Ontologies in Linguistics and Psychology
Theoretical models and open problems

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Section I

Preliminaries: mind and language

- **Frege-De Saussure: the duality of linguistic sign**
  - Communication and information

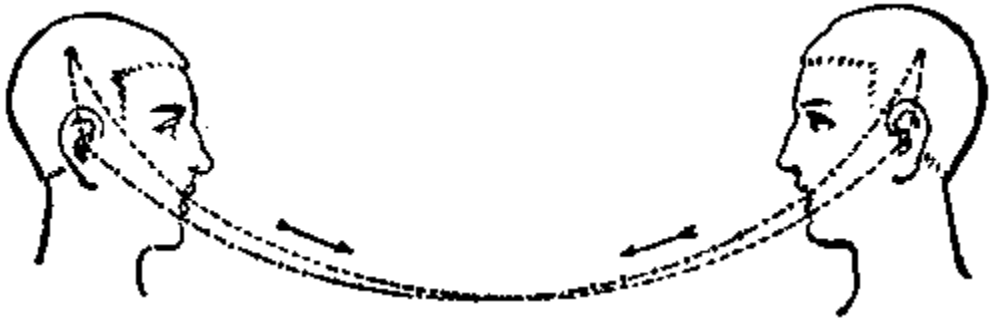
Ontologies in Logic and Linguistics

- **Types, Sets and Mereologies**
  - *The discussion on parts and wholes*
  - Properties and applications
  - *Plural, generics and collective noun phrases, indefinites*

Mind and Language

- **De Saussure**: a linguistic sign is a phenomenological unity made up of a cognitive/conceptual content, the "mental image" (***signifié***), and a material support, allowing the transmission of the information associated to the cognitive content, the "acoustic image" (***signifiant***).

The semiotic circle



Communication flow = constant exchange of roles between **speaker** and **hearer**. The conceptual / mental content is transformed by the human speech-auditory system (mouth, larynx, ears …) into the material support (air, sound waves), that allows the transmission of information and, on the other side, the comprehension of the message.
(*Cours de linguistique générale*, 1916)

