QUANTUM COGNITION AND NATURAL LANGUAGE INTERPRETATION

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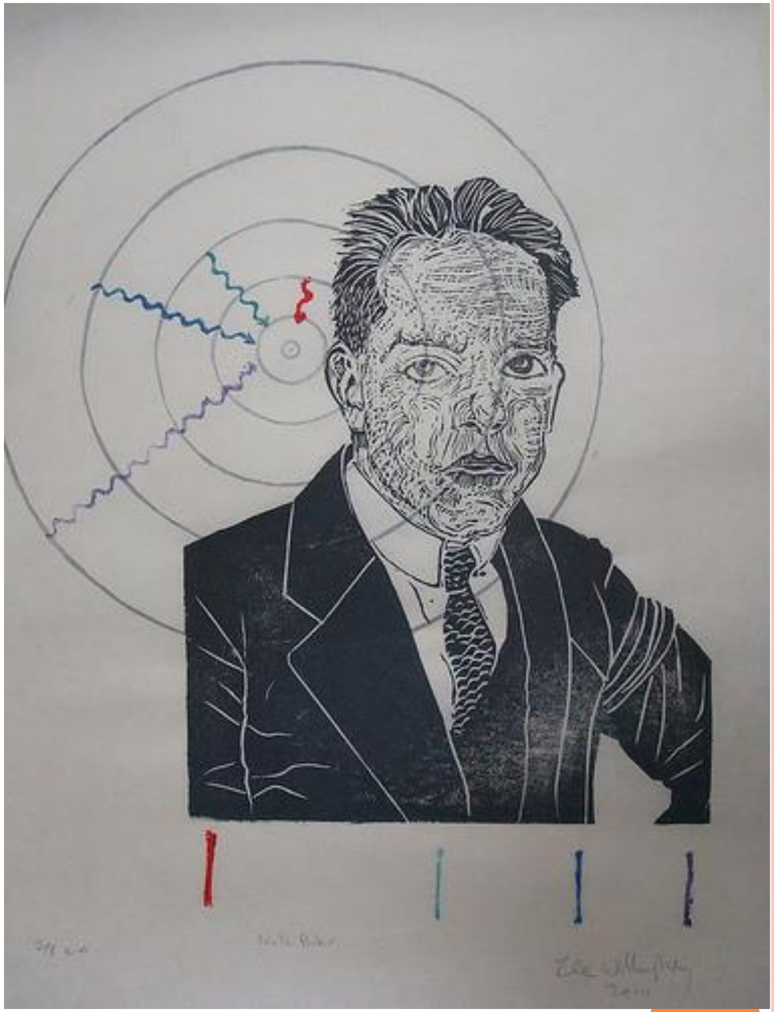
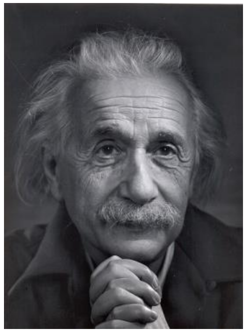
Bohr´s (1913) Atomic Model

- Almost exact results for systems where two charged points orbit each other (→ spectrum of hydrogen)
- The model cannot explain the spectra of larger atoms, the fine structure of spectra, the Zeeman effect.
- Conceptual problems: conservation laws (energy, momentum) do not hold.



Quantum Mechanics

Heisenberg



Einstein

Bohr

Pauli

- Historically, QM is the result of a successful resolutions of the empirical and conceptual problems in the development of atomic physics (≈1900-1925)
- The founders of QM have borrowed some crucial ideas from psychology

COMPLEMENTARITY

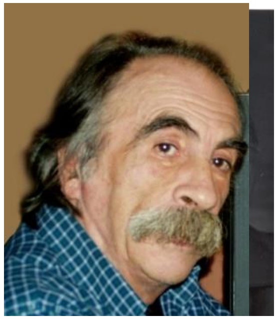
- William James was the first who introduced the idea of complementarity into psychology

  “It must be admitted, therefore, that in certain persons, at least, the total possible consciousness may be split into parts which coexist but mutually ignore each other, and share the objects of knowledge between them. More remarkable still, they are complementary” (James, the principles of psychology 1890, p. 206)

- Nils Bohr introduced the idea into physics (Complementarity of momentum and place) and proposed to apply it beyond physics to human knowledge.

