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Where do semantic domains come from?

The enigma

William James 1980: "The baby, assailed by eyes, ears, nose, skin, and entrails at once, feels it all as one great blooming, buzzing confusion; and to the very end of life, our location of all things in one space is due to the fact that the original extents or bignesses of all the sensations which came to our notice at once, coalesced together into one and the same space"

How do children develop from the blooming, buzzing confusion to handling *concepts* and then to using *words*?

Two learning processes

DAZED AND CONFUSED
Right Now I'm Having Amnesia And Déjà Vu
At The Same Time.....

Conceptual spaces

- Consists of a number of dimensions (colour, size, shape, weight, position, time, prize ...)
- Dimensions have topological or geometric structures
- Dimensions are sorted into *domains* (space, colour ...)
- Concepts are represented as *convex* regions of conceptual spaces

CONCEPTUAL SPACES

THE GEOMETRY OF THOUGHT

— PETER GÄRDENFORS
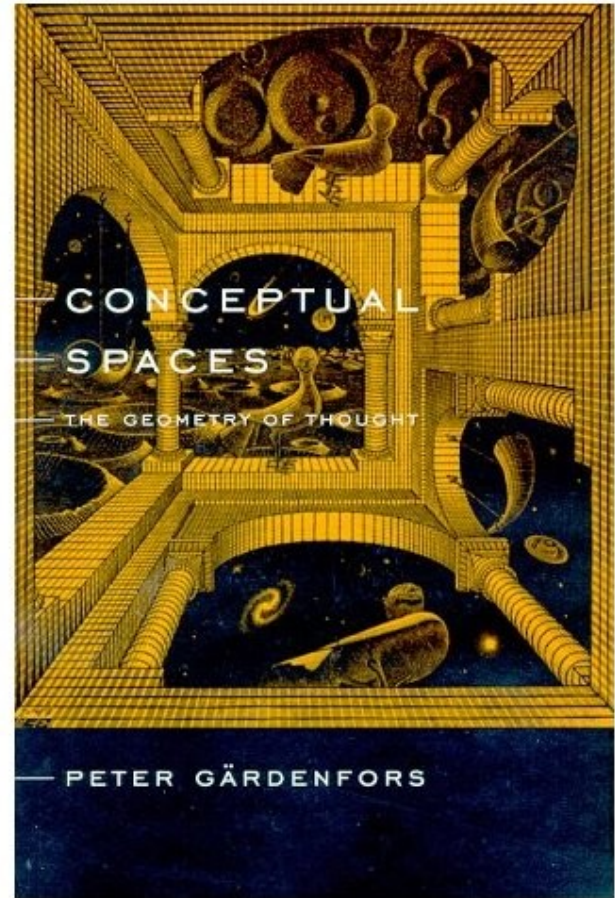
The color spindle
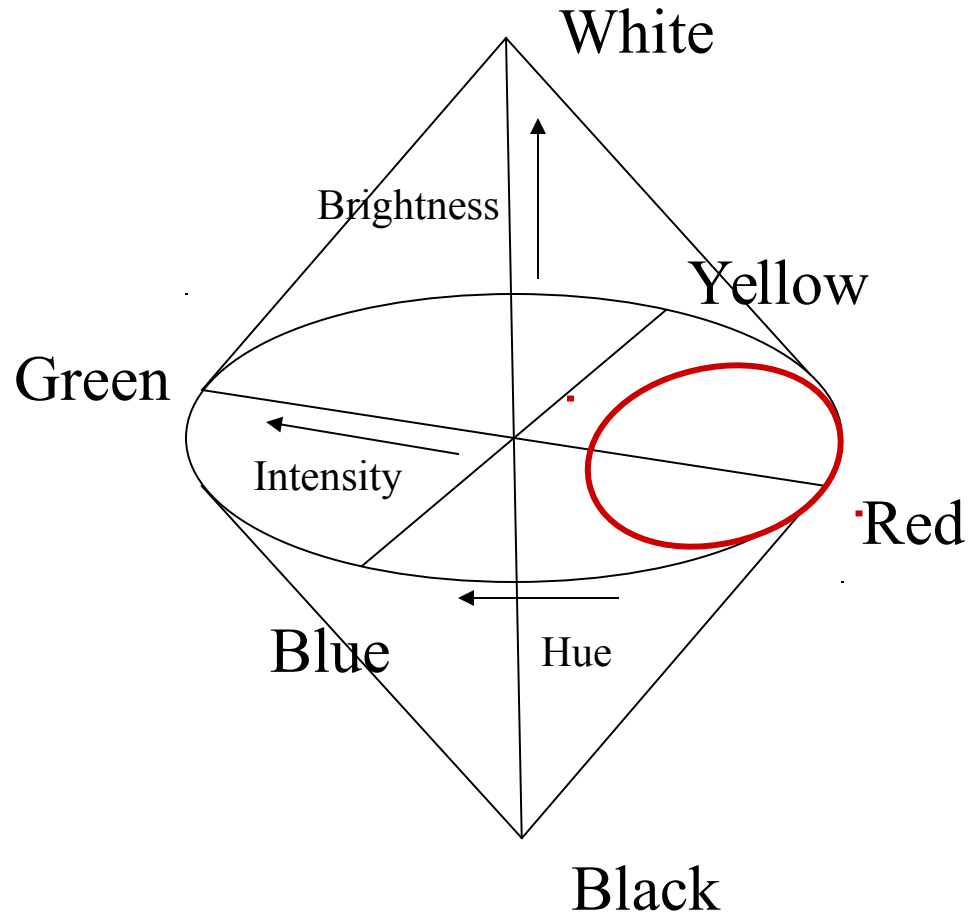
Conceptual spaces