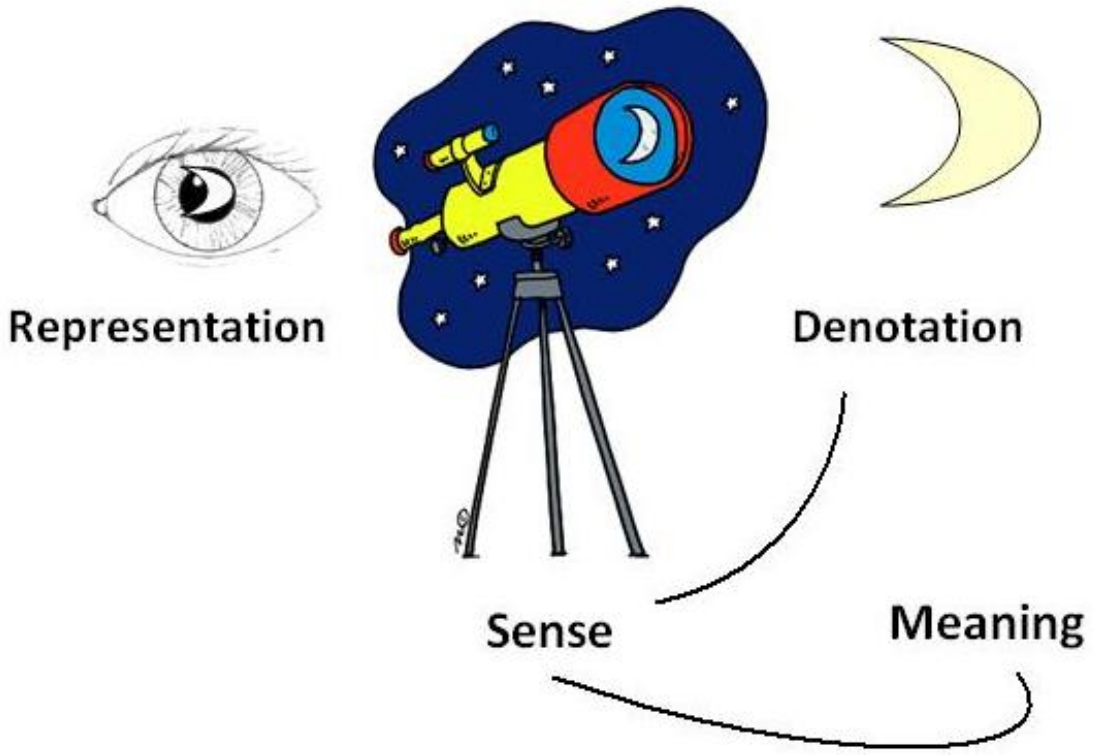
Language and the world

- **Frege**: A linguistic sign has a **sense** and a **denotation**; the sense is the way / instruction / information needed to obtain / reach / individuate the denotation (the object designed by the linguistic sign). Linguistic **meaning** is based on this fundamental relation.

  (*Sinn und Bedeutung* 1892)

- Perspectival view of meaning: the telescope

The telescope



- Meaning, therefore, is not **in** the mind/brain, meaning is a tool, an *instrument of vision*, of knowledge, that is *inter-subjective*, socially shared and used.
- Frege recognizes also a mental dimension, that is behind meaning and is related to the subjective point of view, that he calls **representation**; while *meaning* puts into relation the human mind with the objective world (experience, formal objects), *representation* is the particular **perspective** that the subjective mind has towards the world.
- Leibniz (*Discourse of metaphysics*)

Ontologies in Logic and Linguistics

- **Husserl's meaning categories**
  - *Cathegoremes* : nominal, adjectival … matters
  - *Syncathegorems* : copula, connectives …
- **Parts vs. wholes**
  - A horse vs. the head of a horse
  - A flock vs. a sheep
  - A country vs. a region of a country

(*Logische Untersuchungen*, 1901)

Ontologies in Logic and Linguistics

- **Frege's hierarchy of functions** (Geach)

  n name

  s sentence, assertion, proposition

  f:n function with one nominal argument

  f:nn function with two nominal arguments

  f:f:n 2_{nd} level function with a 1_{st} level functional argument of one nom. arg.

  f:f:nn 2_{nd} level function with a 1_{st} level functional argument of two nom. arg.

Ontologies in Logic and Linguistics

- **Lesniewski's grammar of semantic categories**
  - *Ontology* : formal theory of entities
  - *Mereology* : formal theory of parts and wholes
  - **Ajdukiewkz** : categorial grammar

    a family of syntactic types generated from the basic types **n** : nouns and **s** : sentences
  - **Lambek** : Calculus of Syntactic Types

- **Properties**:
  - Completeness vs. incompleteness
  - Dependency
  - Inclusion vs. overlapping, partiality
- **Applications**:
  - Plural reference
  - Mass terms
  - indefinites, generic noun phrases

Plural reference

- If a term admits the definite and indefinite article and the plural ending, then normally under our perfect adult usage it is a **general term**. ... A singular term names ... just one object, ... a general term is true of each, severally, of any number of objects.

  (W. O. Quine, *Word and Object*, 1960, 90-91)

- A term is semantically singular if it designates one object, and **semantically plural** if it designates more than one object. 'Socrates' is semantically singular, and 'Lennon and McCartney' is semantically plural.

  (P. Simons, *Parts and Moments*, 1987, 143)

a. The beaver is a rodent.

b. A beaver is a rodent.

c. Beavers are rodent.

d. John and Peter are pianists.

e. Dinosaurs are extinct.

Cumulative meaning

So called **mass terms** like *water*, *footwear* and *red* have the semantic property of referring cumulatively: any **sum of parts** which are water is water. Grammatically they are like singular terms in resisting pluralization and articles.