Quantum Cogniton

Aerts
1994



Conte
1989

Khrennikov
1998

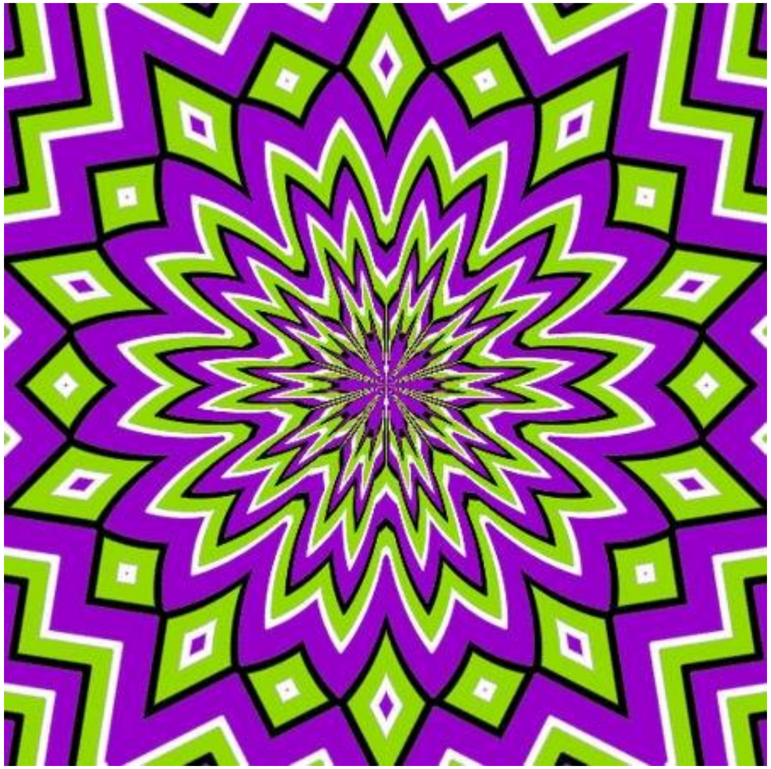
Atmanspacher
1994

- Historically, Quantum Cognition is the result of a successful resolutions of the empirical and conceptual problems in the development of cognitive psychology
- Tversky and Kahneman asked for the specifics of Human's intuitive statistics. → Puzzles of bounded rationality.
- Quantum probabilities give a systematic account for resolv-ing the puzzles. Independent motivation for quantum probs!

Quantum Cognition and Compositional Semantics

- Natural Language Interpretation is Direct and Context-Sensitive
  - Example 1: Adjectival Modification
  - Example 2: Borderline Contradictions

Direct Interpretation (Millikan)



- Perception = direct interpretation of sensory input
  - automatic, unreflective, instinctive
  - normally, it is not based on some kind of reasoning.
- NL Comprehension
  - Syntax & Semantics: automatic, unreflective, etc.
  - Pragmatic interpretation: indirect, reflective, normally based on reasoning (inferentialism)

Direct Perception through Language

- We directly perceive a *red chair* here. We automatically derive that without deliberation about the reliability of the sources (reflected light).

- DPL: Natural language interpretation is basically as direct as perception
  - Derivation of utterance meaning does not proceed by conscious inference
  - The content of the heard utterances integrates automatically our „belief boxes“

Descartes vs. Spinoza

- Can people comprehend assertions without believing them?
  - Descartes suggested that people can and should
  - Spinoza suggested that people should but cannot.
- Burge (1993): We may invoke (conscious) justification for **not** believing the content of some utterance. The default position, however, is to accept such contents as true.

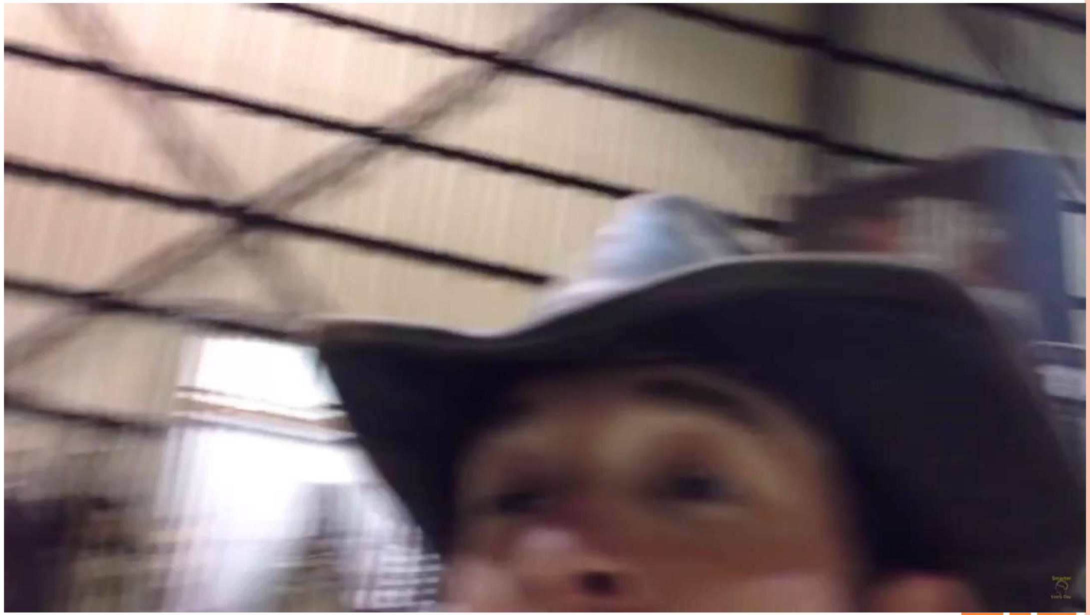
Dual Process Theory

Schneider & Shiffrin 1977	Automatic (pre-conscious)	Controlled (conscious)
Stanovich & West 1999	System 1	System 2
Kahnemann & Tversky1996	Fast	Slow

- The process of accepting assertions we understand is realized by fast processing (i.e., it is automatic)
- Damasio claims that emotions are generated by fast processing but cannot persist without slow (conscious) processing
- Car driving, piano playing, bicycling etc. call for skills which are learned by transferring System 2 capabilities into system 1 capabilities.

