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Rethinking Conceptually-Based Inference: Commentary on "Fifteen-month-old infants attend to shape over other perceptual properties in an induction task," by S. Graham and G. Diesendruck, and "Form follows function: Learning about function helps children learn about shape," by E. Ware & A. Booth

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The question of what representations underlie young children's categorizations and early word learning has an extensive history. Answers have been shaped by several longstanding debates, including the conceptual/perceptual debate raised by Graham and Diesendruck (G&D) in their article in this issue. Their contribution to this debate is an experiment examining 15-month-old infants' attention to shape, color and texture in an inductive inference task. Infants were presented with a novel object that possessed a nonobvious property demonstrated by acting on the object (e.g., the object squeaked when squeezed). They were then presented test objects that matched the exemplar in shape, color or texture and their attempts to produce the demonstrated properties observed. G&D found that infants performed the demonstrated actions most often with the shape-matching test objects. Furthermore, the number of actions infants performed was significantly related to the intercorrelated variables of vocabulary size, number of count nouns known, and age.The data presented by G&D make an important contribution to our understanding of infants' performance in inductive inference tasks. In particular, no previous studies have examined infants' differential attention to particular dimensions in these tasks, or related performance to vocabulary development. However, we disagree regarding the nature and implications of this contribution. We believe that this disagreement, to a large extent, stems from a more fundamental disagreement regarding the conceptual/perceptual debate. We first present our take on that debate. Briefly, we believe it is not so easy to separate perceptual and conceptual bases for children's categorizations. Rather, we argue for a process-based account of categorization grounded in developmental accounts of perception, action, learning, attention and memory. We then illustrate how our take leads to a different interpretation of G&D's data and thus a different conclusion regarding its implications.

A process-based developmental account of children's early categorizations also bears on interpretation of the studies presented by Ware and Booth (2010) in their article in this issue, addressed to the role of function in children's development of the "shape bias." They gave 17-month-olds extensive experience with the functions of novel objects, and showed some preference to attend to shape in a subsequent categorization task. The authors argue that this

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is so because function highlights the importance of shape via "conceptually-based processes." In contrast, we argue that it is infants' developing ability to attend to and represent shapes, and the link between shape and what can be done with an object, that is the basis for the Ware and Booth (W&B) results. We discuss the implications of W&B's data from our perspective, and how these data fit with the larger literature on the development of word learning biases, including the debate on the role of conceptual and perceptual processes. We conclude with a discussion of the implications of these alternative perspectives for the field more generally. The Perceptual/Conceptual Debate When young children behave in such a way as to suggest they see two distinct objects as equivalent, they are categorizing. So, when a 10-month-old infant looks longer to a picture of a collie following presentation of several pictures of cats, but looks equivalently to a novel picture of a persian, we interpret this behavior as categorizing the persian, but not the collie, with the other cats. Similarly, when a toddler generalizes a novel name provided for an exemplar object to another novel object, we interpret this behavior as putting the two objects in the same nominal category. Researchers have long been interested in the bases of these categorizations. In the case of the looking task, one might explain the difference in behaviors that indicate categorization by saying that the infant attended to, perceived, and remembered the common perceptual features across cats, and looked longer to a collie, but not a persian, because the collie differed perceptually from their perceptually-based category representation of cats. Alternatively, one might explain the difference by saying that the infant's experience of cat exemplars activates their conceptual representation of cats. Infants looks longer to the collie because their conceptual understanding of that category includes the knowledge that dogs bark, like bones, and chase sticks, while cats meow, drink milk and chase mice. These differing possible explanations generally represent the difference between "perceptual" and "conceptual" accounts of categorization (Rakison, 2005b).

The perceptual account suggests that infants base their categorical decisions on readilyperceptible features that they learn and represent through exposure to the category exemplars they experience. This account inspires research examining how the task and stimulus context, infants' looking behavior, and developmental history come together to give rise to category learning (French, Mareschal, Mermillod, & Quinn, 2004; Oakes, Coppage, & Dingel, 1997; Oakes & Ribar, 2005; Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). In contrast, the conceptually based categorization involved in the conceptual account relies on deep, nonobvious properties, rather than "mere" surface features, to group items. Although details of different versions of the accounts vary, the general distinction is between perceptual and conceptual information, with each drawn upon to different extents and thereby leading to differences in categorization (Goldstone & Johanson, 2003; Rakison, 2005b; Oakes & Madole, 2003; Samuelson, Perry & Warrington, 2007).