Semantically they are like singular terms in not dividing their reference ... but semantically they do not go along with singular terms in purporting to name a unique object each. (W. O. Quine, *Word and Object*, 1960, 91)

a. Water is a cold liquid.

b. The water I am drinking is cold.

c. The beaver is a rodent.

d. Beavers build dams.

Indefinite and generic noun phrases

a. La balena diventa sempre più rara.

The whale is becoming very rare

b. Due ufficiali hanno liberato tre ostaggi.

Two officers have released three hostages

a. Le balene diventano sempre più rare.

b. Alcuni ufficiali hanno liberato molti ostaggi.

a. * Una balena diventa sempre più rara.

b. Una balena è un animale protetto.

c. ??Militari hanno liberato ostaggi.

Set theory and natural cognition

The mathematical superiority of set theory unfortunately gave rise to the tacit assumption ... that set theory is also ontologically superior ... and this assumption was reinforced by the fact that the language of sets does indeed possess greater expressive power, even in extra-mathematical contexts, than does the language of extensive wholes ... however ... the language of sets is not an adequate basis for a *lingua characteristica* in the sense demanded of a realistic, descriptively adequate, formal ontology.

(B. Smith and K. Mulligan, *Pieces of a Theory*, 1982, 24-25).

Sets and natural kinds/collections

The idea of a set is somehow 'genetically' related to ideas of such naturalistic objects as *packs*, *bunches*, and *flocks*. Nevertheless ... sets are not the same sort of things ... First, packs, bunches, ... displace volumes, have mass, and come into and pass out of existence. Sets, by contrast, are non-physical and eternal. Secondly, sets cannot change their members, packs, ... can .... Thus, **a set of wolves and a pack of wolves are different**. Thirdly, packs, ... do not exist if nothing is in them; this is not so for sets.

(G. Bealer, *Quality and Concept*, 1982, 101)

Ontologies in Psychology

- **Wittgenstein: family resemblances**

  Things which may be thought to be connected by one common feature may in fact be connected by a series of overlapping similarities, where no one feature is common to all.

  Language games are the paradigmatic example of a group that is related by family resemblances.

Categorization: concepts and prototypes

Prototype theory is a cognitive approach to categorization in which some members of a category are taken as more central, prominent, than others.

When people is asked to give an example of the concept *furniture*, *chair* is more frequently cited than *stool*.

furniture ⟹

chair, sofa > couch, table > easy chair, dresser, rocking chair > > coffee table > desk > bed

E. Rosch, *Cognitive Representation of Semantic Categories, 1975*

Prototypes

Prototype theory is a radical departure from traditional analysis of concepts in terms of necessary and sufficient conditions as in Aristotelian logic, which leads to set-theoretic approaches of extensional or semantics.