Backward Bicycle

When you turn the handlebar to the left, the wheel moves to the right



First Resumé

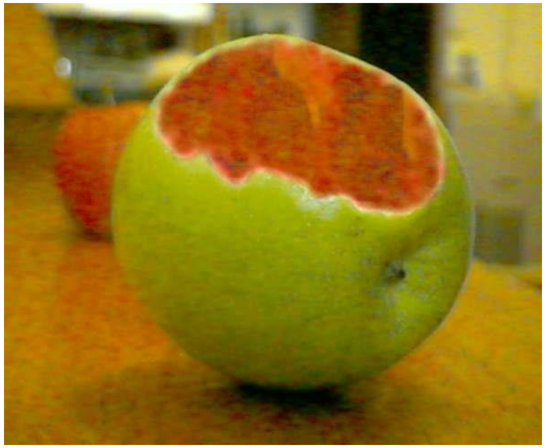
- The assumption that NL interpretation is as direct as perception (DPL-thesis) has important consequences for constructing psychologically adequate models of interpretation.
- I propose to take DPL as a serious challenge for computational models of NL interpretation
- DPL – properly generalized – asks for a default mode of NL interpretation which is fully compositional and runs automatically.
  - In Quantum Cognition, fast processing is realized by tensor products and certain reduction operations

CONTEXT SENSITIVITY: THE EFFECT OF CONTRAST CLASSES

- A collie is a dog, but a tall collie is not a tall dog
- Red nose
  red flag
  red beans



- This is a green apple (but inside it is red)
  - My preferred example for truth-conditional pragmatics
  - François Recanati: *Literal Meanings* 2004; *Truth Conditional Pragm.* 2006)

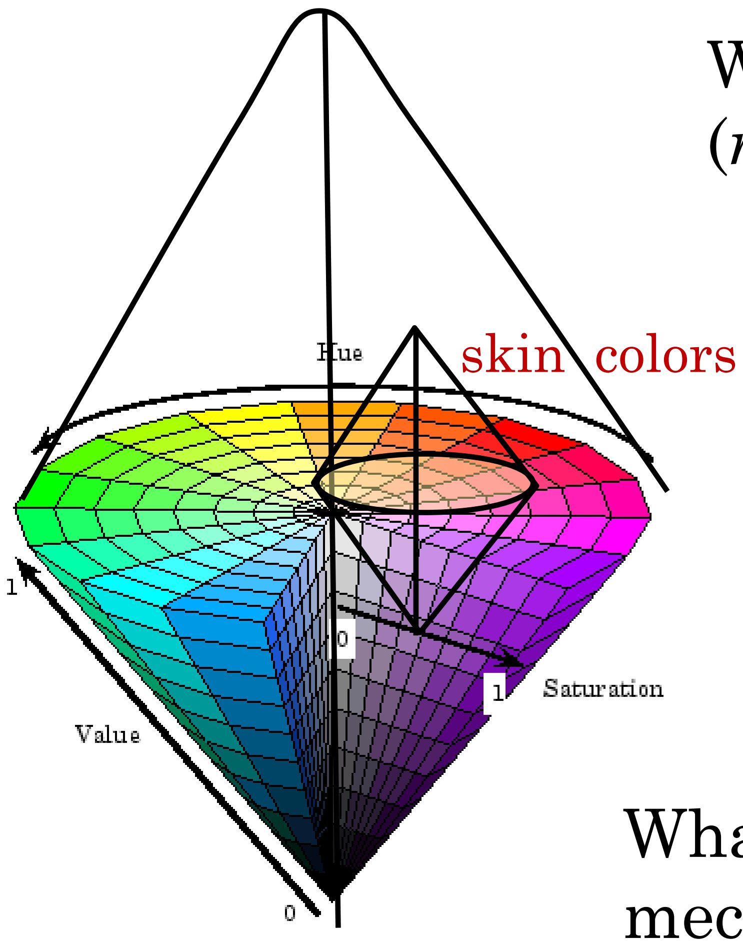


How to calculate truth conditions?

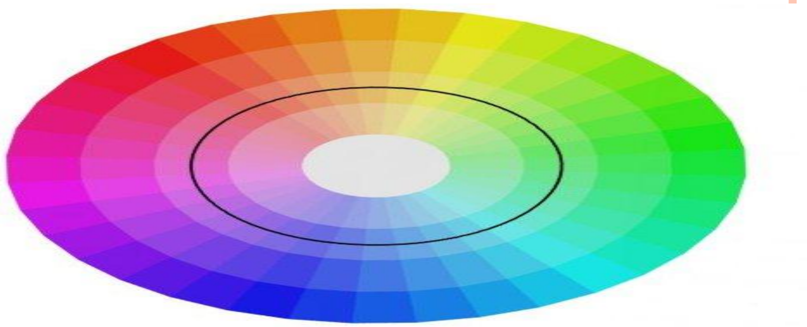
- The mechanism of adnominal functors requires idiosyncratic lexical entries for fixing the interpretations of complex expressions.
- *E.g., Quasi-deictic elements*
  tall boy → $\lambda x\ [tall^*(x,N)\ \&\ boy(x)]$
  $^*\ tall(x, N) \Leftrightarrow size(x) > N$ (Sag, Bartsch, Bosch)
- Alternative suggestions from Cognitive Linguistics
  - Blending theory** (Fouconnier & Turner)
  - Modulation (Recanati)
- What is the computational mechanism? A lovely notation does not yet provide a real mechanism.

** In blending theory, the part of a concept for which a given modification is relevant is referred to as an 'active zone', first discussed as such in Langacker (1991). In the case of an apple, the color is only relevant for the skin of the apple, which is its active zone.

Concept combination á la Peter Gärdenfors



What is the color of a *red nose* (*red flag*, *red tomato*)?

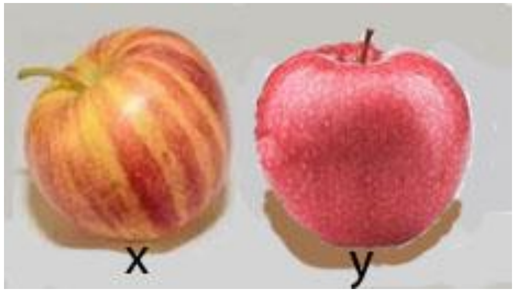


What is the computational mechanism of combination?

