coupled with the similarity structure of those classes (attributes shared by humans and nonhuman animals, but not cars), are important determinants of the growth of category organization during early cognitive development.

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The development of modeling or the modeling of development?

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Abstract: We agree with many theoretical points presented by Rogers & McClelland (R&M), especially the role of domain-general learning of coherent covariation. Nonetheless, we argue that in failing to be informed by key aspects of development, including the role of labels on categorization and the emergence of constraints on learning, their model fails to capture important features of the ontogeny of knowledge.

The book *Semantic Cognition* by Rogers and McClelland (2004) is an elegant demonstration that a simple parallel distributed processing (PDP) model can exhibit behavior that matches the behavior found in a range of empirical studies on infants' conceptual development. As such, Rogers & McClelland (R&M) make a compelling case that domain-general, rather that domain-specific, mechanisms that are sensitive to lower- and higher-order covariation underpin early concept formation. Although we concur with many of the authors' claims and their general theoretical perspective, in this commentary we propose that R&M have overlooked a number of key points about development which are crucial to consider in modeling early concept formation.

An important aspect of early concept learning overlooked by R&M is the role of verbal labels. Labels affect categorization and concept development in infants as young as 9 months (e.g., Balaban & Waxman 1997; Xu 2002), and their effect continues to grow in the subsequent months (e.g., Fulkerson & Haaf 2003; Nazzi & Gopnik 2001; Waxman & Markow 1995). Thus, labeling may be an important additional mechanism by which infants construe semantically related items as similar to one another in the absence of observable similarities.

Unfortunately, the role of labels cannot be investigated in R&M's network because they are implemented as simple stimulus features (the *ISA* relation). In our opinion, it is erroneous to implement basic-level category labels as features akin to having wings or barking. The principle of coherent covariation gains traction because the feature *can move*, for example, is informative in that not all entities can move and that being able to move predicts other properties. Labels are different: Many things from different semantic categories can move, but only canaries are canaries. From this perspective, the category label is the piece of information that varies most coherently and is most predictive of the item's category.

To explore the consequences of labels on concept formation, a model needs to map multiple exemplars (e.g., many different canaries), to a single label. In the process of learning to associate a single label with multiple category exemplars, the label becomes strongly associated with features most predictive of the category (Lupyan 2005) providing the "glue" that may be necessary for cohering together items from categories with high intra-category variability (Lupyan, in press). Thus, rather than adding a simple feature, labels can be thought to schematize a given stimulus by placing it into a relationship with the other members of the category.

An additional concern relates to the fact that humans, and especially human infants, demonstrate clear limits on learning, whereas connectionist networks are capable of learning essentially any pattern of inputs (Massaro 1988). This point is overlooked in two ways by R&M's model. First, in a number of simulations the model is able to show patterns of behavior that match those of infants only after it receives a level of experience that is unavailable in the real-world or the laboratory setting. The model, for example, has only begun to differentiate conceptually the input stimuli after 50 epochs, but by this time the network has been exposed to over 50,000 trials (Siegler 2005).

Second, and more important, R&M expose the model to all of the covarying input at the same time, yet infants are limited in the amount and kind of correlated information they can process. Before approximately 7 months of age, for example, infants are unable to encode relations among static features (Younger & Cohen 1986), and it is not until around 14 months of age that they can encode object features or whole objects with dynamic motion-related cues such as *can fly* or *can walk* (Rakison 2005). That infants are unable to process certain kinds of information constrains concept learning, but, at the same time, it also facilitates concept learning; that is, it allows infants to learn about more fundamental aspects of things in the world while at the same time ignoring other aspects. R&M's model, in contrast, is exposed simultaneously to a wide range of information which in an infant would probably lead to what William James (1890) called a "blooming, buzzing confusion." R&M argue that they used input features that they consider to be important or salient to infants, but in our view this approach disregards a large database of empirical data that shows to which features infants actually attend in developing concepts (see Madole & Oakes 1999).

Finally, the architecture of R&M's model is sufficiently flexible and powerful to demonstrate learning for any input pattern. Fitting a PDP model to existing data is not the strongest test of the theory advocated by the model (Roberts & Pashler 2000); more powerful support for the theory behind the model is to generate novel predictions that are borne out by empirical studies. Moreover, from our perspective any model that tries to emulate a set of empirical findings with infants or children must take developmental issues into account. We have recently developed such a PDP model for early concept formation that is theoretically compatible with that of that of R&M, but that incorporates development in a number of plausible ways (e.g., increasing over time the number of hidden units and reducing over time the weight-decay parameter of fast but not slow learning links) (Rakison & Lupyan, in press). This developmentally oriented model exhibits behavior that is unintuitive but nonetheless matches that found in infants. For example, 14-month-olds learn relations in simple causal events that are consistent and inconsistent with the real world (e.g., agents possessing moving or static parts), but 16-month-olds demonstrate constraints on learning by failing to learn the inconsistent events (Rakison 2005). From our perspective it is necessary for models to be informed and compatible with key developmental findings and issues if traction is to be made in determining the origins, nature, and development of concepts.

Semantic redintegration: Ecological invariance

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