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# **Proceedings of the Annual Meeting of the Cognitive Science Society**

### **Title**

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### **Permalink**

<https://escholarship.org/uc/item/16h106w6>

### **Journal**

Proceedings of the Annual Meeting of the Cognitive Science Society, 27(27)

### **ISSN**

1069-7977

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### **Publication Date**

2005

Peer reviewed

# Solutions to Fodor’s Puzzle of Concept Acquisition

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Our goal is to engage workshop participants in a dialectic on *Fodor’s Puzzle of Concept Acquisition* (Fodor 1975, Laurence and Margolis 2002), focusing on the following interrelated questions:

- Can a person ever acquire a new conceptual primitive? If so, how?
- How might a child expand the combinatorial expressive power of his or her representational system?
- How might a child expand his or her hypothesis space of possible word meanings?

This workshop will present and discuss admissibility of solutions from a diversity of perspectives:

Development:	Dedre Gentner Alison Gopnik Frank Keil Jean Mandler Jesse Snedeker
Computation:	James L. McClelland Sourabh Niyogi Timothy T. Rogers
Philosophy:	Jerry Fodor Stephen Laurence Eric Margolis

We hope that the insights gained from studies of cognitive development (Mandler 1992, Gentner 2003, Mandler 2004, Keil 2003, Gopnik et al 2004) and computational models of learning (Rogers and McClelland 2003, Niyogi 2005) may be reconciled with the puzzle raised earlier and tested for admissibility (c.f. Piatelli-Palmarini 1980, Fodor 1998).

## Viewpoint Abstracts

### Baptism

*Jerry Fodor*

Despite various differences of formulation, all (nonbehavioristic) accounts of concept learning, both in philosophy and in psychology, suppose that it exhibits the familiar characteristics of nondemonstrative inferences. In particular, it requires a body of “data” specifying positive and negative instances of the extension of the concept to be acquired; there must be a source of “hypotheses” specifying candidate identifications of that concept (i.e. candidate identifications of what the positive instances have in common), and some sort of “confirmation metric” that decides which of the candidates the data best support. The present issue concerns the vocabulary in which the hypotheses are formulated. On the one hand, on pain of circularity, it cannot itself be acquired by the process of concept acquisition in which it is exploited. On the other hand, it must be rich enough to specify a correct candidate hypothesis for each concept that the acquisition mechanism can learn. In traditional theorizing (e.g. in Hume) these conditions were reconciled by assuming that the primitive concepts in which candidate hypotheses are formulated are all innate, a conclusion that seems to be demanded if circularity is to be avoided. Traditional formulations generally assumed that most concepts can be identified in the vocabulary of a relatively small primitive basis. (Hume holds (i) that all the concepts that can be learned at all can be reduced to constructions out of sensory concepts and (ii) that the sensory concepts are themselves innate.) I take it that Hume was right about the logic of the situation; the assumption that the base concepts are innate is unavoidable. But it now seems that he was wrong about the prospects for conceptual reductions; it now appears that very few concepts are reducible any others, sensory or otherwise. The required conclusion seems to be that our conceptual repertoire must be largely unlearned. This should be viewed not as a paradox but as a straightforward inference from the principle that the mechanism of nondemonstrative inference is hypothesis formation and confirmation.

## Analogical Learning

*Dedre Gentner*

Analogy is a general learning process by which abstract knowledge can arise from experience. Structure-mapping processes foster learning and conceptual change in at least four ways: they highlight common relational systems; they promote inferences; they call attention to potentially important differences between situations; and they lead to re-representations that maximize common structure.

Most prior work focuses on analogy as a means of importing knowledge from a well-understood case to a less familiar one, by aligning the structures and projecting further inferences. This kind of mechanism is important in learning, but it cannot explain the origins of human learning without postulating some initially well-structured knowledge. I focus here on another form of analogical learning – *analogical encoding* – in which comparison between two partly understood situations results in better understanding of both. This occurs partly through normal alignment processes, which naturally act to promote common connected relational structure over more local matches. In addition, re-representation of initially context-specific predicates can lead to a more abstract relational structure and to a more uniform internal relational vocabulary.

Two further points are that (1) structure-mapping operates even over close literally similar pairs to boost the salience of relational structure, which means it can operate very early in learning; and (2) the scope of analogical processing is greatly amplified by language learning. Hearing a common label invites comparison between the referents, and the resulting process of alignment and mapping can influence the meaning derived for the term. Specifically, I hypothesize that learning relational terms potentiates developing relational concepts – a class of concepts that is central to abstract thought and that is notoriously late in development. Studies of children and of nonhuman primates lend support to this contention. In sum, mutual facilitation between analogical processing and language learning acts to bootstrap learning.

