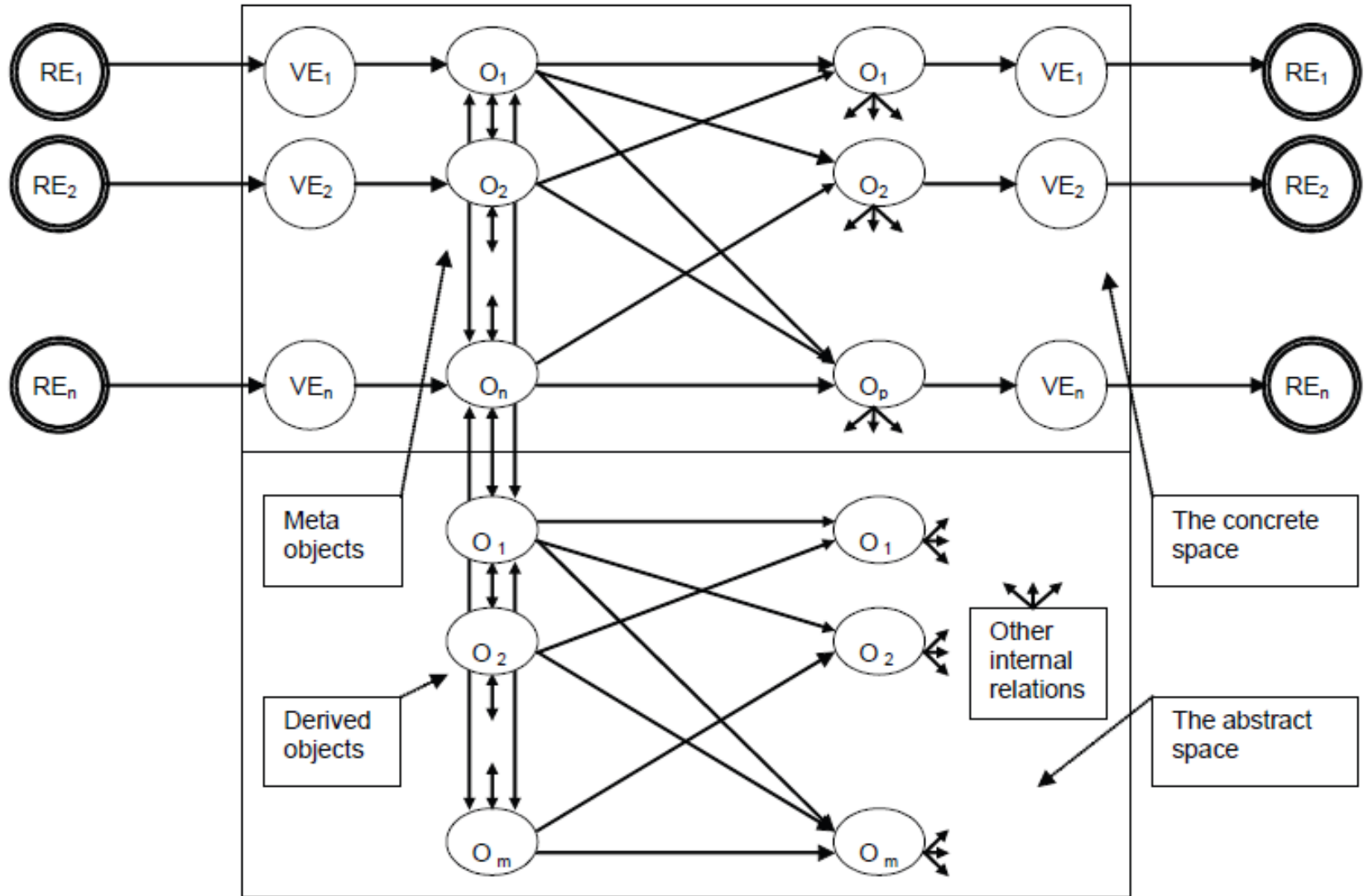
<http://enel.ucalgary.ca/ICINI/ICfCI/ICINI-1305-OAR-Wang.pdf>