Typicality and the conjunction effect

- x=*guppy* is a poorish example of a *fish*, and a poorish example of a *pet*, but it's quite a good example of a *pet fish*
  - $c_x(\textit{pet fish}) - c_x(\textit{fish}) > 0$

- In case of "incompatible conjunctions" such as *pet fish* or *striped apple* the conjunction effect is greater than in "compatible conjunctions" (*red apple*).
  - $c_x(\textit{striped apple}) - c_x(\textit{apple}) > c_y(\textit{red apple}) - c_y(\textit{apple})$



- Do not treat the phenomenon as superposition (sum) but as a kind of multiplication (tensor product)!

Adjectival Modification Goes Quantum

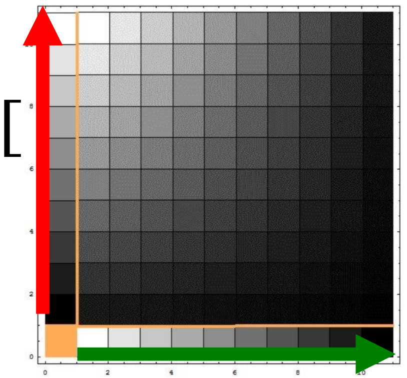
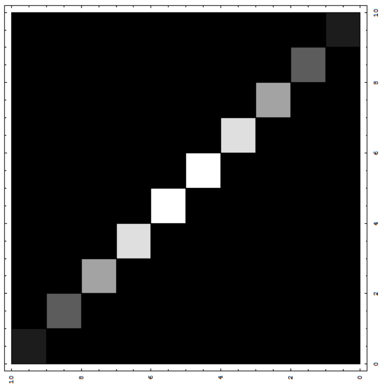
- $\vec{a}$ Attraction vector for "being an apple"
  - $\vec{a}$ lists the typicality for being an apple for all instances
- $\vec{b}$ Attraction vector for being striped
  - $\vec{b}$ lists the typicality for being striped for all instances
- The phenomenon of modification is treated as a kind of multiplication (tensor product), contrasting with superposition (sum)

