Computational Psycholinguistics

Lecture 1: Introduction

Afra Alishahi

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(based on slides by Matthew Crocker)

What is Comp. Psycholinguistics?

- Using computational methods to model cognitive processes of language
- Study these processes through simulation
  - Evaluate existing theories of language understanding
  - Explain the observed human behavior
  - Predict behavioral patterns that have not been experimentally investigated
- Provide insight on how people process language

Areas of Comp. Psycholinguistics

- Speech perception and articulation
- Representation of the mental lexicon
- Lexical access and lexical choice
- Sentence processing: syntactic, semantic, pragmatic
- Situated language processing: interaction of language with task/context
- Embodied language processing: intertwining of language with other cognitive and perceptual systems

The Focus of This Course

- How we learn the knowledge of language: Human Language Acquisition
- How we use the acquired knowledge in developing an interpretation for a sentence: Human Sentence Processing

Human Language Acquisition

- Representation of the linguistic knowledge
  - What is innate, what is learnable?
  - How is the knowledge organized in mind and brain?
    - Are there separate areas/levels for representing lexical/syntactic/semantic knowledge?
- Acquisition of the linguistic knowledge
  - What are the processes involved in language learning?
  - Are different types of knowledge acquired in order?

Learnability in Acquisition

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Modularity in Acquisition

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Computational Lang. Acquisition

- Computational modeling of human language acquisition:
  - Providing cognitively plausible formalisms for representing linguistic knowledge
  - Developing algorithms that can acquire knowledge of language from exposure to linguistic data

Human Sentence Processing

- Construction of an interpretation for a sentence
  - How does the human language processor work?
  - How is it realized in the brain?
  - How does language interact with other cognitive systems and the environment?

Mechanisms in HSP

- Construction of an interpretation for a sentence
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Modularity in HSP

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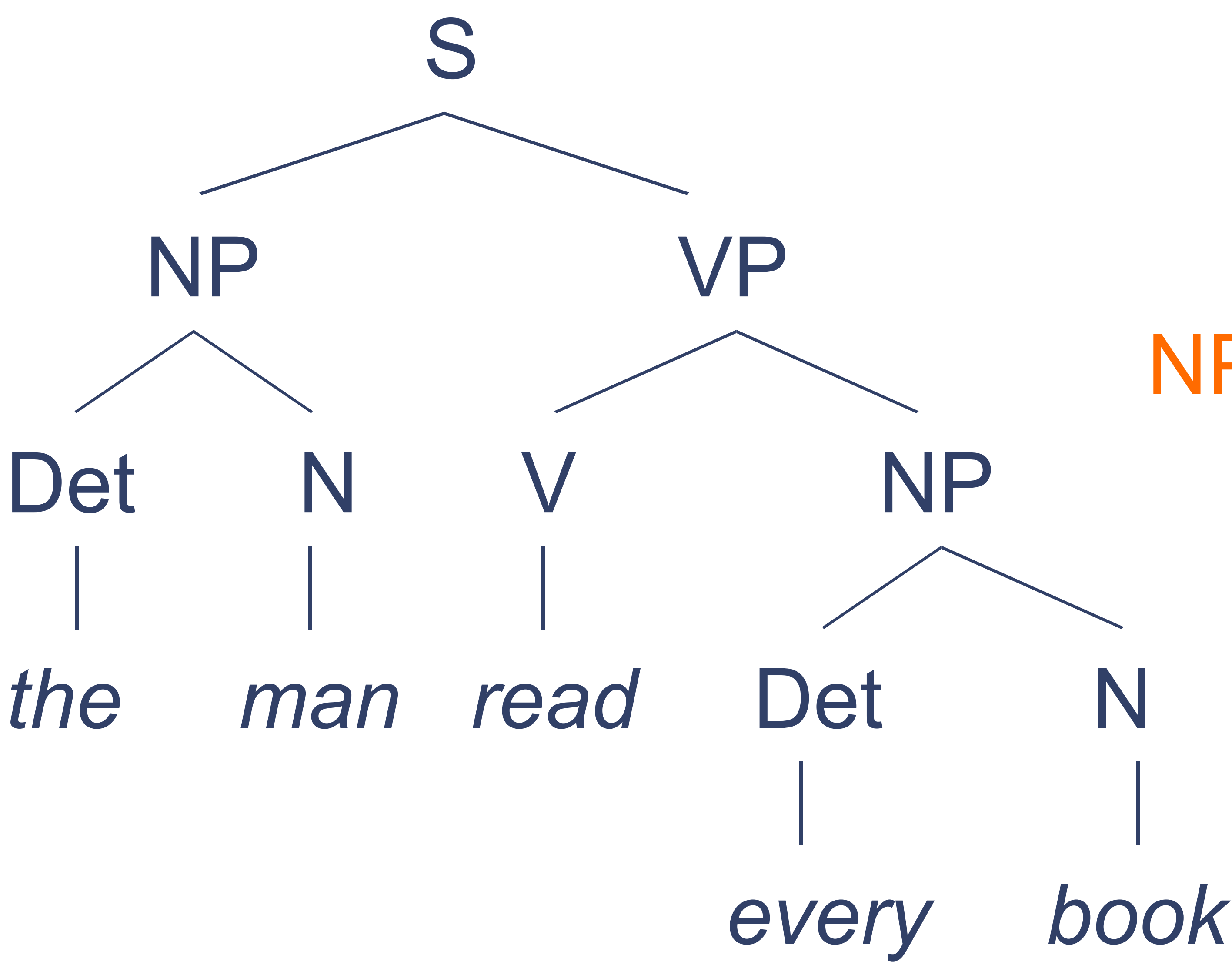
A Simple Example