# Objects, Attributes, and Relations (OAR)



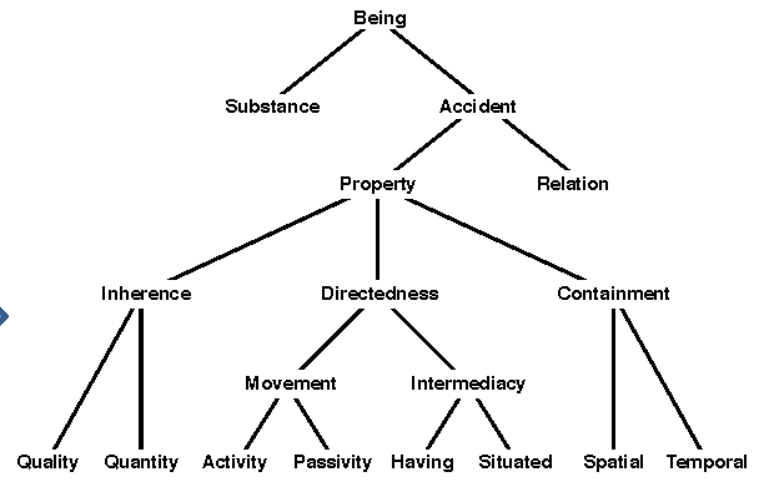
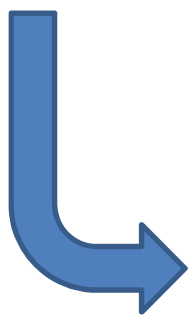
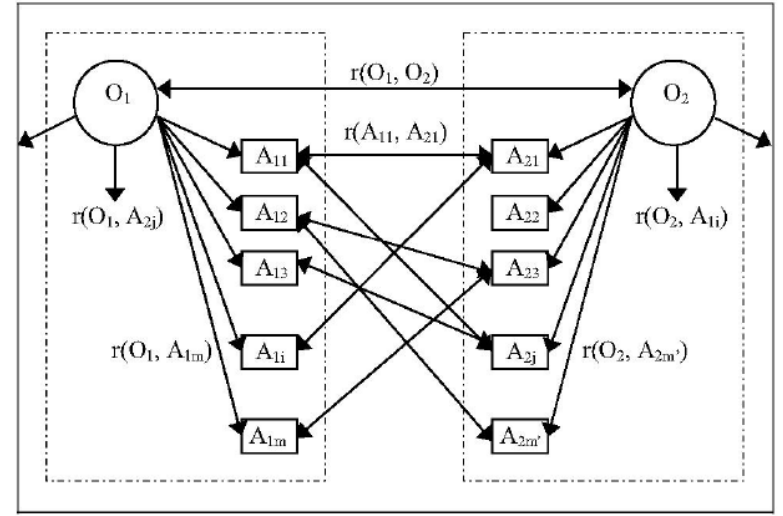
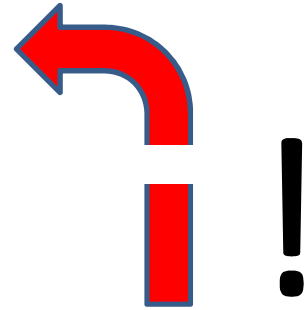
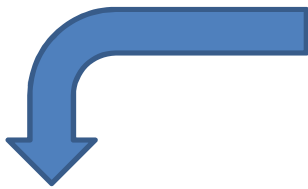
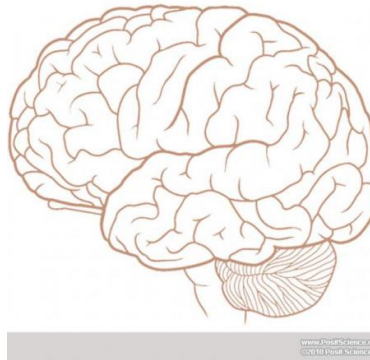
OAR Model of Neural Informatics for Knowledge Rep. in the Brain, Wang 2007  
<http://enel.ucalgary.ca/IJCINI/ICfCI/IJCINI-1305-OAR-Wang.pdf>

The external world	The internal world				The external world
Real Entities	The Image Layer	The Abstract Layer		The Image Layer	Real Entities
	Virtual Entities	Os/As	Relations	Os/As	



OAR Model of Neural Informatics for Knowledge Rep. in the Brain, Wang 2007  
<http://enel.ucalgary.ca/IJCINI/ICfCI/IJCINI-1305-OAR-Wang.pdf>

1. Ontologies (1) formulated to understand the physical world
2. Information systems ontologies (2) designed to model human perception of the world
3. Information systems ontologies used as a basis for modelling human cognition (OAR)
4. Human cognition is therefore (falsely?) summed to be the total of ontological relations!!





# discussion

- Is LTM (thus, OAR) classification of cognition sufficient?
- Does viewing cognition through the lens of current models limit out ability to understand the actual operation of ‘thinking’?
- **NDR’s Problem**