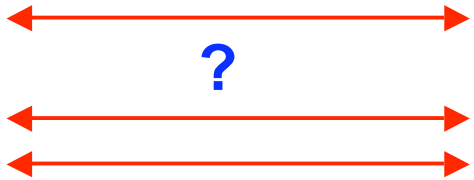
Defining the elementary computations that form the basis for the neurobiological representation and processing of speech and language.

(1) The research program *a la Marr*, with detailed linking hypotheses between computational, algorithmic, and implementational levels, has not been cashed out with much success. The 'neural basis of speech and language' is too often an example of interdisciplinary cross-sterilization.

(2) The cognitive sciences (linguistics, hearing & speech, psychology, computer science) have provided hypotheses about the putative primitives in this domain -- say

- **distinctive feature**
- **morpheme**
- **determiner**
- **movement**
- **variable binding**

Etc.



Neurobiological approaches (systems neuro-science, neurophysiology, cognitive neuro-science, computational neuroscience) provide hypotheses about biological primitives -- say

- **dendritic spine**
- **neuron**
- **cortical column**
- **LTP**
- **rate coding**

Etc.

(3) But there are few convincing linking hypotheses that bridge the primitives of linguistics and the neurosciences and that will work towards the unification across domains.

Neurobiological research on speech and language remains largely correlative rather than mechanistic and explanatory. The granularity mismatch problem (operating on objects of entirely different granularity) and the ontological incommensurability problem (reduction is hopeless) challenge progress.

(4) Proposed approach: computational research that attempts (a) to fractionate linguistic representation into generic formal operations and (b) to identify the neuronal basis for generic formal operations. Examples: *concatenation* - *hierarchical structure* - *variable binding*. Such an approach links more naturally to research in other domains, e.g. vision, neural coding, imaging.

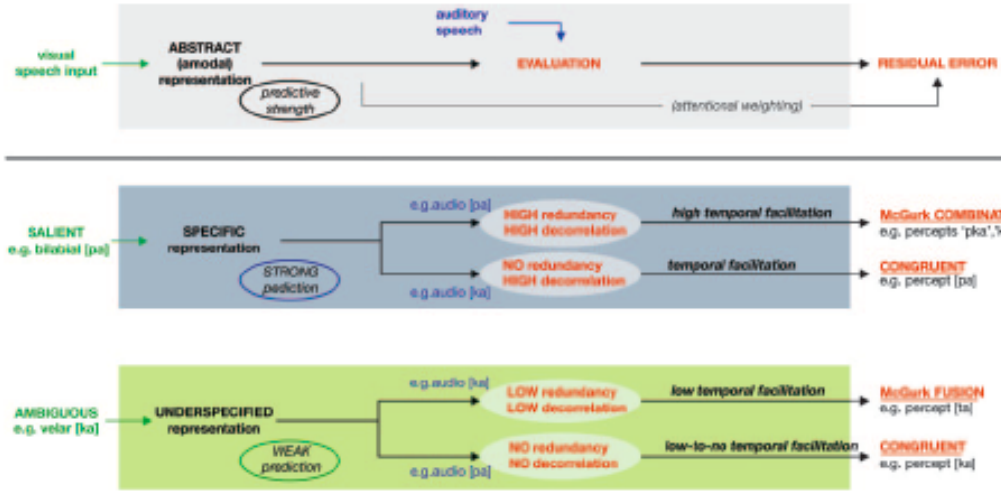
Predictive coding and analysis-by-synthesis approaches
for visual object recognition, speech recognition, language processing, and multi-sensory integration

How does the brain deploy (even very complex structured) knowledge to guide and constrain perceptual analysis in such a nuanced and extraordinarily rapid manner?

- **visual object recognition: Yuille & Kersten (2006). Vision as Bayesian inference: analysis by synthesis?**
- **speech perception: Halle & Stevens (1958, 1963). Analysis-by-synthesis as a program for research.**
- **language processing: Lau et al. (2006). The Role of Structural Prediction in Rapid Syntactic Analysis.**
- **multi-sensory perception: van Wassenhove et al (2005). Visual speech speeds up the neural processing of auditory speech**

[See also On Intelligence, J. Hawkins & S. Blakeslee, 2004]

van Wassenhove, AV speech



Halle & Stevens