- Information is organized by *quality dimensions*

- … that are sorted into *domains* (space, time, temperature, weight, color, shape …)

- Domains are endowed with a *topology* or *metric*

- *Similarity* is represented by distance in a conceptual space

Integral vs. separable dimensions

A set of dimensions is *integral* if one cannot assign an object a value on one dimension without giving it a value on the others. Otherwise the dimensions are *separable*. E.g. weight is separable from temperature.

Dimensions within a modality are integral (e.g. colour).

Several psychological tests for integrality

A *domain* is defined as a set of integral dimensions.

Where do the domains come from?

- Spelke's core knowledge domains: Space object, action and number

- These domains form the foundation for language learning

- Why these domains?

- My hypothesis: They pick out sets of *invariances* in the world

- My position is empiricist, rather than the nativist view of Spelke and Carey

The brain picks out invariances

- Gibson's theory of invariances
- He defines an invariant as a 'non-change' that persists during change
- No account of the mechanisms
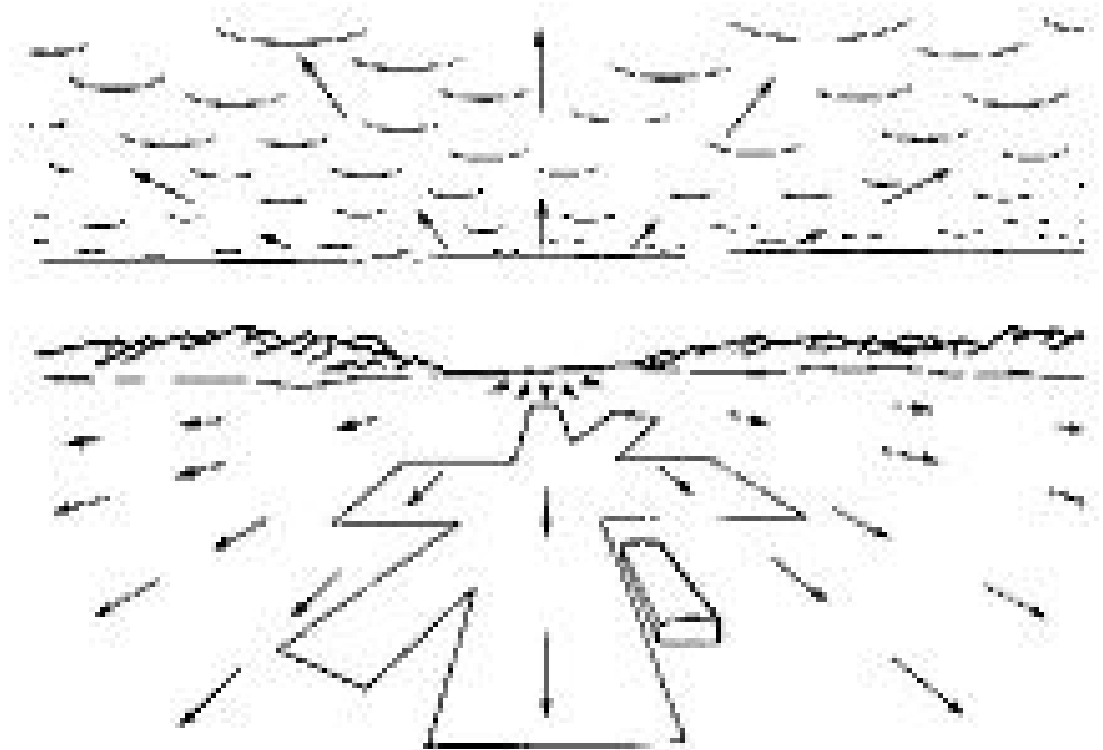
Core knowledge domains

