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Learning in core and non-core number domains

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ABSTRACT

Much early knowledge acquisition is domain-specific. Different knowledge structures are defined by different sets of principles. These serve to identify those data that belong to a given structure and exclude those that are irrelevant. Domain-specific structures direct attention to those aspects of experience that can be assimilated to the structure and thereby grow it. Core domains are defined by *a priori* skeletal structures.

Learning in non-core domains occurs later and is much more dependent on structured instruction because it must proceed in the absence of the skeletal structures that direct early learning. The distinction between core and non-core domains is developed with particular reference to representations of number and quantity, in animals, infants, young children, and adults. The role of language in humans is also considered. These content-rich ideas about mental structures are related to Piaget's general stage theory.

Core and non-core domains

A new account of cognitive development has come into being over the past 25 years, one that employs the notion of separate domain-specific mental structures (Carey & Spelke, 1996; Gelman, 1990, 1998; Gelman & Williams, 1998; Spelke, 2000). All who have adopted this move share the assumption that there are dedicated, mental structures that represent particular organized kinds of learning. I add the distinction between core and non-core domains to capture the fact that only some domains are represented in an innately given skeletal form. Core domains serve as the basis for learning the kinds of organized knowledge that occur early on the fly, given a potentially supporting environment. In fact, these skeletal structures serve to define what environments are relevant due to their active search

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and uptake of nurturing data. The idea of an active assimilation of relevant data is akin to the Piagetian assumption that the mind actively uses structure mapping between what is in the mind and data in the world that can be comparably organized. Therefore core domains constitute a class of learning tools that contrasts with the passive laws of association.

There is a fundamental developmental difference between core and non-core domains. Development of non-core domains is not driven by skeletal structures. These have to be created de novo. Their acquisitions depend on formal instruction, from teachers and the hard work of the learner. Individuals usually need to spend many years working on an organized understanding of the domain (Bransford, Brown, & Cocking, 1999; Gelman & Williams, 1998).

My emphasis on the role of potentially knowledge-rich structures in driving development in core domains is distinctly different from Piaget's commitment to general stages of learning and development. It was motivated by the accumulating evidence that preschool-aged children, and even infants, had more abstract knowledge than was assumed by stage theorists, like Piaget, and by traditional empiricist/associationist learning theorists. The Piagetian view that preschoolers are perception bound, pre-causal, pre-logical, and so on, did not comport with evidence of conceptual competence in this age group (Carey, 2009; Gelman, 1990; Gelman & Baillargeon, 1983; Spelke, 2000). Nor did the Piagetian view that infants are born with nothing but reflexes and various sensory abilities.

There is now much contrary evidence: Young infants treat objects as permanent and solid (Baillargeon, 1987; Carey, 2009); they abstract numerical and quantity information (e.g., Brannon, 2002; Kobayashi, Hiraki, & Hasegawa, 2005; Koechlin, Dehaene, & Mehler, 1997; McCrink & Wynn, 2004; Starkey, Spelke, & Gelman, 1990; Wynn, 1992; Xu & Spelke, 2000); and they reason causally (Bullock, Gelman, & Baillargeon, 1982; Gelman & Gottfried, 1996; Gopnik & Schultz, 2007; Kinzler & Spelke, 2007; Leslie, 1984). These experimental findings motivated my proposing that there exist core domains, and my more general, rational-constructivist view of early development.

In what follows, I first expand on the idea of core domains and then turn to consider non-core domains. This is followed by comments on domain-specific vs. domain-general processes and their possible interaction with core domains. I then turn to natural numbers, the principles that set them apart from other core domains, and evidence that they constitute a core domain. The principles that define this domain are already seen in the approximate number system, which humans share with a wide range of non-human animals. I have proposed that this system guides the development of young children's verbal counting and simple arithmetic with the natural numbers, but that it is an obstacle to, rather than a driver of, the development of an understanding of the rational numbers and algebra. Learning the rational numbers and algebraic reasoning are examples of learning in non-core domains because their principles do not map straightforwardly to the core domain of natural numbers (Hartnett & Gelman, 1998; Lorti-Foegues & Siegler, 2015; Smith, Solomon, & Carey, 2005).

Core domains

Core domains endow beginning learners domain-specific nascent organizations, each of which features different sets of skeletal structures. Since the mind is known to actively interpret data in terms of available structures, these skeletal structures will actively engage relevant data, that is, the kinds whose structure can map to the structure of a particular core domain. In other words, a domain's active search for, and uptake of, structure-matching data serves to "puts flesh" on the skeletal structure. Given a healthy infant in a typical social, cultural and physical environment, learning in core domains moves forward without formal instruction, on the fly, and universally. As each Core structure blossoms, ever more relevant examples of data are recognized and assimilated.

The well researched and widely recognized core domains are those that govern the perception of and reasoning about objects, natural numbers, causality, the animate vs. inanimate, language, and sociality (Baillargeon, Kotovsky, & Needham, 1995; Carey, 2009; Gelman, Durgin, & Kaufman, 1995; Gelman & Lucariello, 2002; Leslie, 1984; Sloane, Baillargeon, & Premack, 2012; Spelke, 2000; Shultz & Vouloumanos, 2010). While this is not an exhaustive list, it is generally assumed that the number of core domains is limited as compared to non-core domains. There is no initial skeletal structure of mind for the domains of calculus, physics, sushi making, jet-plane engineering, chess, and so on. The number of non-core domains is large and indeterminate and depends on whether learners are committed to