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# Biology and Beyond: Domain Specificity in a Broader Developmental Context

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**Key Words**

Biological thought · Cognitive constraints · Conceptual development · Culture · Domain specificity

**Abstract**

The assumption of domain specificity has been invaluable to the study of the emergence of biological thought in young children. Yet, domains of thought must be understood within a broader context that explains how those domains relate to the surrounding cultures, to different kinds of cognitive constraints, to framing effects, to abilities to evaluate knowledge and to the ways in which domain-specific knowledge in any individual mind is related to knowledge in other minds. All of these issues must come together to have a full account of conceptual development in biology.



There has been a surge of research in recent years on the emergence of biological thought, much of it elegantly reviewed by Inagaki and Hatano [2002]. Biological thought has proven to be an especially fertile area of research because of the ways in which it brings together so many key issues concerned with how our concepts develop within larger sets of beliefs. One central theme has been domain specificity [Keil, 1981; Wellman & Gelman, 1992; Hatano & Inagaki, 2000]. A focus on bounded domains of thought, such as folkbiology, folkpsychology, or folkphysics has proven to be a highly fruitful research strategy, as the structure of knowledge in a particular domain provides insights into learning and representations and into how those psychological processes connect with causal and relational structures in the world. In many areas, discussions of concepts and conceptual development are almost incoherent without anchoring those discussions in domains. There are now several detailed discussions of how the distinguishing properties of the living world

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and of thought about those properties might lead to distinct cognitive domains [Atran, 1998; Hatano & Inagaki, 1994; Inagaki & Hatano, 2002; Keil, 1992, 2003]. Here, I consider how these central domain-specific ideas interact with other processes that go beyond the normal sense of domain. I use as a model the work of Giyoo Hatano, who brilliantly showed how discussions of domain-specific processes and representations must be linked up to more domain-general cognitive and sociocultural issues.

The following issues intersect with the study of domain specificity: the role of embedding cultures, the influences of a priori constraints, the roles of framing effects, the ability to evaluate the quality of knowledge, and the social interdependence of knowledge structures. Each of these is considered here in reference to the development of biological knowledge.

## Embedding Cultures

Conceptual domains are embedded in cultures that have strong influences on their natures, boundaries, and level of differentiation. Views ranging from those heavily emphasizing social construction of reality to those stressing universals of biological thought across all cultures all have to acknowledge cultural influences. Recent work, however, goes further by showing how the domain of folkbiology interacts in specific ways with different cultures. The growth of biological knowledge across cultures reveals a common ground and areas of cultural variation. For example, young children in many, if not all, cultures know that animals, plants and inanimate things are fundamentally different kinds of things with different properties. Yet, these children also show considerable cultural variation in the extent to which they attribute biological properties to categories such as plants [Hatano, Siegler, Richards, Inagaki, Stavy, & Wax, 1993]. Local cultures can refine and expand knowledge [Hatano & Miyake, 1991], and a simple activity such as caring for a goldfish can enhance aspects of biological thought [Inagaki, 1990]. Similarly, as some cultures advance in understandings having to do with Western urbanization, they may also lose insights into the natural world. Thus, there are 'devolutions' of biological knowledge in urban children compared to rural children in the same society or to those in more traditional cultures [Atran, Medin, & Ross, 2004].

These new lines of work acknowledge real structure in the causal and relational regularities of living things, a structure that is largely distinct from other sorts of natural and artificial kinds. In this way they depart from older views emphasizing complete social construction of reality. We further see how cultural practices and beliefs interact with those structural patterns, and how each of those in turn interact with cognitive biases and constraints [Hatano, 2005]. Some patterns are so robust, such as the distinctions between plants, animals and inanimates, as to be extremely salient in all cultures. Similarly, there may be a powerful tendency to see living kinds as part of unique and richly structured taxonomy [Atran, 1998]. Yet the details of that taxonomy, and indeed the level of detail at which people find it the most natural to reason about kinds, may vary as a function of culture and expertise.

We do not simply want to equate culture with expertise [Hatano, 2005]. Thus, people who achieve great expertise within a culture differ from laypeople in their folkbiology [Medin, Ortony, Lynch, Coley, Ross, Atran, Burnett, & Blok, 2002], differences that reflect a process of being ever more sensitive to some aspects of real-world structure. Cultures can also have such an effect, but more often they probably increase sensitivity to one facet of causal and relational structure, such as ecological relations, at the expense of another, such as molecular mechanistic ones [Medin et al., 2002]. It is not yet clear if cultures must make some sorts of trade-offs because of cultural cognitive capacity limitations on just how many fully articulated interpretative schemas a culture may bring to the same phenomena. Perhaps one culture can have different and highly differentiated sets of interpretative systems for the same phenomena that are triggered by different contexts, such as the sacred, the mundane and the interpersonal.