Tensor Product plus Compression

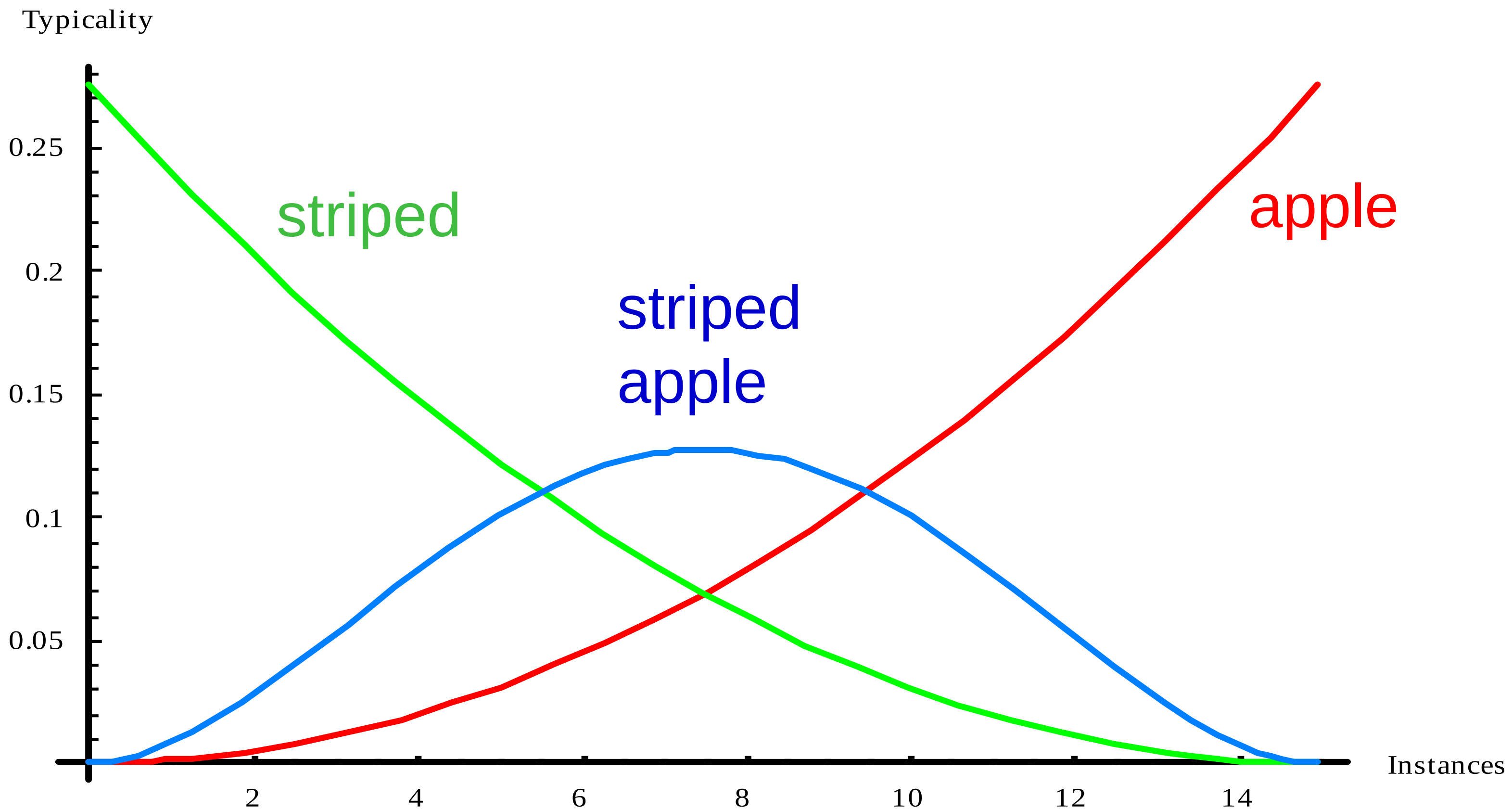
Modification

- Tensor Product
- Compression

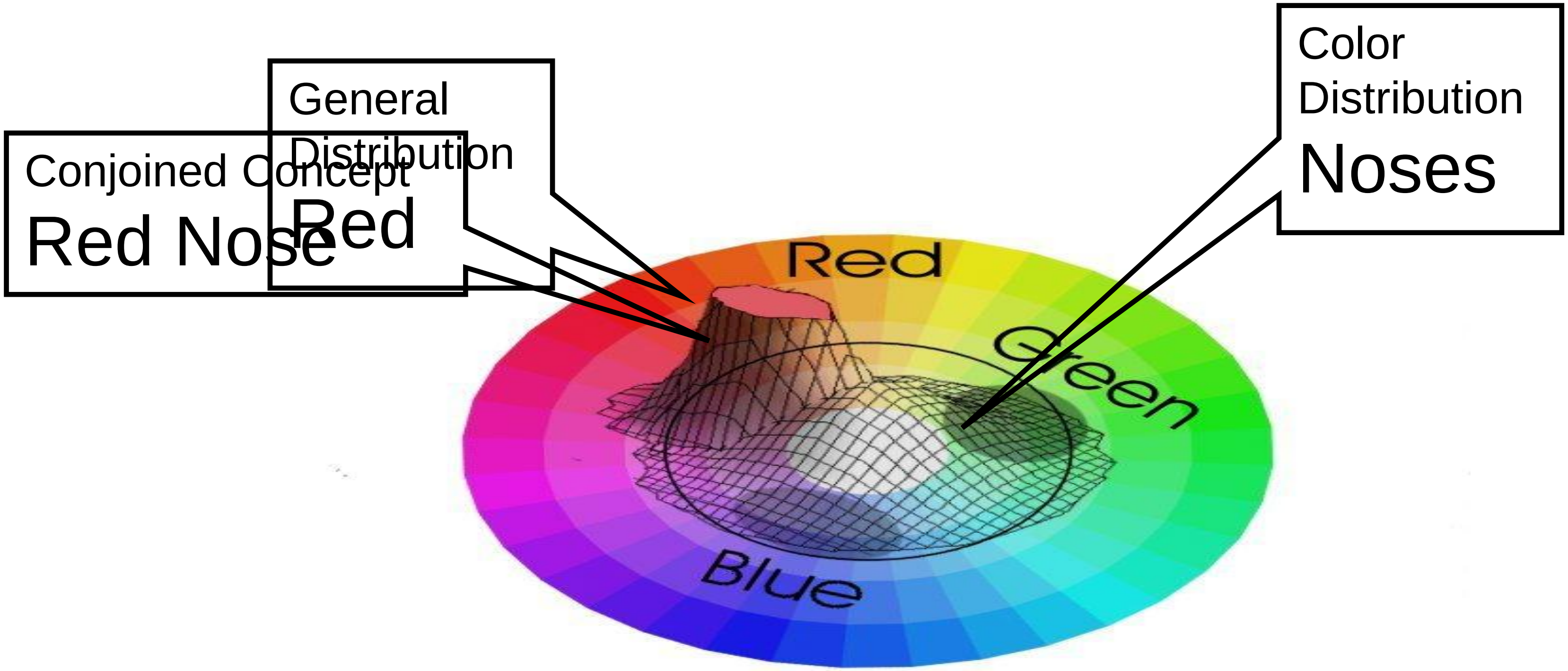
$$\vec{a} \circ \vec{b} = \Delta(\vec{a} \otimes \vec{b})$$

Δ [] =  (diagonal vector)