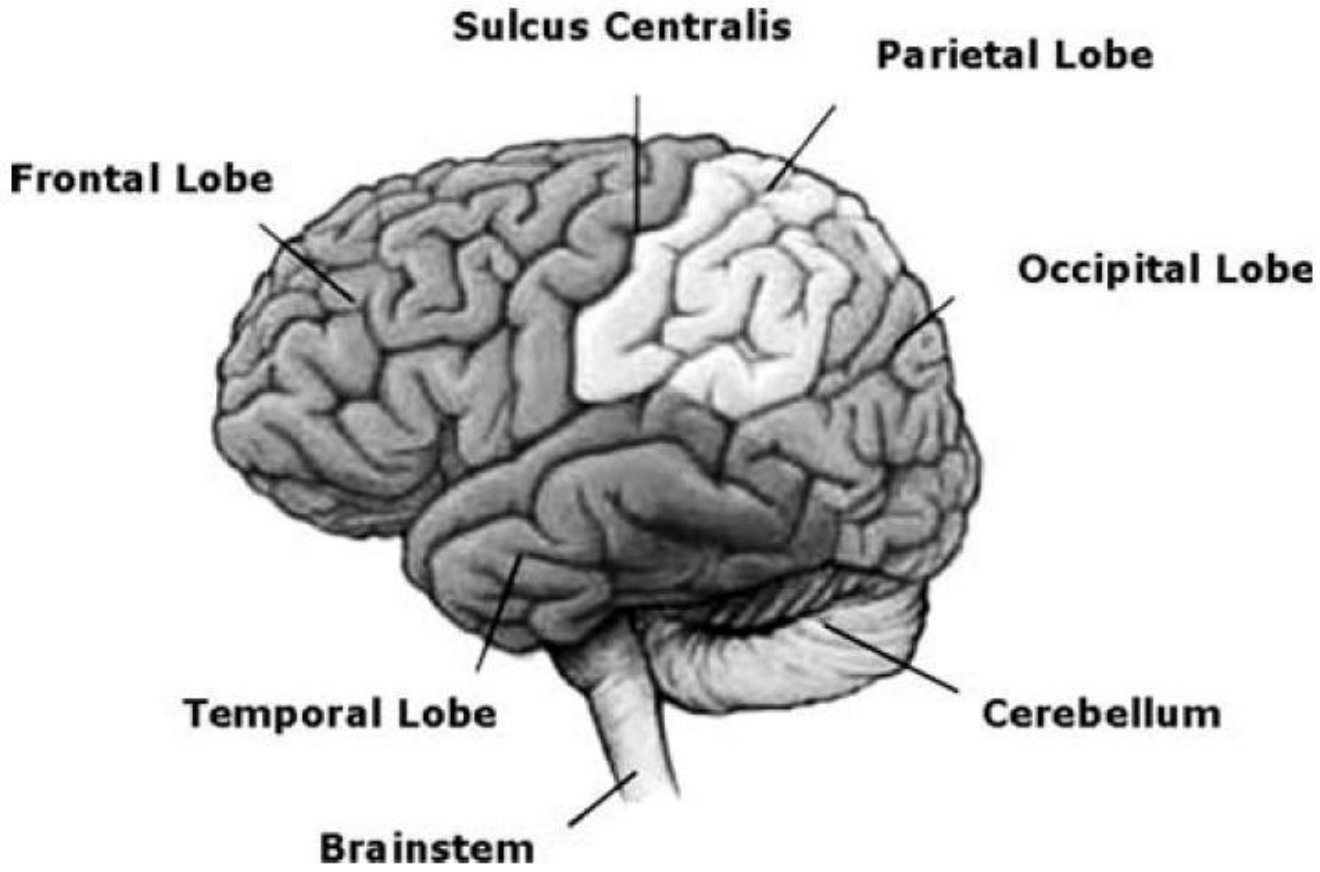
Instead of a definition of **bird** as the set of elements with the features [+feathers], [+beak] and [+ability to fly], prototype theory would consider a category like **bird** as consisting of different elements which have **unequal status** - e.g. a *robin* is more prototypical of a *bird* than, say a *penguin*.

This leads to a **graded notion** of categories, which is a central notion in many models of cognitive semantics, like in the work of G. Lakoff

Ontologies in Psychology

- Mind-body relations
  - Mentalism
    - Fodor
  - Functionalism
    - Searle, Churchland
  - Connectionism
  - Embodiment
  - Neurosciences

