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Review

The Universal Generative Faculty: The source of our expressive power in language, mathematics, morality, and music

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ABSTRACT

Many have argued that the expressive power of human thought comes from language. Language plays this role, so the argument goes, because its generative computations construct hierarchically structured, abstract representations, covering virtually any content and communicated in linguistic expressions. However, language is not the only domain to implement generative computations and abstract representations, and linguistic communication is not the only medium of expression. Mathematics, morality, and music are three others. These similarities are not, we argue, accidental. Rather, we suggest they derive from a common computational system that we call the *Universal Generative Faculty* or UGF. UGF is, at its core, a suite of contentless generative procedures that interface with different domains of knowledge to create contentful expressions in thought and action. The representational signatures of different domains are organized and synthesized by UGF into a global system of thought. What was once considered the *language of thought* is, on our view, the more specific operation of UGF and its interfaces to different conceptual domains. This view of the mind changes the conversation about domain-specificity, evolution, and development. On domain-specificity, we suggest that if UGF provides the generative engine for different domains of human knowledge, then the specificity of a given domain (e.g., language, mathematics, music, morality) is restricted to its repository of primitive representations and to its interfaces with UGF. Evolutionarily, some generative computations are shared with other animals (e.g., combinatorics), both for recognition-learning and generation-production, whereas others are uniquely human (e.g., recursion); in some cases, the cross-species parallels may be restricted to recognition-learning, with no observable evidence of generation-production. Further, many of the differences observed between humans and other animals, as well as among nonhuman animals, are the result of differences in the interfaces: whereas humans promiscuously traverse (consciously and unconsciously) interface conditions so as to combine and analogize concepts across many domains, nonhuman animals are far more limited, often restricted to a specific domain as well as a specific sensory modality within the domain. Developmentally, the UGF perspective may help explain why the generative powers of different domains appear at different stages of development. In particular, because UGF must interface with domain-specific representations, which develop on different time scales, the generative power of some domains may mature more slowly (e.g., mathematics) than others (e.g., language). This explanation may also contribute to a deeper understanding of cross-cultural differences among human populations, especially cases where the

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generative power of a domain appears absent (e.g., cultures with only a few count words). This essay provides an introduction to these ideas, including a discussion of implications and applications for evolutionary biology, human cognitive development, cross-cultural variation, and artificial intelligence.

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1. Introduction

The ideas developed in this essay grow out of several different intellectual traditions within the formal and cognitive sciences. Broadly speaking, we are interested in what enables human minds to generate a limitless range of ideas and expressions across many different domains of knowledge. To what extent is this facility enabled by domain-general or domain-specific mechanisms? To what extent are these facilities shared with other organisms and to what extent are they uniquely human? To what extent are the generative mechanisms that operate in different domains of knowledge the same or different, and why? What accounts for the developmental timing and maturation of different domains of knowledge? And could the creative, generative power of human intelligence be realized in computing machinery? This essay provides an introductory sketch of an idea that, we believe, helps shed new light on these fundamental questions.

2. Different traditions of thought

One tradition that not only launched many of the questions noted above, but developed a significant position on the answers, is Chomsky's (1955; 1995) work in linguistics, and the nature of mind more generally. The argument, in brief, is that humans are endowed with a finite cognitive computational system that generates an infinity of meaningful expressions. This is a linguistic system or faculty, with unique — specific to our species and the domain of language — recursive procedures that interface with both the conceptual-intentional (semantics/pragmatics) and sensory-motor (phonology/phonetics) systems to generate hierarchically structured representations. This intensional system — I-language — is internal to an individual, and is often described as forming a language of thought. The sets of expressions this system enumerates have been described (not by Chomsky) as E-languages (e.g., English, French, Japanese, etc.).

Based on Chomsky's linguistic framework, some have argued that language enables the expressive power of all other domains, and in many cases, provides the cognitive glue across domains. Thus, for example, Spelke (2016) has argued that what enables us to integrate different domains or modules of thought, including aspects of space and number, is language. In a classic set of experiments (Hermer & Spelke, 1994; 1996) on spatial reorientation following disorientation, young children appear incapable of integrating information about landmarks with information about the geometry of the space, a result that parallels those originally carried out on rats (Cheng, 1986). Such integration only occurs when children acquire spatially-relevant words (e.g., *right of, in front of*), the linguistic glue that integrates information from the landmark and geometry systems. Moreover, the flawless performance of adults was reduced to that of young children and rats when they were required to carry out a verbal shadowing task, one that effectively blocks access to the language faculty. This perspective sets up language as both the generative machinery of thought and the system that enables interfaces across domains. Similar ideas have inspired models of artificial intelligence in which the human-like AI understands the world by using linguistic machinery to combine commonsense knowledge with perceptual (particularly visual) representations in the form of explanatory "stories" (Winston, 2012).

Other traditions recognize the generativity of language, and in some cases, acknowledge what may be its unique computations, but argue that other domains of thought and expression are also generative: a generative system being a finite computational procedure for *explicitly* enumerating (potentially infinitely many) expressions; the most interesting expressions being in some sense "meaningful". For instance, Monti and Osherson (2012) as well as Dehaene, Meyniel, Wacongne,