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Minimal Nativism: How does cognitive development get off the ground?

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When constructing a mind, what are the basic materials, structures and blueprints a young child has to work with? Are most of the structures already in place, with children merely working to embellish them? Do children begin with several buildings already in place (the Physics Building, the Social Building, the Number building, etc.), and only decorate a bit as they get older, perhaps building bridges between them using language? Such a view might describe a strong innate core hypothesis (Spelke et al., 1994). Or does the child begin with more of an empty plain, and an ability to construct whatever is necessary out of whatever materials are at hand at the time? Such a view might be more along the lines of classic empiricism (Quine, 1964).

Many other views are possible, lying somewhere between the extremes of positing that the child starts with everything, and positing that the child starts with nothing. For example, perhaps the child begins with a powerful general-purpose learning mechanism and a general blueprint for how to organize the world's entities into core domains, but no detailed, specific understanding of how these domains operate. Or perhaps the child begins with a powerful learning mechanism and a general blueprint for cognitive architecture, but no abstract concepts – only raw sensory experience. Yet if her sensory experience can be structured by a few crucial 'proto-concepts' - low-level input analyzers that tug her learning apparatus in certain appropriate directions – that minimal scaffolding could be sufficient.

Of course metaphors for cognitive development will only take us so far. In the last few years, a number of stimulating proposals for how cognitive development might get off the ground have been framed by computational modeling researchers, and these models offer to bring greater precision, clarity and subtlety to classic "nature versus nurture" debates. At the same time, recent empirical work with young children offers striking new data that both motivates and challenges these computational accounts. Our symposium brings together some of the researchers who have contributed to these developments from both computational and empirical perspectives (Goodman, Ullman, & Tenenbaum, 2011; Spelke & Kinzler, 2006; Tenenbaum, Kemp, Griffiths, & Goodman, 2011; Ullman, Harari, & Dorfman, 2012; Ullman, Goodman & Tenenbaum, 2010; Xu & Kushnir, 2012). Our goals are to survey the landscape of developmental possibilities across multiple domains of physics, psychology, number, geometry, and language; to bring recent models and empirical work into closer contact; and to confront, honestly and clearly, the deep challenges that remain unaddressed.

Our plan is to have four 15-minute talks, followed by a 30-40 minute discussion. **T. Ullman** will speak first, sketching out the space of potential approaches to a "minimal scaffolding" for cognitive development, and touching briefly on his own work modeling the development of intuitive physics, intuitive psychology, and the interface between these domains. **N. Goodman** will then present the "probabilistic language of thought" view – that an innate, abstract, domain-general, language-like ability for composing and manipulating conceptual representations is the minimal structure necessary for learning, potentially supplemented with specific 'named-functions' or input-analyzers for certain domains. **S. Ullman** will then expand on the notion of innate perceptual input analyzers, illustrating with a case study drawn from his recent work on computer vision systems that learn to identify and reason about agents and actions in real-world video. **E. Spelke** will approach these issues from the standpoint of her recent work on the development of space, number and other mathematical concepts. She will also provide a more general critical perspective on the various computational perspectives presented earlier. This will set the stage for our discussion, to be facilitated by **Tenenbaum** and **Spelke**, with the active involvement of audience participants as well as all our speakers.

Tomer Ullman: The theoretical landscape, and a case study in the origins of physical and psychological knowledge

Cognition can be viewed as a program, albeit an incredibly complex one. Cognitive development then is the process by which the mind moves from one program to another. I will introduce a range of approaches to modeling cognitive development as different takes on the problem of "program induction" or "program synthesis". I will argue for the value of beginning with abstract templates that can capture deep patterns common to the explanatory structure of theories in many domains. I will show how this approach provides insight into the development of children's first physical and psychological concepts, such as force and utility, as well as the interface between these domains. I will briefly speculate on how these templates might arise or grow over the course of development or evolution.

Noah Goodman: Minimal nativism and the language of thought

How much must be built into the language of thought? Universal formal languages can be built with a very small number of primitive operations, yet adult humans have a large number of conceptual operations ready-to-go for new situations. Indeed, developmental psychologists have argued that a significant and rich subset of these are innate primitives. I will argue that a universal language of thought together with a powerful learning mechanism is able to construct many of the needed concepts very quickly. However, I will find that some basic concepts can be learned more easily when supported by low-level modules that transform the perceptual input -- input analyzers. This combination cuts a middle road between strongly nativist and strongly empiricist view -- a minimal nativism.

Shimon Ullman: Bootstrapping from domain-specific 'proto-concepts'

Already in their first months of life, infants rapidly learn to recognize complex objects and events in their visual input. Two striking examples are the detection of agents' hands and their direction of gaze, properties which play an important part in understanding actions and goals (Woodward 1998, Flom et al. 2007). In computational schemes, these problems are notoriously difficult. In contrast, detecting hands and gaze direction, and using them to make inferences and predictions, are natural for humans, and appear early in development. I will briefly describe how these problems can be solved using a learning scheme guided by an empirically motivated innate mechanism – the detection of 'mover' events in dynamic images, which are the events of a moving image region causing a stationary region to move or change after contact. The implications go beyond the specific tasks, by showing how domain-specific 'proto concepts' can guide the system to acquire meaningful concepts, which are significant to the observer, but statistically inconspicuous in the sensory input.

Such proto-concepts may exist in other domains, forming a bridge between the notion of innate conceptual knowledge and that of learning mostly from sensory experience.

Elizabeth Spelke: The origins of spatial and numerical thinking

When children begin to learn arithmetic, measurement, and geometric symbols such as maps, what cognitive systems support this learning process? I propose that this process is supported by four domain-specific cognitive systems: two core systems of number and two core systems of geometry. These systems are present and functional at the time that a child or animal first encounters the entities on which they operate: in this strong sense, they are innate. The systems also remain functional throughout life and support mathematical reasoning in adults as well as children: in this sense, they are foundations of mature mathematical reasoning. But the systems are far less general or powerful than the formal mathematical systems that children come to acquire, including the systems of natural number and Euclidean geometry. Powerful, domain-general systems for representing the information delivered by core systems, and for forming new concepts from this information, therefore constitute a fifth foundation for mathematics.

This may be the general scheme for much of later conceptual knowledge: combining core domains that have isolated innate concepts using later maturing domain-general systems.

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