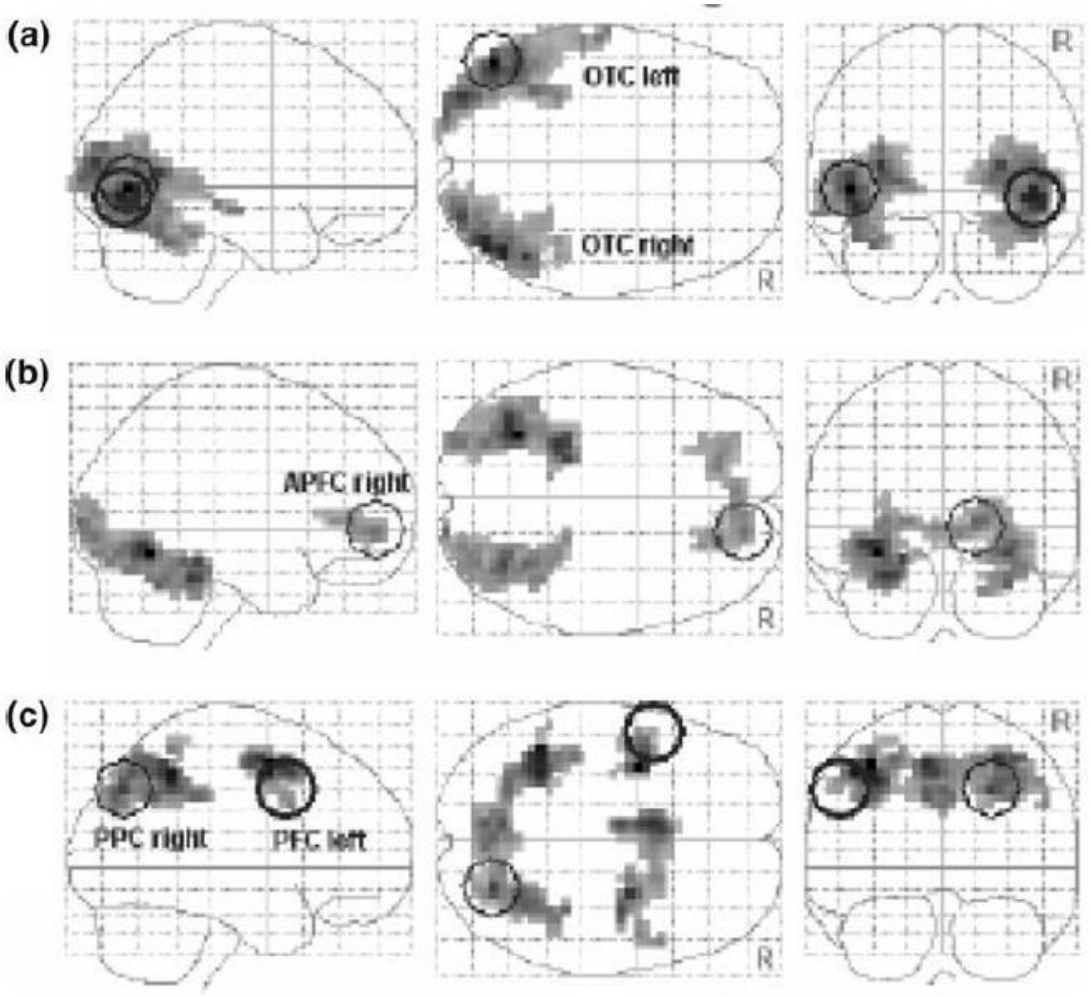
Brain regions



Reasoning task with emotional contents

VARIAZIONE DEI COMPITI DI RAGIONAMENTO DEDUTTIVO RELATIVAMENTE A:							
CONTENUTO							
CONCRETO				ASTRATTO			
VALENZA EMOZIONALE				VALENZA EMOZIONALE			
NEUTRA		NEGATIVA		NEUTRA		NEGATIVA	
N° 20 SILLOGISMI		N° 20 SILLOGISMI		N° 20 SILLOGISMI		N° 20 SILLOGISMI	
N° 10 SENZA RELAZIONI SPAZIALI	N° 10 CON RELAZIONI SPAZIALI	N° 10 SENZA RELAZIONI SPAZIALI	N° 10 CON RELAZIONI SPAZIALI	N° 10 SENZA RELAZIONI SPAZIALI	N° 10 CON RELAZIONI SPAZIALI	N° 10 SENZA RELAZIONI SPAZIALI	N° 10 CON RELAZIONI SPAZIALI

Brain “activations”



Section II

The Geometry of Cognition

- **Cognitive abilities**
  - **Perception**
  - **Reasoning**
- **Linear Logic and cognitive science**
  - **Positive vs. negative**
  - **Analysis of syllogisms**
- **Reasoning experiments**