An alternative perspective gaining ground, however, is that there is no clear distinction between perceptual and conceptual knowledge. Rather, categorization behaviors emerge within a moment as prior knowledge is brought to bear by relevant perceptual cues (Ahn & Luhmann, 2005; Barsalou, 1999; Jones & Smith, 1993; Samuelson & Smith, 2000; O'Regan & Nöe, 2001; Port & van Gelder, 1995; Spivey & Dale, 2006, Spivey, 2004). According to this view, categorization behaviors cannot be said to be based on one qualitatively different type of knowledge to the exclusion of the other, or even based more on one type of knowledge than the other, because "perceptual" and "conceptual" are not separate entities. Rather, through the processes of perceiving, attending, remembering and acting on the things around them, infants come to represent the relation between, and interconnectedness of, what things look like, what they do and/or what can be done with them. This is the position we take here. As we demonstrate, doing so changes our interpretation of tasks such as those used by G&D and by W&B, both of which present infants stimulus events that involve actions on objects that produce outcomes. Doing so also leads us to different accounts of the behaviors infants demonstrated in these studies and, therefore, differences in the conclusions we draw from them.

The inductive inference task used by G&D was designed to measure infants' ability to draw inferences about the presence of nonobvious properties. Originally, the task was one in which infants' discovered through manual exploration what actions produced interesting object properties. Infants' expectation that objects possessed those newly discovered properties was then assessed by the frequency with which infants reproduced actions known to elicit the property on disabled objects. Baldwin, Markman, and Melartin (1993) allowed infants to explore a single object that was capable of producing an interesting nonobvious property upon acting on it in a particular way. Infants were then given a similar novel object that either was capable of producing the nonobvious property or that was disabled and thus unable to produce the nonobvious property. For example, infants' might have explored a horn-shaped object that honked when squeezed and a novel object that was silent when squeezed. The logic behind the task was that infants' expectation that a particular object (e.g., horn) possesses a particular nonobvious property (e.g., honks) is violated when acting on disabled objects. Behaviorally, this violation should lead infants to frequently reproduce actions known to elicit the nonobvious property on disabled objects. Indeed, Baldwin et al. found that 9- to 16-month-olds more frequently reproduced such actions on disabled objects than on those that remained capable of producing the nonobvious property. In G&D's version of the inductive inference task, infants were presented with an event in which a target object was demonstrated to produce a nonobvious property (a sound). Infants were then presented three novel objects that each matched the target object on one perceptual dimension. An infant might have been shown a ribbed, blue sphere that squeaked when squeezed, for example, and tested with a pink, ribbed sphere (same shape), a fuzzy, blue star (same color), and a ribbed, green pillow (same texture). Following Baldwin et al. (1993), G&D evaluated the frequency with which infants performed target actions on the three novel objects in an unpredicted condition, in which the objects' actions were disabled, and a predicted condition, in which the objects were capable of producing the nonobvious property. Infants more frequently reproduced target actions in the unpredicted condition, and those actions were more likely to be performed on test objects that shared the same shape with the target object than test objects that shared either color or texture. G&D conclude that infants expect objects sharing the same shape to also share nonobvious properties, suggesting that they appreciate that shape similarity is a reliable cue to category membership." Moreover, they conclude, infants treat shape as a reliable cue to object kind. We disagree with each of these conclusions, contending they rest on an unwarranted assumption that infants had formed a mental representation of the object possessing the hidden property.

Inductive Inference: What is Represented? The logic behind inductive inference is pictured in panels A and B of Figure 1. One observes that robins can fly, decides robins and sparrows are the same kind of thing, and concludes that sparrows can also fly. Such inferences indicate what things infants place in the same category. However, because one cannot directly ask infants about nonobvious properties, an indirect measure is required; one must show infants two potential members of the same category and look for behavioral evidence that they generalize a nonobvious property from one to the other. This process is pictured in panels C and D of Figure 1 for G&D's task. When the exemplar object was presented, acted on, and produced the sound, there were three perceptually available relations that infants *may have* learned—between the object and action on it (i.e., ribbed, blue spheres are squeezed), the action and sound (i.e., squeezing elicits squeaking), or the object and sound (i.e., ribbed blue spheres squeak). G&D are primarily concerned with the link between the test object in panel D and the nonobvious property (the dashed red arrow). However, they must examine this link via infants' actions on the object, and thus the links between the object and the action and the action and the nonobvious property.