- The structure of our cognitive representations have been chiseled out by evolution

- Wallace Stevens: "I am a native in this world, and think in it as a native thinks"

- Spelke and Kintzler (2007) on representations of objects, actions, numbers and space

- "These systems serve to represent inanimate objects and their mechanical interactions, agents and their goal-directed actions, sets and their numerical relationships of ordering, addition and subtraction, and places in the spatial layout and their geometric relationships"

Space

- Invariances of the blooming, buzzing confusion on the retina

- First results in an *egocentric* space that is invariant of eye, head and body direction

- Is later extended to an *allocentric* space that is also invariant of body location

- Egocentric is for action, allocentric for location

- (Almost) 3D Euclidean spaces

Zenith
True sky
Moon's apparent size
Flattened sky
Horizon
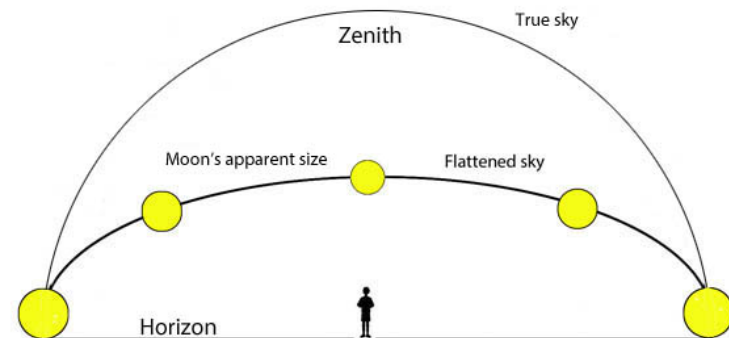
Space

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- Egocentric is for action, allocentric for location
- (Almost) 3D Euclidean spaces
- Invariances considerably *reduce dimensionality* of sensory information

Objects

Spelke's four constraints:

(i) *continuity* (all parts of an object move together)

(ii) *solidity* (objects move only on unobstructed paths and, consequently, no two objects occupy the same place)

(iii) *gravity* (if not supported, objects fall downwards)

(iv) *inertia* (objects do not change their motion abruptly)

I add (v) objects have a *shape*

Object invariances

- *Solidity*: Relative locations of object parts are invariant (solid objects) or relative locations within parts are invariant and connection points are invariant (objects with movable parts)
- *Shape* important for early categorization
- Object properties are invariant when objects change location