Cognition as interaction

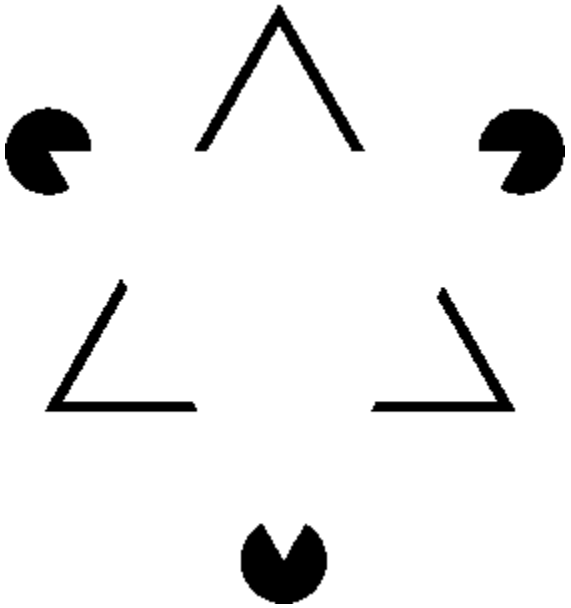
- We consider the question of studying **interaction** inside cognition as a general framework on the basis of which also interaction inside linguistics can be explored.
- Geometrical character of proofs: logic as a space in which the objects freely interact by means of cut elimination.
- Design of a calculus in which objects (agents) are described by the structure (geometry) of their interactions (ludics, game semantics).

Cognition

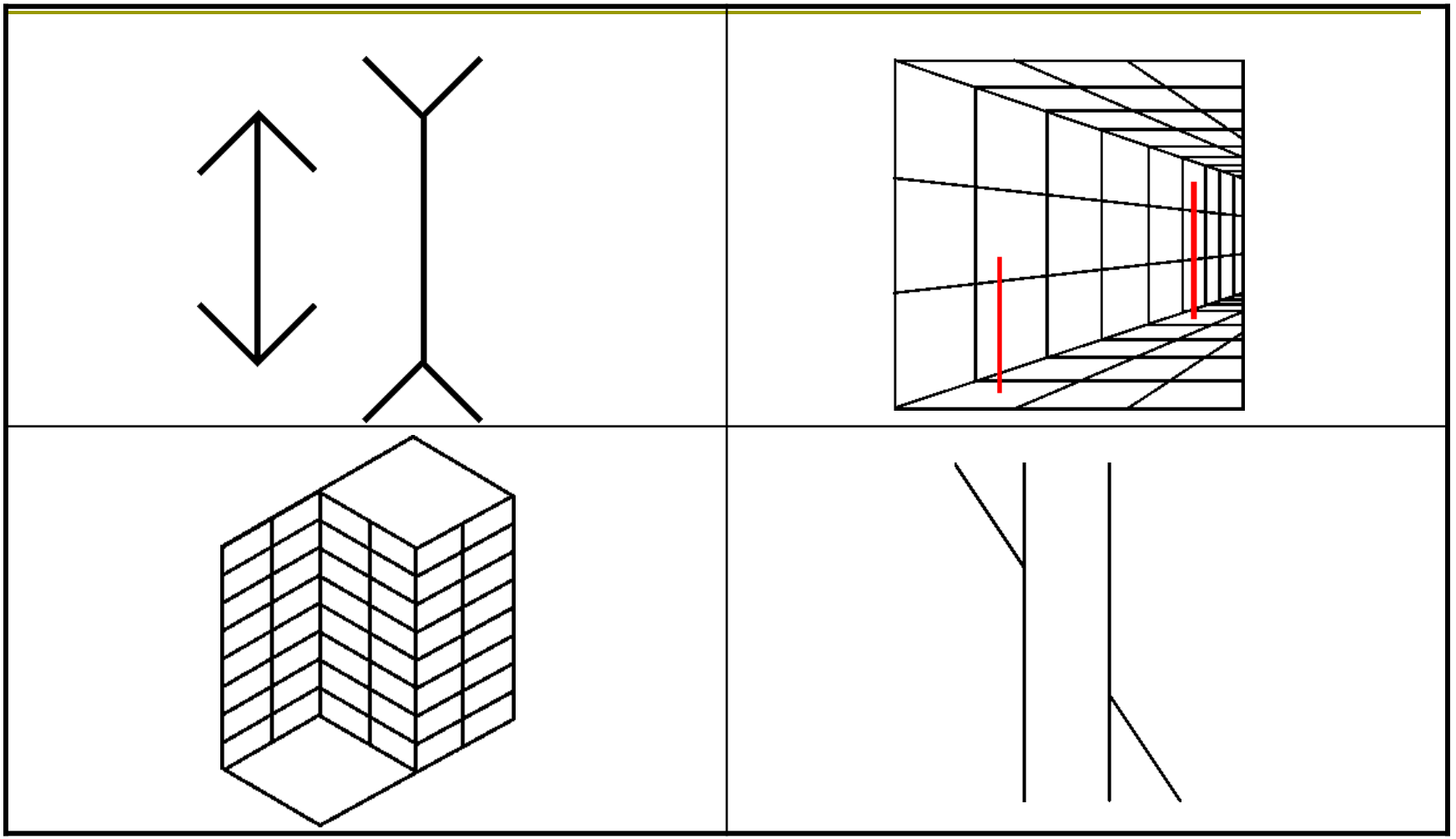
- The general human mental (and physical) ability involving perception, memory, language, thinking and reasoning
- Sensomotory faculties, brain activities, general intelligence, etc.