S ➜ NP VP

NP ➜ Det N   VP ➜ V NP

NP ➜ Det N

Characteristics of HSP

- People are highly accurate in understanding language
- People process language rapidly, in real-time
- People understand and produce language incrementally
- People rapidly adjust to context, and are robust
- People achieve this despite limitations on processing resources

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Computational HSP

- Computational modeling of human sentence processing:
  - Development of algorithms that can
    - recover the intended meaning of a sentence from its spoken or textual realization
    - reflect the characteristics of human sentence processing

Acquisition vs. Processing

- How is acquisition related to processing?
- Competence: what it means to "know" a language
  - syntactic and semantic rules and representations provided by a linguistic theory
- Performance: how is such knowledge used on-line to recover the meaning for a given sentence
  - a psychologically plausible parsing algorithm

The Competence Hypothesis

- Assumptions:
  - Linguistic theory is isomorphic to human linguistic knowledge
  - Comprehension and production share same knowledge
- Variations
  - Weak competence: people recover *representations* that are isomorphic to those of linguistic theories
  - Strong competence: people *directly* use grammatical knowledge and principles of linguistic theories

Competence vs. Performance

The horse raced past the barn fell.

- The sentence is perfectly grammatical according to grammar rules (*competence*)
- Many readers are unable to recover the correct meaning (*performance*)
- Compare with:

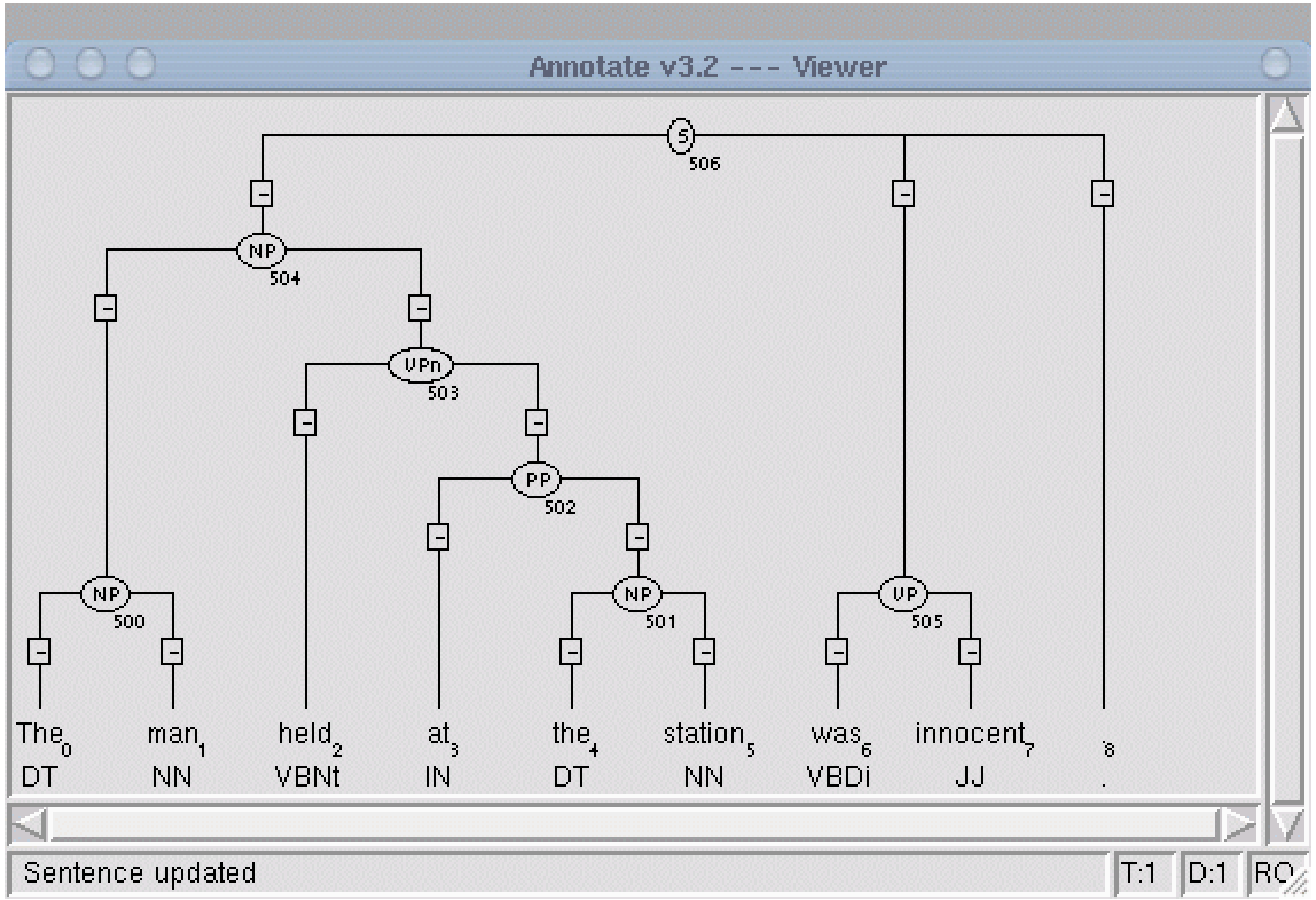
The patient sent the flowers was pleased.