Humans are excellent at identifying actions

https://www.biomotionlab.ca/Demos/BMLwalker.html
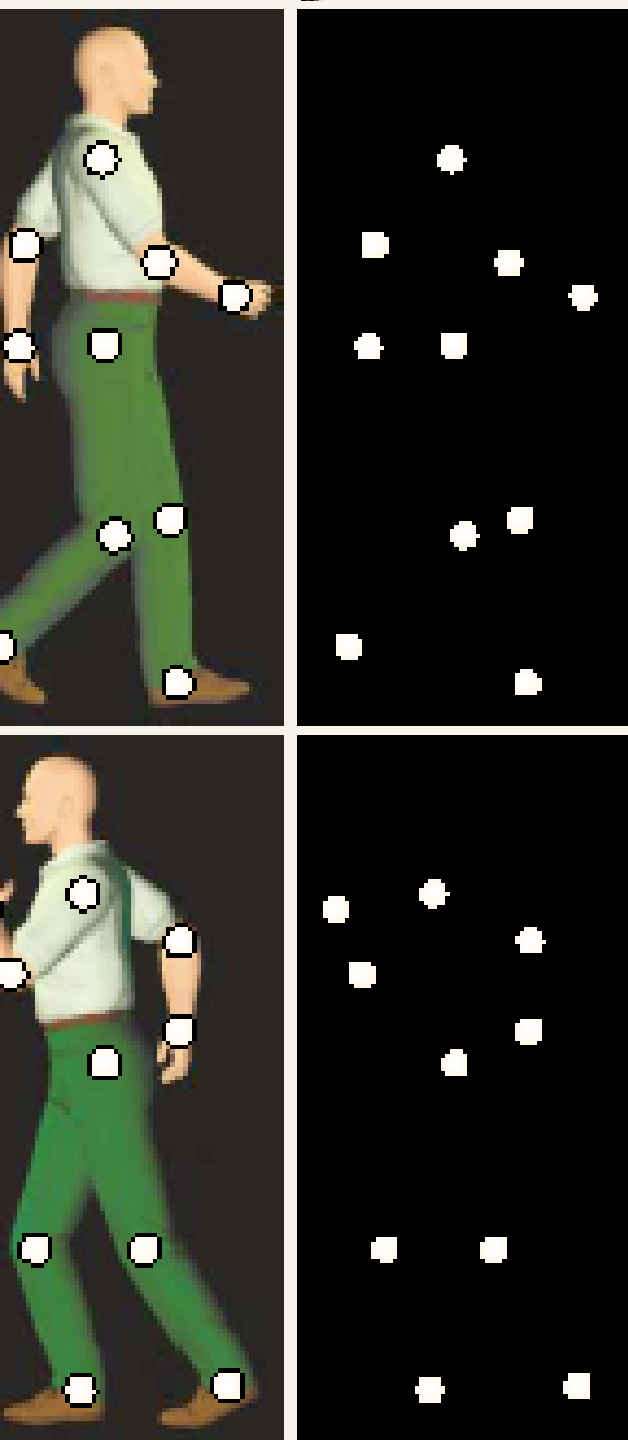
Actions

- Johansson's patch light experiments

- Runesson: The kinematics of a movement contains sufficient information to identify the underlying dynamic force patterns

- Actions are categorised via invariances of force patterns

- Again a considerable reduction of dimensions

Numbers

- Numbers are properties of sets

- Two early number systems:

- Approximate numbers – humans and animals are good at detecting *proportions*

- Subitizing – we directly perceive the numerosity of up to four objects immediately

- The latter system is later extended to the full cardinal numbers

- Children learn to count, that is, to form a 1-1 mapping between words and objects

Main problem: How to describe the sets of invariances

- I have tried to informally identify the main invariances for each of the core domains

- Can they be given a mathematical characterisation? (like Galilean invariances for Euclidean space)

- What groups them together?

- Can it be shown that the sets of invariances are "orthogonal" to each other?