An example: visual perception

- Kanizsa triangle
- A brilliant white triangle is perceived that is not really framed
- The figure is the result of the organization of the context (*visual contour*)



Other cognitive “illusions”



Positive vs. negative

- Recent formulations of linear logic and ludics pay particular attention to the intrinsic ***positive*** and ***negative*** polarity of *logical operators* (connectives and quantifiers).

- This distinction appears to have interesting applications to cognition, and particularly to the analysis of human reasoning.

Connectives in LL

- Connectives and quantifiers (and their duals) belong to the positive or to the negative class.

- The dual of a positive operator is a negative operator and the dual of a negative operator is a positive operator.

LL Connectives

- The *positive class includes*: ***tensor*** (⊗), ***plus*** (⊕), and the ***existential*** quantifier (∃), which are *irreversible operators*.

- The *negative class* includes: ***par*** (℘), ***with*** (&), and the ***universal*** quantifier (∀), which are *reversible operators*.

Reversible vs. non reversible

- *In LL logical operators* are classified as *reversible* and *irreversible*.
- A rule introducing a ***reversible*** operator allows one to infer from the conclusion of the rule the premise (or the premises) from which the conclusion is drawn.
- This is not the case with ***irreversible*** operators: the premise (or the premises) cannot be inferred from the conclusion

Formulas

- Formulas are classified on the basis of their main *logical operator*:

- if it is ***reversible*** (also called *asynchronous)* the process to prove such a formula is mechanical. Such a step is a descriptive one.

- if it is ***irreversible*** (also called *synchronous)* one has to make a choice in proof search, since the premises are not fully determined by the conclusion. An irreversible step of analysis discriminates the whole proof-search process and represents an active and creative step.

Polarities

- the *positive* polarity plays a *creative-irreversible* role
- the *negative* polarity plays a d*escriptive-reversible role*
- *negation* sends from one polarity to the other $A^{\textbf{positive}}$ $A^{\perp\,\textbf{negative}}$
- alternating polarities characterize proof search

Syllogism

- A deductive argument composed by two premises and a conclusion:

1) All humans are rational — 1) $\forall(x)(U(x) \rightarrow R(x))$

2) All Greeks are humans — 2) $\forall(x)(G(x) \rightarrow U(x))$

$\therefore$ All Greeks are rational — $\therefore \forall(x)(U(x) \rightarrow R(x))$