## The Influences of Constraints

Any consideration of the conceptual change within the domain of biology must consider the sorts of constraints that guide change in that domain. One set of such constraints are domain-specific [Chomsky, 1975; Keil, 1981]. With respect to biology, these would be limitations on the structure of biological thought not seen in other domains. The possibility of domain-specific constraints on folkbiology remains an area of active exploration. Some possible constraints might be: (1) a tendency to see biological kinds as embedded in unique hierarchies [Atran, 1998], in contrast to other kinds such as artifacts that can be in several hierarchies at once; (2) a tendency to assume that while animal parts can have purposes, as whole entities they cannot (e.g., tigers are not for any thing, but tools, such as hammers, are [Greif, Kemler-Nelson, Keil, & Guiterrez, 2006]), and (3) a tendency to imbue living things with vital forces [Inagaki and Hatano, 2006]. It is possible to think of constraints as being directly linked to representations, as has been the case in discussions of constraints on syntactic knowledge [Chomsky, 1975]. Alternatively, one can see constraints as arising from learning mechanisms [Hatano & Ingaki, 2000]. These two alternatives may in fact be complementary. Thus, if a learning mechanism is biased towards certain kinds of information and if it processes that information in ways that yield knowledge structures with a characteristic pattern, that pattern might well be described as a constraint on knowledge representations. In both cases, the constraints are on classes of representations and do not directly code for a particular knowledge and thus are not making statements about specific beliefs or concepts as being innate.

These domain-specific constraints are normally thought of as intrinsic to a child's cognitive architecture. In addition, domain-specific constraints might arise through early learning. Thus, a child's encounters with certain animals might lead the child to develop biases about animals in general, biases that could therefore influence later learning. In addition, knowledge transmitted to the child through the culture can also come to have a domain-specific constraining role [Hatano & Ingaki, 2000].

Domain-general constraints can interact with all forms of domain-specific ones to further guide the course of learning and the ultimate character of mental representations. These constraints can range from those that guide patterns of error feedback in learning, such as the connectionists' delta rule, to biases to prefer some kind of logical operations (conjunction) over others (disjunction) [Hatano & Suga, 1977].

All too often, researchers act as if domain-general constraints on learning are in competition with domain-specific ones, when in fact they should be seen as complementary.

Biological thought has proven to be an especially valuable arena in which to study the various kinds of constraints and their interactions. It illustrates how all kinds must be taken into account for an adequate model of development. In addition, detailed studies of biological thought suggest new ways in which domain specificity might emerge. Consider for example, the tendency by children to engage in both essentialist [Gelman, 2003] and functional [Keleman, 1999] stances. Neither of these alone is uniquely applied to biology, since chemical elements and compounds can have essences and because functional descriptions can apply to artifacts. Yet, the two modes of interpretation in concert very nicely pick out the domain of biology [Keil, 1992]. We therefore start to see how the intersections of two broader domains of constrained thought can yield a new much more specific domain. If living kinds somehow elicit both essentialist and functionalist interpretations, then biological thought might have a unique structure arising from the intersection of both forms of interpretation.

The level of restriction imposed by constraints is also a critical issue. Thus, domain-specific constraints could range from the ones that specify in great detail the format of knowledge structures in a domain to the ones that provide much gentler, skeletal constraints. It may be that, for biological thought, the domain-specific constraints present at the start of conceptual development are so abstract and skeletal in nature that they must be heavily supplemented by local sociocultural constraints to be able to sufficiently enable learning and an appropriate degree of cultural consensus [Hatano and Inagaki, 2005].

## Framing Effects

The study of conceptual change in biology has also made salient the importance of framing effects. In particular, the same class of entities can often be fruitfully understood within more than one interpretative system [Schult & Wellman, 1997]. Living kinds can be understood as brute physical objects and thus interpreted in terms of a physical mechanics. They can be understood as intentional agents and thus interpreted in terms of a naïve psychology. They can also be understood as living kinds and interpreted in terms of a naïve biology. Each interpretation will lead to its own inferences and conclusions as well as biased construals of information.

In addition, even in the realm of biology itself, there can be different interpretative schemes, such as adopting an ecological/adaptive stance or adopting a mechanistic/reductionist one. One can, for example, explain how some flowers follow the sun over the course of the day in terms of the functional value of keeping their faces pointed in that direction or in terms of how light falling on the tissue of those plants causes heliotropism by activating certain potassium pumps that enlarge cells on one side of the plant more than others. Both accounts explain the behavior, they just do so in very different ways.

Multiple systems of explanation offer quite different accounts of what develops. In the realm of biology, it has been suggested that younger children understand animals exclusively in terms of a naïve psychology and only use a naïve biology in the middle elementary school years [Carey, 1985]. This claim has been suggested by developmental shifts in inductions about properties [Carey, 1985]. However, when the presence of multiple systems is considered, a very different account of conceptual development emerges. Young children might make inductions about the properties of animals on the basis of psychological similarity not because they can only understand animals in such terms, but rather because they tend to favor that system first in that experimental setting, a kind of framing effect. If so, then changing the framing might suddenly get them to make judgments in a biological way. That is exactly what happens when children are given brief framing statements designed to trigger biological thought [Gutheil, Vera, & Keil, 1998].