## A new solution to the problem of induction: Bayes nets, causal learning, and theory formation

*Alison Gopnik*

How can we induce novel concepts rationally from patterns of evidence? Fodor’s classic challenge is part of the larger challenge of providing a rational epistemology for science. It takes the classic problem that we lack a “logic of discovery” for science and applies it to the broader problem of conceptual development. The “theory theorists” reply to this challenge in the past has been that children solve it however it is that scientists solve it – admittedly not a very satisfying answer. However, recent developments in philosophy of science and statistics provide a route to answer this question more precisely. Work within the causal graphical models or Bayes net formalism has shown that, given certain quite general assumptions, it is possible to rationally induce

causal relations among variables from patterns of conditional probability and intervention in the data – indeed automated systems have been designed that do just that. Moreover, our work has shown that very young children implicitly make similar assumptions, and can normatively infer causal structure from evidence. This work is relevant to conceptual structure in two ways. First, many accounts of concepts suggest that concepts should be defined in terms of their inferential role – their inferential relations to other concepts. Causal relations are a particularly rich source of inferential relations, and in some sense, learning new causal relations between a concept and other concepts means creates a new concept. More crucially, however, causal Bayes nets provide algorithms for inferring novel unobserved variables from data in certain circumstances. Certain assumptions provide a direct rational basis for creating new concepts. I will report work showing that adults and children infer novel unobserved variables in this way (Kushnir et al, in press, Gopnik and Nazzi 2003)

## The Hidden Strengths of Weak Theories

*Frank Keil*

The solution to Fodor’s puzzle may lie in rethinking the nature of intuitive theories. This rethinking causes notions of conceptual change, psychological essentialism and deference to all shift in ways that relate to the puzzle. Intuitive “theories” may be far sparser than they first appear in both adults and children, so sparse that they couldn’t possibly be the basis for distinguishing most kinds. We may often confuse the possession of such theories with the ability (shown even in preverbal infants) to track highly abstract causal and relational patterns and the ability to link these patterns to broad domains in ways that enable people to frequently override mere typicality of features in making judgments about categories and their members. Our expanding knowledge of these patterns may not represent coherent theory change, as much as it represents ever more sophisticated abilities to understand how essences are causally linked to phenomenal properties and to appropriate groups of experts. By deflating theories in this manner, it may be possible to avoid some of the problems with concepts as being comprised of richly detailed and theoretical structures, while also raising the possibility that the abstract and skeletal concepts of infants can provide a foundation for the concepts that older children and adults come to possess.

## Expanding your mind

*Stephen Laurence and Eric Margolis*

Fodor’s argument for radical concept nativism amounts to the challenge of showing how a primitive concept can be learned. As we see it, the way to meet this challenge is to start with a theory of content that applies to primitive concepts e.g., a causal theory of content of the kind that Fodor himself is well-known for championing. We will argue that such a theory requires sustaining mechanisms to mediate between concepts and the properties they express and that explaining how con-

cepts are learned amounts to explaining how these sustaining mechanisms are established in light of experience. We will give a few examples that illustrate how the process works. If there is time, we may also contrast our response to Fodor’s position as outlined in his book *Concepts: Where Cognitive Science Went Wrong*.

## How concepts get started

*Jean Mandler*

We can’t answer Fodor’s puzzle of concept acquisition without asking how concepts are actually learned. Developmental data are informative here, especially how infants do it, because their conceptual learning precedes language learning (which can muddy the issue) and is foundational for later new acquisitions. To my knowledge there is no evidence to support the idea that infants form concepts on the basis of hypothesis formation and testing, as Fodor suggests is required for concept learning. Instead, I suggest, they make use of an attentive, analytic mechanism (which I call Perceptual Meaning Analysis) to generate abbreviated descriptions of their perceptual observations. The outputs of PMA are not hypotheses, but redescrptions of what has been observed. The viability of this view rests in part on the evidence that the first concepts about objects are at a broad global level, such as animal and inanimate thing, a level that only gradually becomes subdivided into everyday classes such as dogs and cups. This view, as opposed to the view that global (superordinate) concepts are higher-order and late developing, helps make sense of what we know about the acquisition process, explains its orderliness, and provides the rationale for the kinds of generalization that take place and the conceptual constraints on associations that have been found. The initial global level provides the definitions that ground classes such as dogs and cups, in effect acting like necessary and sufficient conditions, and may not be subject to the prototyping, exceptions, and ambiguities that over time come to characterize many adult concepts. (I assume that on anyone’s view a dog is not a dog unless it is an animal, and a cup is not a cup unless it is a container). I discuss why the first outputs of PMA may be characterized as structured primitives, and note in passing that unstructured sensory concepts, such as red, are new, difficult, and late acquisitions, although even they can eventually be learned (perhaps requiring language to do so).

