

open the possibility that multiple recodings (possibly cast at different levels of complexity) of the same input remain available for further processing, a property that is undoubtedly central to flexibility in any learning system.

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Flexible feature creation: Child's play?

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Abstract: Schyns, Goldstone & Thibaut's argument is evaluated from a developmental perspective. Theoretically, feature creation is not necessarily problematic; this view derives from the assumption of innate content (primitive feature sets). Alternative assumptions (e.g., Piaget's theory) are possible. Preschool children readily search for novel features in response to task demands. This is compatible with functionalist approaches, but not the rationalist ones criticized by the authors.

What is innate? Alternative views. Schyns, Goldstone & Thibaut are to be commended for attempting to address a critical problem: if the symbol-grounding problem is solved by primitive feature sets, how can we account for (sporadic) flexible and creative induction based on nonprimitive features? If primitives are used productively, what are the production rules? More radically, when and how do people create new features? The difficulty of the problem is underscored by Fodor's (1975) reductio that all complex concepts are innate. Although the Schyns et al. approach is more sober, primitive constituents are regarded as a necessary evil (sect. 1.1, para. 4). Are primitive vocabularies necessary? Can the problem be solved without innate content (see Braine 1994)?

The symbol grounding problem is inherently developmental, and developmental analysis yields an alternative formulation: Piaget was aware of the problem, and did not believe in primitive content (i.e., features or concepts) but rather in primitive action patterns. Specifically, a set of innate reflexes evolve into controlled action schemes (later internalized as mental schemes). By analogy to Gibson's differentiation hypothesis (Gibson & Gibson 1955), the infant's ever-finer differentiation of the physical world is reflected in differentiated action responses. Primitives are not content, but structure and *process* – specifically, perceptual learning and motor learning routines. My point is not to advocate Piaget's theory, but to remind us that what is innate might not be primitive feature sets. Whether or not primitive features are assumed, however, feature creation remains to be specified.

The growth of flexibility. Schyns et al. link feature creation to flexibility, a welcome observation. Flexibility is most clearly construed from a functionalist position, by questioning how subjects elect specific features appropriate for different tasks. Subjects might select either previously conceived aspects or novel aspects of the stimulus array. If the latter is typically more effortful and uncertain than the former, there will be a trade-off: feature search will occur only when existing features are ill-suited to a problem. Schyns et al. consider how stimulus characteristics affect feature creation, but they do not address how task and context facilitate or inhibit feature creation. For example, Bransford et al. (1989) suggest that conceptual highlighting of contrasting features might promote feature creation. Deák and Bauer (1996) found that preschoolers search for subtle (and presumably novel) features in certain task contexts, given sufficiently complex stimulus items (this qualification is consistent with Schyns et al.'s argument about stimulus characteristics; see sect. 2.5).

In terms of development, Schyns et al. imply that apprehension

of novel features poses particular difficulties for young children (sect. 3.3.2, para. 3–4). However, learning novel feature contrasts is so critical for young children, it would be surprising if they were deficient in it. Schyns et al. seem to know this, and conclude correctly that current popular approaches (i.e., innate theories; perceptual biases) are not enough to specify how children create or select relevant features from an array. Theoretical shortcomings aside (see Deák 1995; in preparation), both popular approaches are empirically wanting. Consider the view that children's feature selection is governed by innate perceptual biases: Deák (1995) qualifies or disconfirms the count noun/shape bias proposed by Landau et al. (1988). A comprehensive review of the literature reveals that preschool children are not *generally* biased to weigh some features over others. Rather, they select stimulus features associated with a particular induction problem (Deák 1995). That is, preschool children are genuinely flexible in shifting attention to features (or combination of features) as task demands change. Moreover, it appears that feature selection and feature creation are closely related, and well-established, by age 3. I will briefly describe data (which inform Schyns et al.'s general position) consistent with this argument.

Deák (1995) found that 3- to 6-year-olds successively attend to different combinations of features in response to different induction tasks: when told that an unfamiliar, complex object "has a toggle," 3- to 6-year-olds extend that fact to another object with the same unfamiliar part. When told that the former object is "made of mylar," children extend that fact to a different object made of the same (unfamiliar) material. How is this relevant to the position stated by Schyns et al., besides being inconsistent with the perceptual bias approach? First, in response to "... has a ..." facts, children apparently search for an unfamiliar part of the object, then seek another object with the same part. Parts were novel, and the objects were complex, with many varying features. Thus, children apprehend and reason about novel features in spite of irrelevant varying information (contrary to Schyns et al., sect. 3.3.2). Second, responses to "... made of ..." facts demonstrate that preschoolers reliably make generalizations about novel kinds of material. This is striking partly because 3-year-olds are believed to lack a coherent concept of material kind (Dickinson 1989). Thus, children "created" a new material feature, although by conventional accounts no feature space existed to be subdivided! This illustrates how task constraints might permit young children to induce novel features or feature combinations. Clues to the nature of the task – for example, the phrases "has a" and "made of" – effectively limit the hypothesis space preschoolers consider.

In sum, assuming that "what is innate" is either nascent theories or rigid perceptual biases (i.e., innate content *qua* primitive features) provides no account of either flexible feature selection or feature creation. A functionalist framework, in contrast, assumes that children have procedures for matching (or learning to match) known or novel features with exigencies of the task at hand. The emergence and nature of these procedures remain to be understood.

Flexible categorization requires the creation of relational features

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Abstract: Flexible categorization clearly requires an adaptive component, but at what level of representation? We have investigated categorization in sequence learning that requires the extraction of abstract rules, but no modification of sensory primitives. This motivates the need to make explicit the distinction between sensory-level "atomic" features as opposed to concept-level "abstract" features, and the proposal that flexible categorization probably relies on learning at the abstract feature level.