1) All birds have wings — 1) $\forall(x)(B(x) \rightarrow W(x))$

2) Some animal is a bird — 2) $\exists(x)(A(x) \wedge B(x))$

$\therefore$ Some animal has wings — $\therefore \exists(x)(A(x) \wedge W(x))$

Aristotelian propositions

- Four Aristotelian *categorical propositions:*

- universal affirmative $\forall(x)(A(x) \rightarrow B(x))$
- particular affirmative $\exists(x)(A(x) \wedge B(x))$
- universal negative $\forall(x)(A(x) \rightarrow \sim B(x))$
- particular negative $\exists(x)(A(x) \wedge \sim B(x))$

cfr. Aristotelian square

Aristotelian propositions in LL

- The *categorical universal* (affirmative and negative) *propositions* turn out to belong to the class of *negative propositions:*

Every A is B

$$(A \rightarrow B) \;\Rightarrow\; (A \multimap B) = (A^{\perp} \parr B)$$

Every A is not B

$$(A \rightarrow \sim B) \;\Rightarrow\; (A \multimap B^{\perp}) = (A^{\perp} \parr B^{\perp})$$

Aristotelian propositions in LL

- The *categorical particular* (affirmative and negative) *proposition* turn out to belong to the *positive class:*

Some A is B

$$(A \wedge B) \Rightarrow (A \otimes B)$$

Some A is not B

$$(A \wedge {\sim}B) \Rightarrow (A \otimes B^{\perp})$$

Reasoning as interaction

- Investigate reasoning as interaction between positive vs. negative propositions
- Traditionally deductive reasoning is treated as a (deterministic) top-down process (from premises to conclusion)
- In a similar way, inductive reasoning is presented as a (probabilistic) bottom-up process.
- Interaction goes beyond both these views

Geometry of cognition

- The assumption is that the properties of logical, and particularly, of human reasoning, studied from the point of view of interaction, exhibit a geometrical nature

- Develop a theoretical framework in which such a geometrical character can be properly expressed and represented: proof nets, ludics

Contradictory propositions

Proposition: α	Contradiction: con(α)
Every man is rational	*Some man is irrational*
Some man is sleeping	*Every man is awake*
Every man is irrational	*Some man is rational*
Some man is awake	Every man is sleeping

Opposite concepts

rational	*irrational*
sleeping	*awake*
walking	*standing*
open	*closed*

Experimental task

- Alternating *positive-negative categorical propositions are introduced*. The subjects are asked to perform a reasoning task where:
- from a *positive* proposition involving a *positive logical operator "some"*, they switch - by searching the *contradictory* - to a *negative* proposition involving a *negative logical operator "every"*
- or from a *negative* proposition they have to switch to a *positive* proposition, alternating an active and creative move, with an automatic and mechanical move.

Preliminary results

- Statistically significant difference in activation power between Every/Some vs. Some/Every tasks, corresponding to the switch from one polarity to the other.
- *Contradictory* tasks appears to be significantly different in brain activation power from the *non-contradictory tasks*.
- Difference between *categorical propositions* with the *operator "some"* with respect to the *categorical proposition* with the *operator "every": positive* and *negative* seem to be associated to different brain activation patterns.

Section III

- **Interaction in language**
  - **Linguistic resources**
    - Composition vs. decomposition
    - Beyond compositionality
  - **Speech acts and conversation**
    - Language games and categorization (Wittgenstein)
    - Performativity (Austin, Searle)
    - The logic of conversation: cooperation, interaction, violation (Grice)
    - Implicatures: conventional vs. conversational

Interaction in language

- Interaction here is means grasping the behavior of linguistic resources
- Linguistic resources are traditionally treated by means of two operations: composition (synthesis) vs. decomposition (analysis)
- How the parts cooperate to form a sentence
- What is the structure (constitution) of a sentence

Geometry of language

- The basic assumption is that also the interaction of linguistic resources has a geometrical nature
- Develop a theoretical framework in which such a geometrical character can be properly represented: proof nets applied to syntactical analysis, ludics applied to semantics and discourse analysis