Mechanistic Developmental Process: Rumelhart Prize Symposium in Honor of Linda Smith

Participants

Larissa K. Samuelson (larissa-samuelson@uiowa.edu)
Department of Psychology and DeLTA Center
University of Iowa
Iowa City, IA, 52242

Anthony Morse (anthony.morse@plymouth.ac.uk)
Centre for Robotics and Neural Systems,
Plymouth University
Plymouth, Devon, PL4 8AA, UK

Chen Yu (chenyu@indiana.edu)
Department of Psychological and Brain Sciences
Indiana University
Bloomington, IN, 47405

Eliana Colunga (colunga@psych.colorado.edu)
Department of Psychology and Neuroscience,
University of Colorado Boulder
Boulder, CO, 80309

Thomas Hills (T.T.Hills@warwick.ac.uk)
Department of Psychology
University of Warwick
Coventry CV4 &AL UK

Organizer

Larissa K. Samuelson (larissa-samuelson@uiowa.edu)
Department of Psychology and DeLTA Center
University of Iowa
Iowa City, IA, 52242

Keywords: cognitive development; word learning; computational models; robotics; dynamic systems.

Motivation

Traditional views of cognition, cognitive development, and word learning have viewed knowledge as divorced from processes of perceiving and acting. Linda Smith has championed a dynamic, mechanistic, and process-oriented view of cognition and focused on questions of development. She has shown how knowledge is embedded in, distributed across, and inseparable from the processes of perceiving and acting in the world. In so doing, she has enabled a new understanding of the nature of cognition and of how new ways of thinking come to be. This Rumelhart symposium in her honor illustrates how this focus on developmental process changes the questions asked and our resulting understanding of cognition. The five speakers will examine the developmental process of word learning from different vantage points ranging from perceptual to social to cognitive, and spanning multiple periods from the first words to rapid vocabulary growth to the building of semantic networks.

Smart Behaviors from Simple Processes

Author: Larissa Samuelson

Abstract: The period between16-months and 3-years of age is one of rapid vocabulary growth and diversification. Children this age are often referred to as "amazing word learners" as they seem to know the whole category to which a new word applies after hearing one exemplar named one time. This perspective leads to theories of development couched in terms of innate knowledge structures and complex hypothesis testing. In contrast, this paper will present a view of development as the accumulation of small moments of knowing based on the specifics of the here-and-now that accumulate over longer timescales via simple associative processes. Data will illustrate how children use multiple sources of information such as the statistics of their vocabulary, associations in language structure, consistent space, and the relative novelty or familiarity of stimuli to solve language problems in a moment. Dynamic Neural Field and Hebbian Recurrent Network models will then be used to show that although children's behaviors look amazing, the processes that underlie them are not.

A Unified View of Early Word Learning: Linking social interaction to sensory-motor Dynamics in Child-Parent Interaction

Author: Chen Yu with Daniel Yurovsky

Abstract: Many theories of early word learning begin with the uncertainty inherent to learning a word from its co-occurrence with a visual scene. However, the relevant visual scene for infant word learning is neither from the adult theorist's view nor the mature partner's view, but is rather from the learner's personal view. To understand the mechanistic nature of early word learning, this talk focuses on micro-level behaviors as they unfold in *real time* in the dynamically complex interactions of child-parent interactions. We found that when infants interacted with

objects in play with their parents, they created moments in which a single object was visually dominant. If parents named the object during these moments of bottom-up selectivity, later forced-choice tests showed that infants learned the name. The sensory-motor behaviors of infants and parents were analyzed to determine how their actions on the objects may have created these optimal visual moments for learning. By studying the quality of parent-child social interactions at the sensory-motor level, the research provides a mechanistic understanding of the developmental dependencies between sensory-motor processes, social behavior, and language learning.

Body Posture and Constraints on Word Learning in Robots and Children

Author: Anthony Morse with Viridiana Benitez
Abstract: The starting point for many theories of word learning is the co-occurrence of the visual object being attended, and the spoken word, but in reality such cross-situational learning has many problems and is unreliable in ways that simply don't match the human data. For example, in a series of recent experiments Smith, Samuelson & colleagues demonstrate that children around 2 years old can learn object names in their absence so long as they are typically observed in consistent locations. We hypothesize that body posture is orchestrating this learning. In ongoing work with Linda Smith, we took this hypothesis literally placing the body centrally and binding ongoing multimodal experience via the body posture as a way to control the humanoid robot iCub, not only to replicate this data but to further generate predictions subsequently confirmed in further child experiments. With iCub we go beyond isolated cognitive modeling, embodying our system in real sensory and motor data, in a real interaction mirroring closely the setup of the psychology experiments. Based in spreading activation and self-organization our model tests and explores the role that the body plays in embodied cognition leading to a wider set of experiments in language learning. Finally we explore the role of competing systems (body and language), and simple learned skills in producing an explosion of word learning in an artificial robot.

Time Considered as a Helix of Precious Words: Modeling the Emergence and Interactions of Word Learning Biases

Author: Eliana Colunga
Abstract: Early word learning may be supported by a developmental feedback loop: the kind of words a child learns early on support the generalization of attentional biases, which in turn guides subsequent word learning. In a series of neural network simulations and a longitudinal behavioral study with toddlers in the lab, we explore the interactions between words learned and word learning biases, and argue that it is this interaction that builds the individual developmental trajectories children follow. First, we look at the development of the shape bias for solids and how its emergence is accompanied by an attentional shift in novel noun generalizations for other solidities, in both networks and toddlers. Second, we look at how the emergence of a shape bias for solids is related to a shift in rate of learning for different kinds of words – shape-based or material-based – in networks and toddlers. Third, we look at how these interactions follow different developmental patterns in typically developing children at risk for language disorders, so-called "late talkers". Finally, we discuss the implications of this approach in increasing our understanding of language disorders, as well as our ability to improve early diagnosis and the design of individualized intervention plans.

Growing Semantic Networks in a Sea of Words

Authors: Thomas Hills with Nicole Beckage
Abstract: Children learn language from exposure to a sea of words. The structure of this sea can be quantified using semantic space models applied to corpora of child-directed speech, which identify potentially meaningful statistical signatures from the company that words keep—including contextual diversity and associative structure (à la Saussure). At the same time, the words children learn can be characterized using computational models of growing networks of semantic information, with the edges between words based on semantic information embedded in the corpora. Our research has aimed at developing a quantitative theoretical account of early word learning based on the structure of the learning environment and the words children know—which we call the associative structure of child-directed language—and using this to predict the structure and growth of children's semantic networks over time. We have used this approach to predict the order of early word learning, to detect differences in typical and late talkers, and to predict differences in child versus adult-directed speech.