Cultures as a whole and areas of expertise can have similar framing effects. Thus, many young children will first make inductions on a biological basis [Ross, Medin, Coley, & Atran, 2003]. In particular, both native American children and majority culture rural children (presumably with greater expertise in biology) make property inductions on a folkbiological basis rather than a folkpsychological one. This effect was anticipated many years earlier in pioneering work looking at how children can be quite flexible in their use of personification in making analogies [Inagaki & Hatano, 1987].

## Evaluating Knowledge

A key part of conceptual development is the ability to evaluate knowledge. If one can see gaps in one's understanding, one can know better when and how to seek out further information, either from direct interactions with the world, or through interactions with other people. The ability to think about knowledge is part of the broader area of metacognition, an area of psychology that has been studied for many years [Kuhn, 2000]. More recently, however we are beginning to see the importance of metacognition in relation to domain specificity. One early glimpse into this process came in a seminal paper that led to the notion of adaptive expertise [Hatano & Inagaki, 1986]. Adaptive expertise is the ability to use expertise in novel, adaptive ways. It seems to critically involve a metacognitive component that enables the expert to step back and put some distance between himself and the task and evaluate it more objectively in terms of the novel situation and the domain of relevance [Hatano & Inagaki, 1986].

A great deal develops with respect to this metacognitive skill during the preschool and elementary school years. Although there are rudiments of metacognitive skills well before kindergarten, younger children do show striking deficiencies. For example, they tend to believe that information they have recently learned is in fact information they have known all along [Taylor, Esbensen, & Bennett, 1994]. They also have difficulty understanding that theories are subjective [Kuhn, 2000; White & Fredericksen, 1998]. Children also share with adults a striking inability to realize just how shallow their understandings are, which is sometimes called an illusion of explanatory depth [Rozenblit & Keil, 2002; Mills & Keil, 2004].

At the same time, young children are starting to be able to take a somewhat more critical attitude towards knowledge. They ask questions, an activity that not only reveals a sense of not knowing but that also helps create a richer sense of the adequacy of current knowledge [Inagaki & Hatano, 1974]. They have a sense that some information, such as that about supernatural beings, which is acquired through the testimony of others, is likely to be less reliable than other testified information, such as that about germs [Harris & Koenig, 2006].

We are beginning to see the importance of such evaluative attitudes to folkbiology. As children start to appreciate the role that knowledge plays in furthering understanding, they also start to be able to look at knowledge as a distinct system and ask how it relates both to the real world and to the minds that create and use that knowledge. In the case of biology, this means that children start to have a sense of what a coherent domain of thought is that is distinct from other domains. Young children have a sense that there is a bounded domain of biology-related understanding that some people are likely to be more expert in than others [Lutz & Keil, 2002; Danovitch & Keil, 2004]. They have an emerging sense of the division of cognitive labor and that there is a distinct division corresponding to biology. The study of metacognition is undergoing a resurgence as it is considered not simply in a domain-general way but rather in a more focused manner in specific domains, such as folkbiology, a focus that can also include the metacognitive awareness of teachers [Lin, Schwartz, & Hatano, 2005].

### The Social Interdependence of Knowledge Structures

As children come to understand the limits of their own understanding, they start to learn how to rely on knowledge in other minds, how to defer to that knowledge and to not have to possess it all directly. This strategy of 'outsourcing' certain details of explanatory understanding is in fact a hallmark of all cultures [Keil, 2006]. None of us knows all the details of how everything works. Even in a highly focused area of studies, scientists must rely on a distributed web of other experts to fully back up their beliefs.

A critical part of a developing skill at grounding one's own knowledge in a larger network of supporting expertise may be the process of comprehension [Hatano & Inagaki, 1991; Hatano, 1998]. This process usually involves negotiations, often implicit, of who will be a resource of a certain kind of knowledge. We know that adults can implicitly negotiate exquisitely sophisticated patterns of sharing and interdependency in groups that have a common mission such as flying a large airplane or steering a large ship [Hutchins, 1995]. Young children may similarly learn to rely on networks of others to understand the complex natural and technological worlds around them [Cole & Derry, 2005].

Biological knowledge in any single mind can only be considered a small fragment of the knowledge in other minds on which it must depend. For example, young children not only have assumptions about animals having distinct essences, they also are likely to have assumptions that there are others who can actually say what those essences are. Moreover, they may even have some sense of which sorts of people are likely to be experts on biology essences [Lutz & Keil, 2002]. The same holds for many other areas beyond essences, such as having a crude sense of vitalistic causality but feeling confident about that sense because one feels it is grounded in knowledge, known by others, about innards and how they work [Gelman, 1990].

## Conclusion

How can the virtues of a domain-specific approach to folkbiology be interwoven with other themes involving culture, constraints, framing effects, knowledge evaluation, and the social distribution of knowledge? One might despair at the prospect of ever being able to tie all these themes together. Giyoo Hatano, however, repeatedly made such integrations in extraordinary ways throughout his distinguished career, as seen by his papers cited here. Taken together as a body, these papers (and many others by Hatano) illustrate how to achieve such an integration. All of us in cognitive science are deeply indebted to Giyoo Hatano for realizing, long before the rest of us, the great value of this broader perspective on conceptual development.

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