Why Computational Modeling?

- Implemented models are essential because
  - human language processing is highly complex
  - it involves interaction of diverse linguistic and non-linguistic constraints
  - it is inherently a dynamic process: recovery of meaning happens in real-time and is influenced by various sources of information
- Computational cognitive models should conform to psychological plausibility criteria.

Psychological Plausibility

- Incrementality: interpretations and expectations are developed word by word

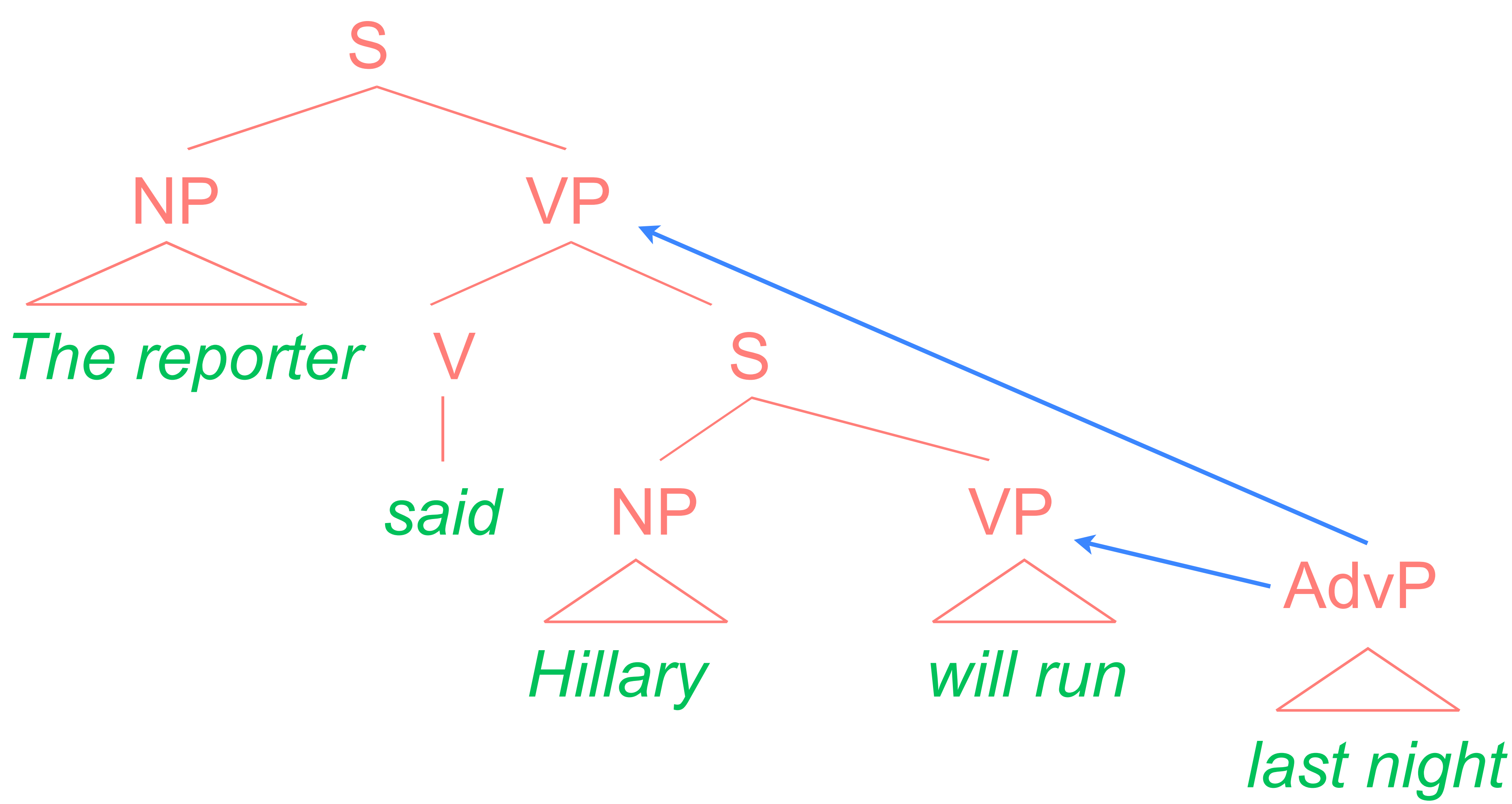


"The man held at the station was innocent"

Crocker & Brants, *Journal of Psycholinguistic Research*, 2000.

Psychological Plausibility

- Handling local and global ambiguity



Psychological Plausibility

- Memory limitations:

The mouse that the cat that the dog chased bit died.

[the mouse [that the cat [that the dog chased] bit] died]

Cognitive Modeling and NLP

- Early NLP (e.g. Winograd, 1983) viewed itself as building models of human understanding
  - Proposals were heavily informed by intuitions about how people understand language
  - Both shared assumptions regarding linguistic competence; concerned with developing algorithms which recover a linguistically adequate representation of a sentence as defined by current syntactic and semantic theories

Cognitive Modeling and NLP

- Modern NLP has shifted emphasis
  - Focus on applications: do limited tasks accurately and robustly, often without real understanding (e.g., spam filtering, document clustering, text summarization, ...)
  - Deep NLU emphasizes on representations, coverage and efficiency, and is not concerned with cognitive plausibility

Cognitive Modeling and NLP

- However, cognitive modeling of language is heavily informed by research in NLP
  - Human syntactic processing is influenced by computational linguistics, specifically natural language parsing
  - Computational modeling of language acquisition is influenced by machine learning techniques