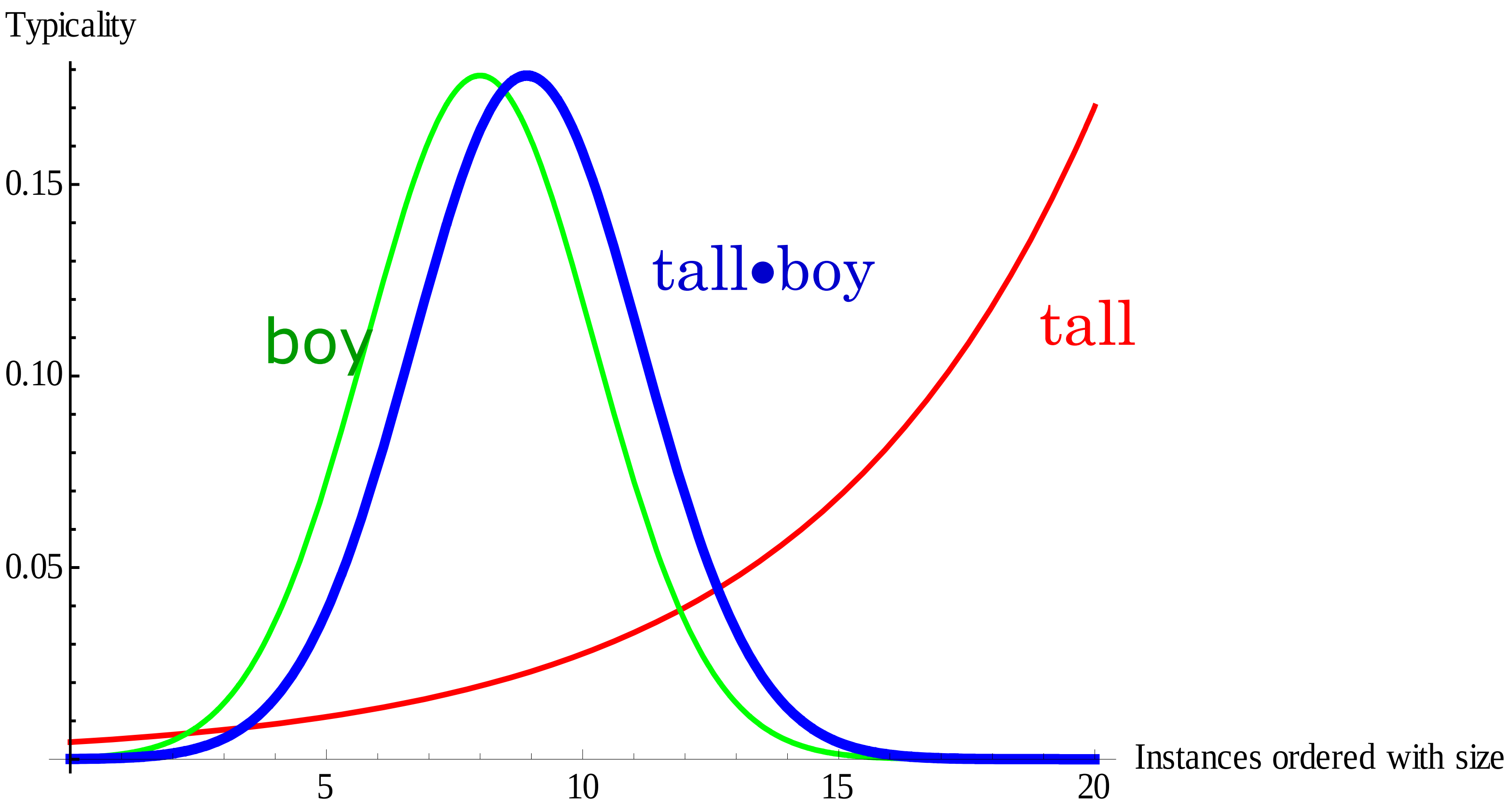
EXAMPLE 1: STRIPED APPLE



Examples 2: red nose



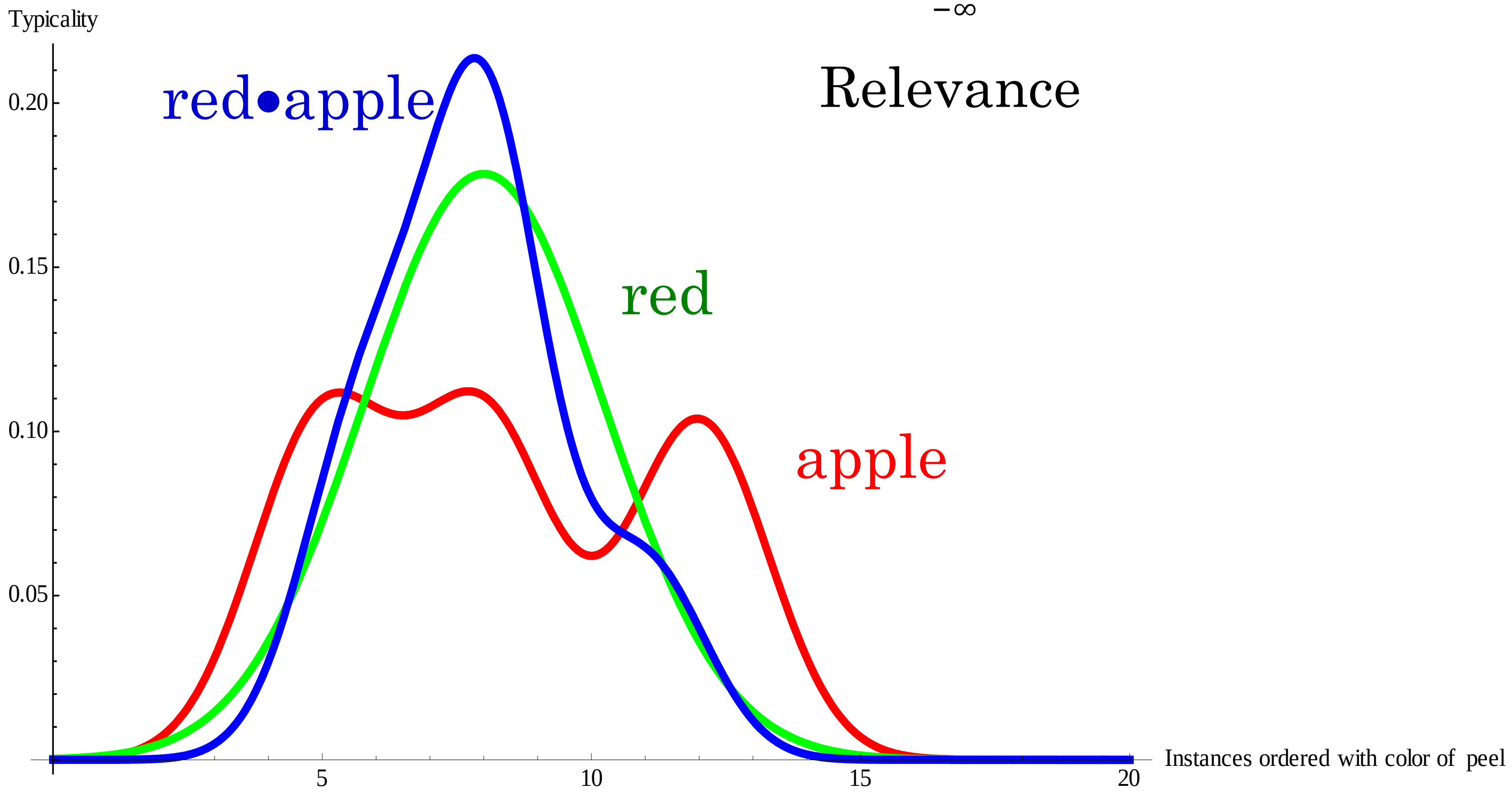
EXAMPLES 3: TALL BOY



Examples 4a: red apple (color of peel)