The brain is not a blank slate

- Prepared for picking up relevant invariances
- Space: "where" pathway (dorsal)
- Objects: "what" pathway (ventral)
- Actions: "how" pathway (dorsal)
- Numbers: interior temporal lobe (Dehaene)
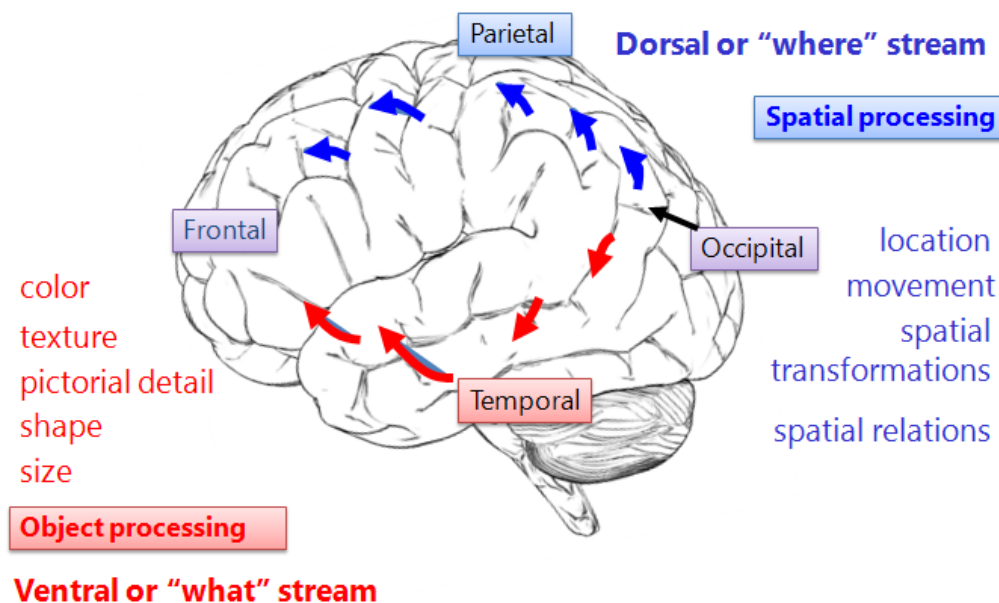
General conclusion

We can share meanings because we share domains that are built up from the same invariances

Are concepts really learned?