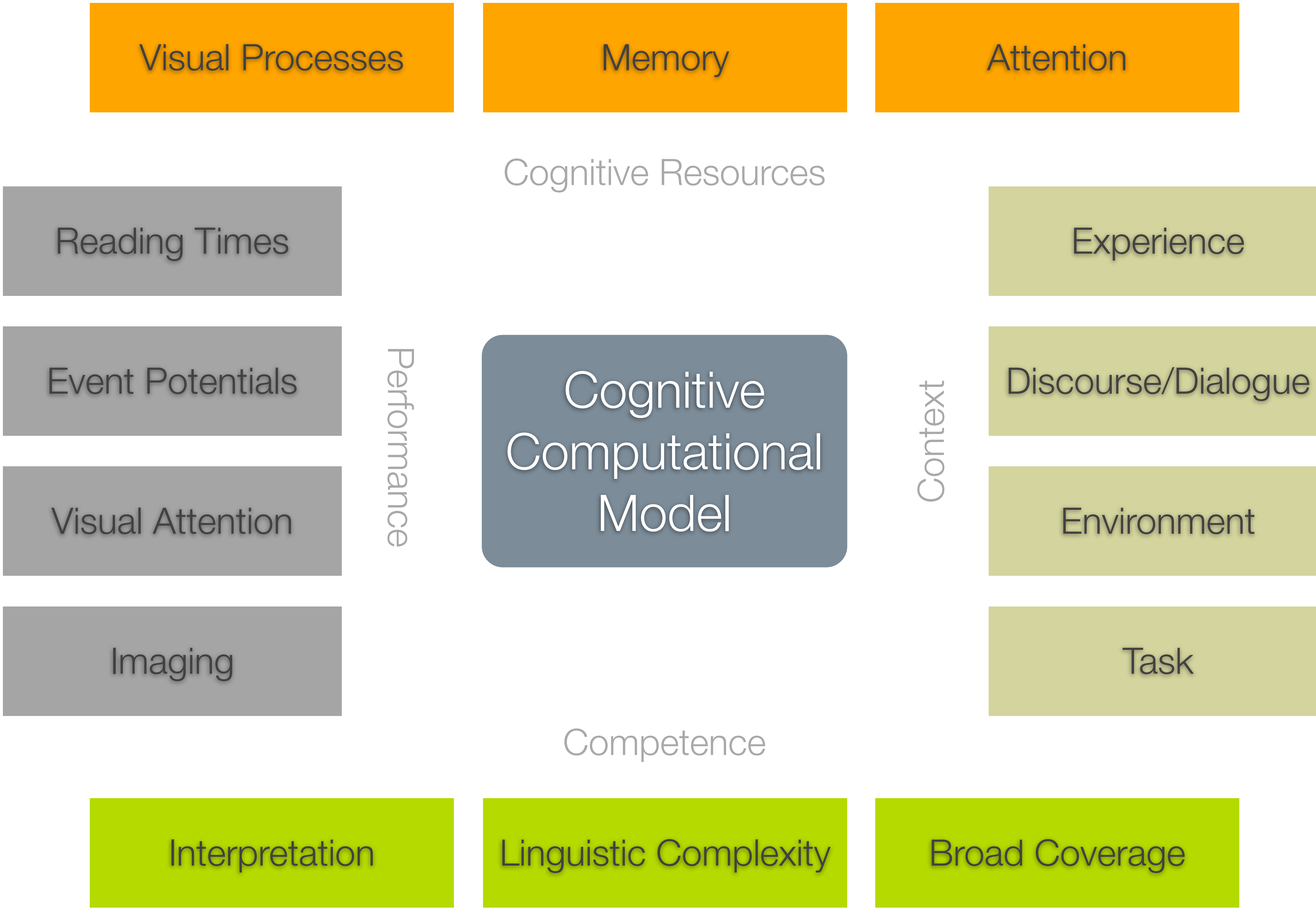
Cognitive Modeling: Evaluation

- Cognitive models cannot be solely evaluated based on their accuracy in performing a task
  - The behavior of the model must be compared against observed human behavior
  - The errors made by humans must be replicated and explained
- Evaluation of cognitive models dependents highly on experimental studies of language

Experimental Studies

- Collected data on child language development
  - CHILDES database (MacWhinney, 1995)

- Experimental methods
  - Reading times
  - Neuroscientific methods
  - Situated spoken sentence comprehension


Visual Processes
Memory
Attention
Cognitive Resources
Reading Times
Event Potentials
Visual Attention
Imaging
Performance
Cognitive Computational Model
Context
Experience
Discourse/Dialogue
Environment
Task
Competence
Interpretation
Linguistic Complexity
Broad Coverage

Marr's Levels of Modeling

- Theories often provide a relatively high-level characterization of a process
- Marr (1982) identifies three levels of describing cognitive processes:
  - Computational level: defines *what* is computed
  - Algorithmic level: specifies *how* computation takes place
  - Implementation level: states how the algorithms are actually *realized* in brain

What if the Model is Flawed?

(stated at computational level)

Theory

↓

Model

(built at algorithmic level, therefore details of processing have to be specified)

Modeling Paradigms

- Symbolic models
    - computationally well-understood, transparent with respect to their linguistic basis, and scalable
- Connectionist networks
    - inspired by the structure of brain, can learn from sufficient exposure to language, use distributed representations that are hard to interpret
- Probabilistic models
    - transparent linguistic basis, combined with an experience-based mechanism

Roadmap

- Modularity in acquisition and processing
- Experimental studies / methods
- Parsing mechanisms
- Handling ambiguity in parsing
- Probabilistic accounts of language processing
- Multiple-constraint accounts of language processing
- Language acquisition
- Connectionist models of acquisition and processing

Course Details

- Weekly lectures: Monday 14:00-16:00
- Weekly tutorials: Wednesday 14:00-16:00 (CIP Room)
- Assessment
  - Final exam: 100%, week of February 15
  - Make-up exam: mid April 2009
  - *Tutorial assignments must be completed to sit the exam*
- Course materials (lecture slides and most readings) will be made available on the course homepage