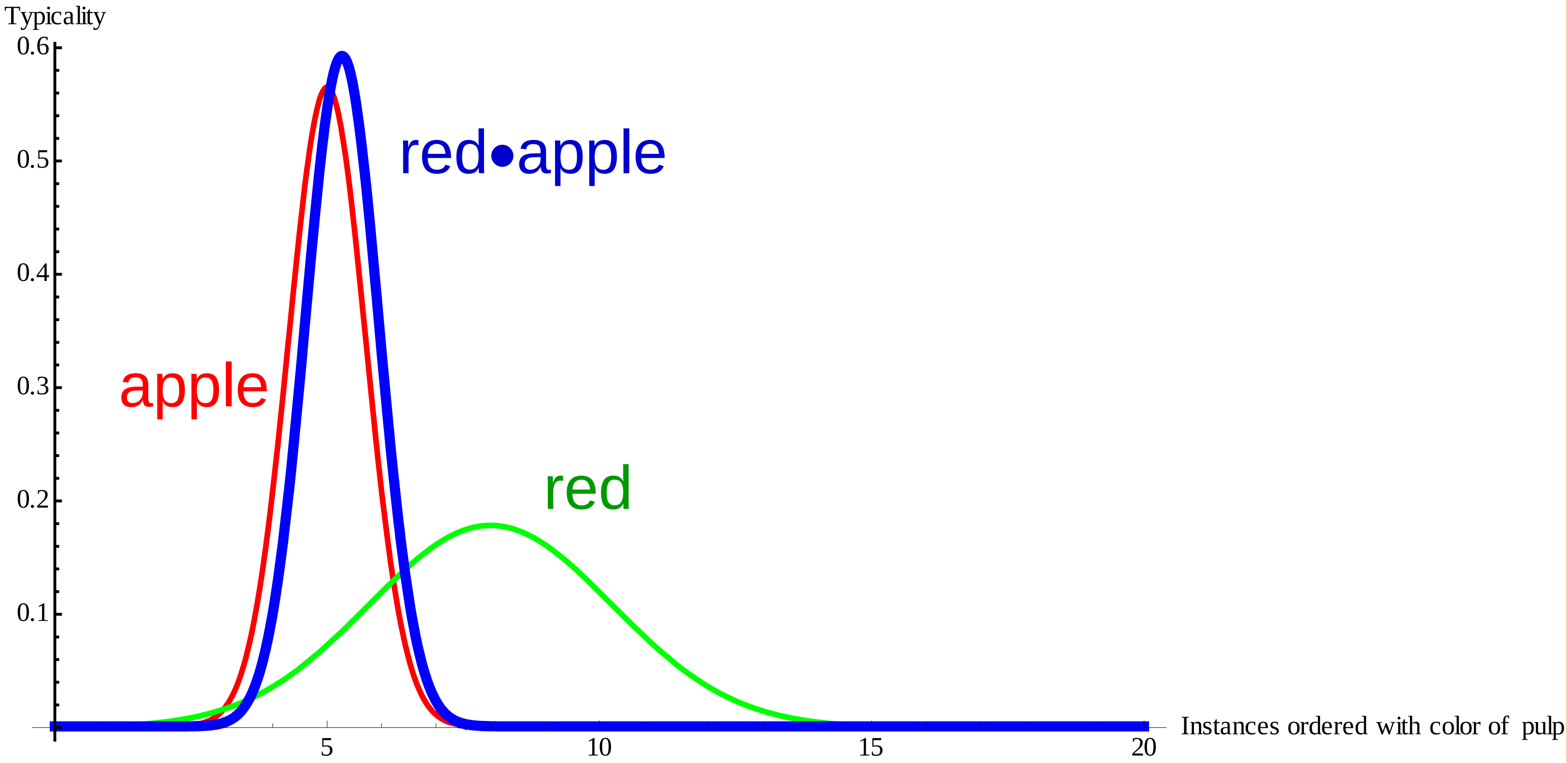
$$KLI = \int_{-\infty}^{+\infty} \mu(x) \log\left(\frac{\mu(x)}{\mu_0(x)}\right) dx$$

Relevance



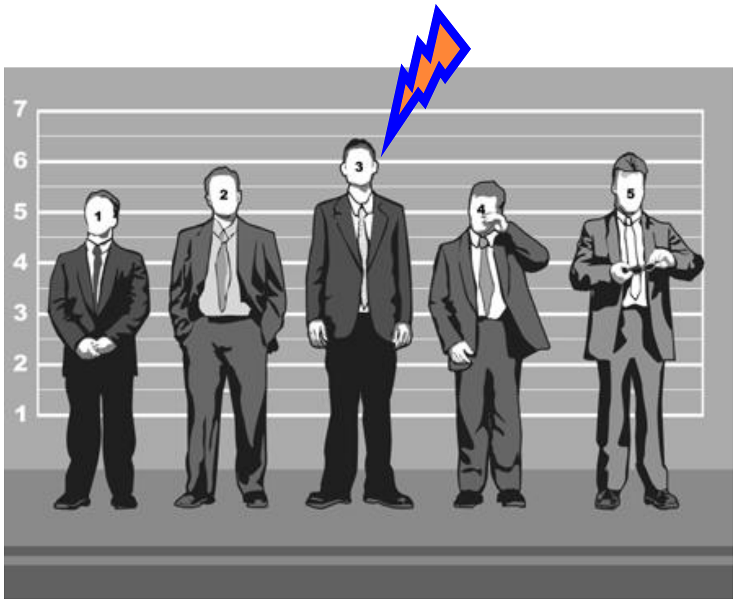
Kullback-Leibler information = 0.25

Examples 4b: red apple (color of pulp)