- Fodor: Basic concepts in Mentalese are innate

- Locke: The mind of the newborn is a blank slate so everything is learned

- My position: Almost everything is learned

- Concepts are *regions* of domains

- This is a second form of learning
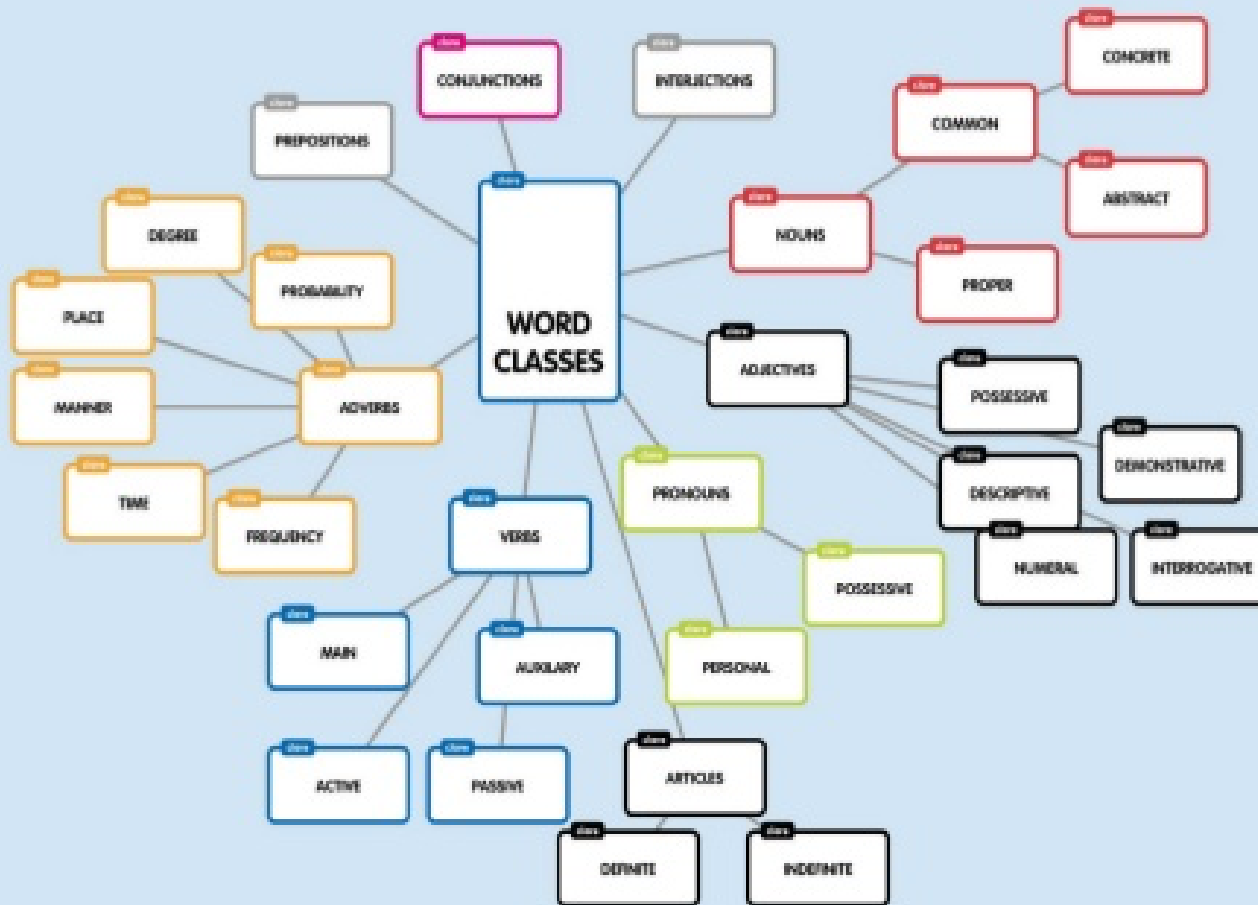
- Most words denote concepts
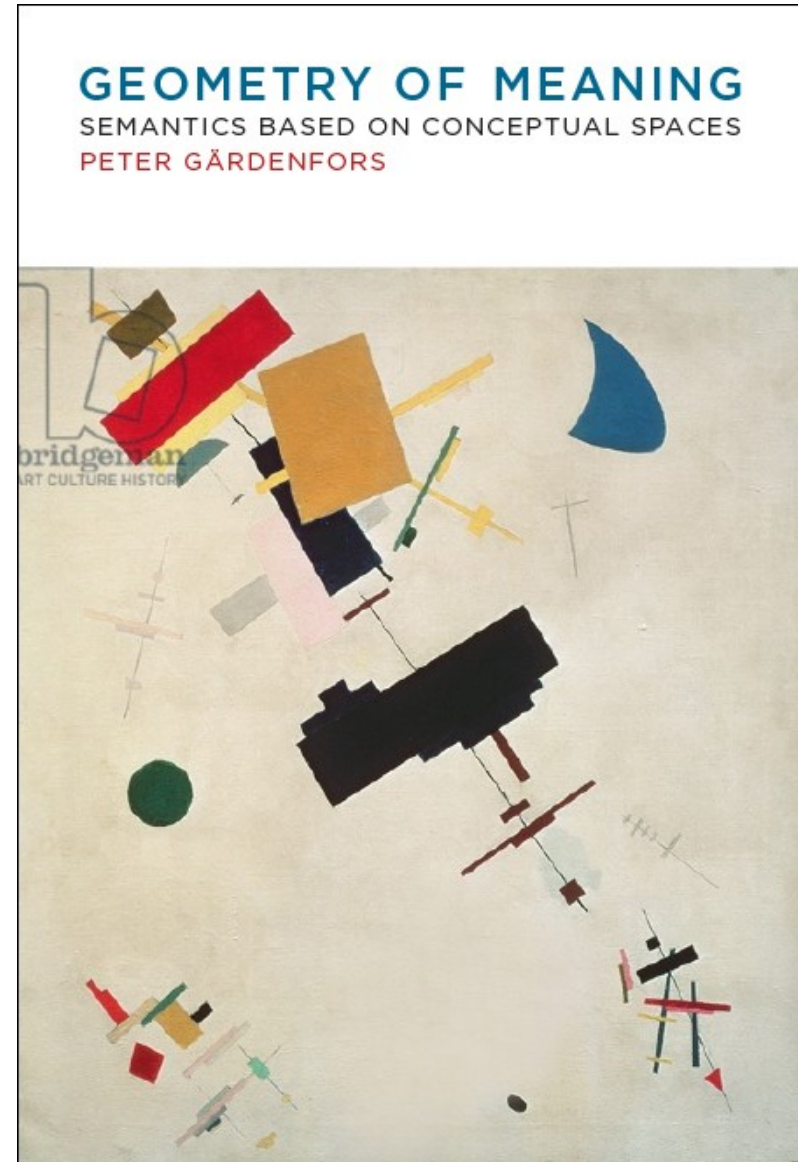
Basic level is most informative