In my view, infants learn most concepts by generalization and association from an innate base of spatial primitives (a base later supplemented by analysis of bodily feelings). This innate base need not be large to form the foundational concepts. Its primitives are structured by virtue of being spatial – examples are path and containment. The primitives are probably based on innate proclivities to attend to motion and certain spatial relations. PMA is not a triggering device (i.e., not a brute-causal mechanism) but one that analyzes and redescrbes perceptual information into conceptual form, using these primitives. This device can be contrasted with perceptual schema formation, which is not accessible to con-

sciousness and so in its unanalyzed form cannot be used for conceptual thought. I have suggested that the output of PMA consists of representations in the form of image-schemas. However, although this type of representation has much to recommend it in terms of understanding thought and imagination, it is not crucial for understanding how new concepts can be formed. For that, it is the analytic mechanism that matters, not whether it outputs image-schemas, perceptual symbols, or some other code.

The concept of animal is used to illustrate how PMA redescrbes observable data into concepts. I use this example to illustrate that even such a foundational concept does not have to be innate. The concept of dog is used to illustrate how new concepts can be formed through differentiation of animal. New kind concepts may typically be learned in this way. At least some new artifact concepts, such as cup, are also derived by differentiation of foundational concepts, such as container. Other concepts, such as relational ones, may follow a somewhat different developmental course. The concept of tight fit is used as an example of a new concept formed by PMA, not by differentiation of an existing concept, but by new analysis of spatial information.

## Universal Theory

*Sourabh Niyogi*

Fodor’s original arguments for the impossibility of genuine expansion of a child’s conceptual apparatus can be understood in the context of a Universal Theory Model of Concepts. I present an architecture where there exists a set of primitives to describe possible theories (Universal Theory), an abstract Theory Acquisition Device (TAD) that outputs a theory  $T^*$  (based on experience or by mental fiat), and a lexicalizable concept generator  $G$  that maps  $T^*$  to a set of possible lexicalizable concepts  $G(T^*)$ . Each of the components of this architecture can be grounded in existing experimental work and have been detailed in computational models. Two viewpoints can be taken on the set of lexicalizable concepts: Viewpoint 1 considers that the child has access to the union of all possible lexicalizable concepts generated by all possible TAD states, yielding the conclusion that concept acquisition is impossible. Viewpoint 2 considers that the child has access to just those lexicalizable concepts  $G(T^*)$  generated by just the current TAD state  $T^*$ , yielding the conclusion that concept acquisition is a possibility if  $T^*$  may change. The puzzle dissolves once one recognizes that the choice between the 2 viewpoints is arbitrary: Fodor (1975)’s claim that “there literally isn’t such a thing as the notion of learning a conceptual system richer than the one that one already has” would appear to be taking viewpoint 1, while work in developmental psychology would appear to be taking viewpoint 2.

## Progressive differentiation and reorganization of concepts in development

Timothy T. Rogers and James McClelland

Over the first year of life, infants' concepts first encompass quite broad semantic categories, and only later extend to more subtle distinctions. First concepts appear very coarse, encompassing all different kinds of things in a small number of very general clusters, and as the developmental process unfolds, new concepts progressively emerge. We describe a simple computational mechanism that illustrates how such conceptual elaboration is possible. In agreement with many others, we suggest that early-developing conceptual representations are organised with respect to certain especially useful or salient properties, regardless of whether such properties can be directly observed. However we argue that in many cases this salience may itself be acquired, through domain-general learning mechanisms that are sensitive to the high-order coherent covariation of directly-observed stimulus properties across a breadth of experience. To support this argument we will describe simulations with a simple PDP model of semantic knowledge acquisition. When trained with backpropagation to complete queries about the properties of different objects, the model's internal representations differentiate in a coarse-to-fine manner. The representations can also show a perceptual to conceptual shift, first exhibiting sensitivity to always-available perceptual information and then discovering coherence in the covariation of contingent properties that are not always directly available. These dynamics provide a basis for understanding both the emergence and the reorganization of concepts during development.

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