Kullback-Leibler information = 0.06

Borderline Contradictions

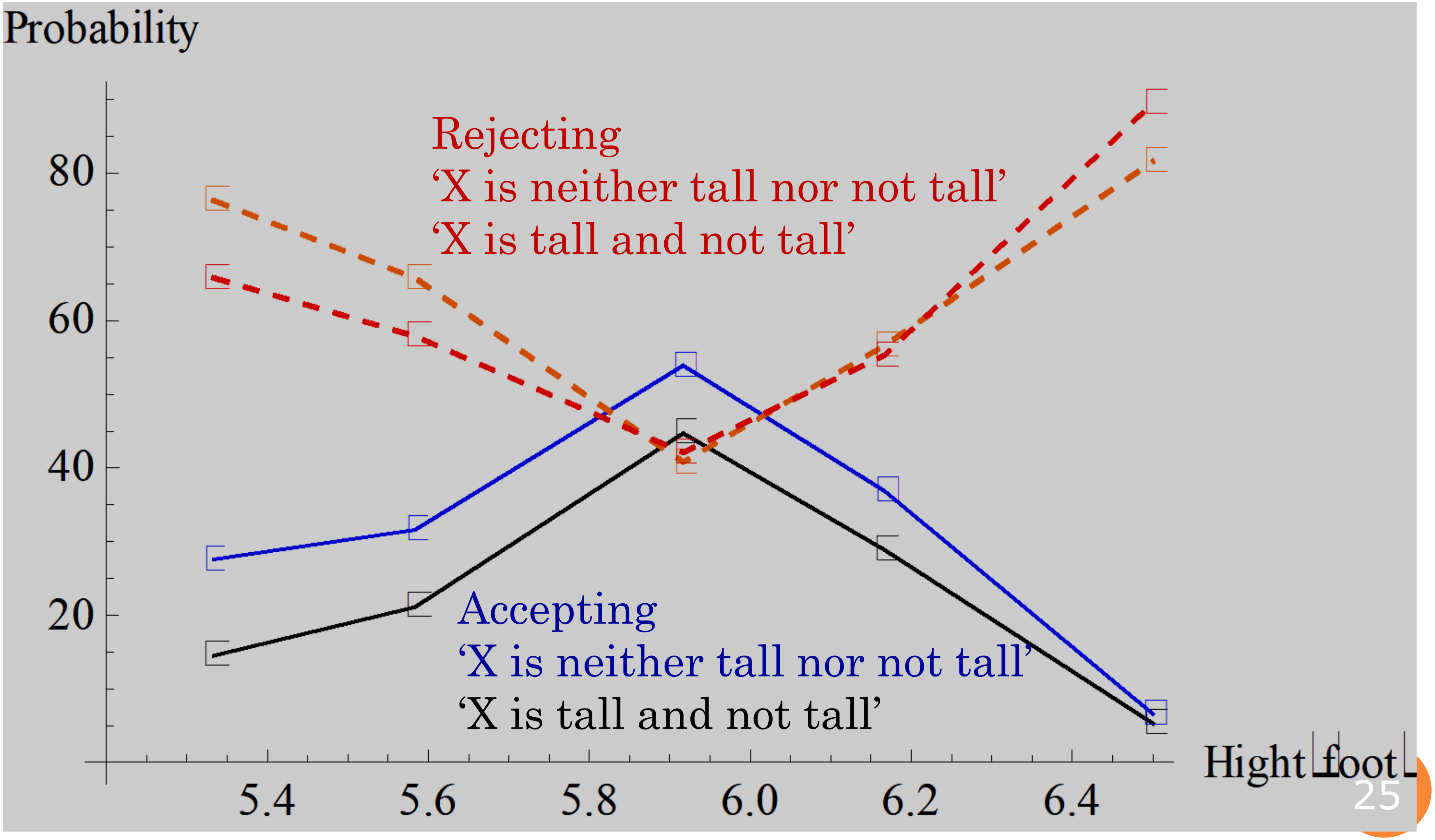


Pictures with 5 persons of different size are presented.
(Order of persons randomized)

Subjects have to judge forms with 4 sentences as True/False/Can't Tell.
(Order of questions randomized)

#3 is tall	True ❑ False ❑ Can't Tell ❑
#3 is not tall	True ❑ False ❑ Can't Tell ❑
#3 is tall and not tall	True ❑ False ❑ Can't Tell ❑
#3 is neither tall nor not tall	True ❑ False ❑ Can't Tell ❑

Data of Alxatib & Pelletier 2011



Conclusions

- Natural language interpretation is basically as direct as perception (DPL thesis)
- This is illustrated for the case of adjectival modification
- The default mode of NL interpretation which is fully compositional and runs automatically.
- Integrate cognitive models, neuronal models and distributional models of meaning (meaning in the text)
- The division of labor between System 1 and System 2 is highly efficient: it minimizes effort and optimizes performance.
  – This gives an evolutionary argument *why* certain states of the brain give rise to conscious experience.