- Animal
- Mammal
- Dog
- Terrier
- Scottish terrier

Core knowledge and word classes

Core knowledge and word classes

- Objects: nouns
- Actions: verbs
- Space: prepositions
- Number: quantifiers
- Properties: adjectives

GEOMETRY OF MEANING
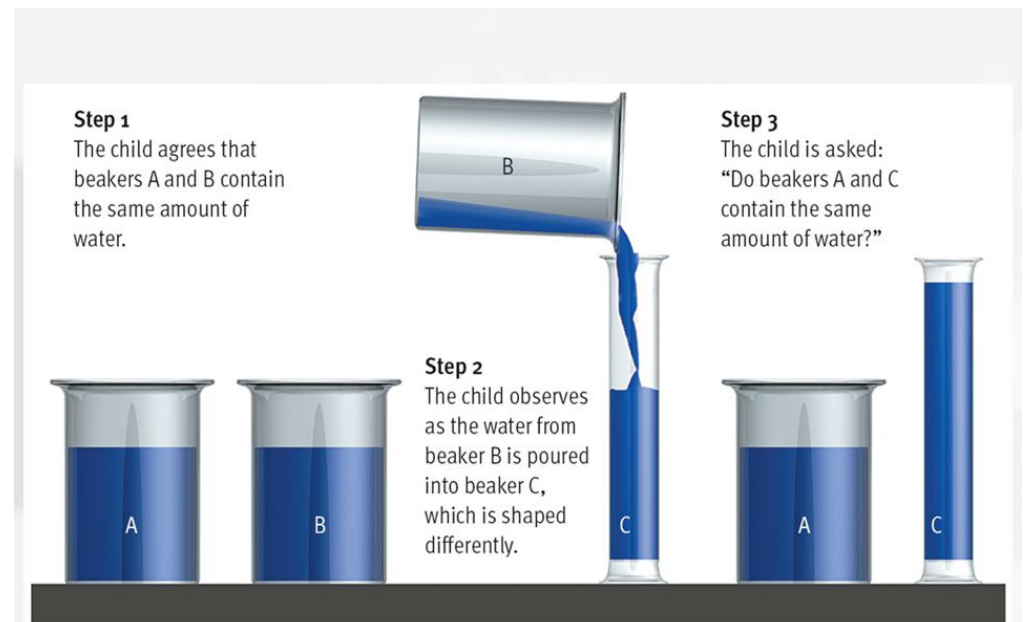SEMANTICS BASED ON CONCEPTUAL SPACES
PETER GÄRDENFORS

The semantic ontology of word classes

- *Nouns* Products of regions of domains (together with correlations between regions)

- *Prepositions* Locational: Region of spatial domain Directional: Vector in the spatial domain

- *Verbs* Manner: Vector (pattern) in the force domain. Result: Vector in some property domain

- *Adjectives Region* of a domain

Properties

- Domains are separated out from core knowledge, in particular in the object system

- Age is separated from length

- E.g. Piaget's conservation task: volume is separated from height

Step 1
The child agrees that beakers A and B contain the same amount of water.

Step 2
The child observes as the water from beaker B is poured into beaker C, which is shaped differently.

Step 3
The child is asked: "Do beakers A and C contain the same amount of water?"

Properties

- Domains are separated out from core knowledge, in particular in the object system

- Age is separated from length

- E.g. Piaget's conservation task: volume is separated from height

- Properties refer to sub-domains of categories

- Properties are expressed by adjectives

The complex first paradox

- Concrete nouns are semantically more complex and neurally more widely represented than those of abstract attributes

- Nouns are more effortful than adjectives to link to their representations

- Paradox: Children learn nouns earlier than adjectives (Werning 2010)

- Solution: Children first learn overall invariants, then dimensionalize

- Noun categories have more invariants than properties

The overall argument

- The perceived world is not random. The brain picks out invariances
- Spelke: Infant core knowledge domains: Objects, actions, space and number
- These domains can (hopefully) be characterised by their sets of invariances
- Invariances can be represented in spatial structures (conceptual spaces)
- In development there is a dimensionalisation of the representations
- This account explains some aspects of language learning, in particular the role of word classes