G&D showed that infants squeezed the spheres more than other blue or ribbed test items. On the basis of this result, they assumed the infants had encoded the relations between spheres and squeezing and squeezing and squeaking (solid arrows in Figure 1D), and, thus, that they treated the exemplar and test object as the same kind. Importantly, however, whether infants actually encoded the relation between squeezing and squeaking and spheres and squeaking was never tested. There is no test of whether infants would be surprised if squeezing the sphere resulted in a different property such as rattling or if spheres mooed. It is not clear, however, what behavioral outcome to expect—if the infant squeezed the sphere and it rattled, would they do it more because it was not what was expected (indicating a representation of the previously presented relation) or because making something rattle is fun? Nonetheless, ambiguities resulting from the fact we are limited to behavioral tests does not justify unverified assumptions —especially when there are data to the contrary in the existing literature. Studies using equally arbitrary relations among actions, objects, and sounds as those used by G&D have shown that infants do not learn relations between particular actions and particular sounds or between particular objects and particular sounds. Figure 1E summarizes the results of these studies. Using habituation, Perone and Oakes (2006) assessed whether 10-month-olds were able to learn the three key relations depicted in the stimulus events used by G&D. For example, to assess whether infants were able learn relations between particular objects and particular sounds (e.g., that purple spheres squeak), infants were habituated to one object that produced a sound when acted on (a purple sphere squeaked when squeezed) and another object that produced a different sound when acted on in the same way (a yellow cube whistled when squeezed). To test whether infants learned the relation between each object and the sound it produced, they were presented a novel combination of the familiar features (a yellow cube squeaked when squeezed). Infants exhibited no evidence of learning relations between objects and sounds. Infants also exhibited no evidence of learning relations between the particular actions performed on objects and the sounds they produced (e.g., squeezing produces squeaking). A critical implication of these findings is that it cannot be assumed that infants represent the intended relations—in G&D's case the representation between the sphere and the squeaking. Rather, we must explicitly test infants' representations of the relations among components that constitute the stimulus event. What representation, then, underlies infants' reproduction of more target actions on objects that share the same shape in the unpredicted, but not the predicted, condition of G&D's task? Our hypothesis is depicted in Figure 1F. We propose that when infants are exposed to an event in which an object is acted on to produce a sound, they associate the particular shape of the object with the particular action performed on the object. Indeed, Perone and Oakes (2006) found that the one relation infants learned among the three key relations was between objects and the actions performed on them. It is not surprising that infants rely on shape information over color or texture as a basis for generalizing actions such as those used by G& D (squeezing, tapping, and shaking). Other studies have shown that manual exploration is required for infants to encode shape information (Ruff, 1984), and manual exploration of objects is associated with developmental change in infants' attention to objects embedded in dynamic events that involve actions on objects that produce sounds (Perone, Madole, Ross-Sheehy, Carey, & Oakes, 2008). Moreover, Perone, Madole, and Oakes (2009) found that 10-month-olds *do* associate particular actions, but not objects, with the presence of an outcome. That is, although infants do not learn relations between particular actions and particular sounds, they do represent the more general relation between actions and the presence of an outcome. In fact, research in cognitive neuroscience suggests there are links between the visual systems used for object perception and recognition, and the motor systems that would be used to act on those objects (Arbib, 1981; Chao & Martin, 2000; Grezes & Decty, 2002; Longcamp, Boucard, Gilhodes & Vely, 2005; Paillard, 1991; Vivani & Stucchi, 1992). Thus, there is reason to believe infants are able to represent the tie between action and the perceptual features of objects. Infants may then reproduce target actions on novel objects more frequently in the unpredicted than the predicted condition because they have formed an expectation that the action elicits an outcome—without an expectation that it should produce a *specific* outcome (squeaking rather than rattling). This would then mean that infants' actions on the test object did not reflect the expectation that it shared the same nonobvious property as the exemplar. Moreover, a series of recent studies investigating action representations in the human adult brain have shown that different components of actions on objects that produce outcomes are encoded in different regions of cortex (Hamilton & Grafton, 2006, 2007, 2008). In particular, information about the kinematics, of actions on particular objects (e.g., reaching for, cupping the hand, and grasping) are encoded in different regions of the brain than outcomes of actions (e.g., squeaking). Hamilton and Grafton (2007) have proposed that these different types of information are represented independently, in part, because the same action and objects can produce very different outcomes. When a switch is flipped, it might turn on a light, a fan, make bubbles, or produce a sound. This proposal fits with recent findings by Perone and Oakes (2006) and others (Elsner & Aschersleben, 2003; Perone et al., 2008) showing that infants' representation of relations among actions, objects, and outcomes is a greater developmental challenge than previously thought.

This work points to the need to examine the specific representations thought to underlie children's performance in any task that requires indirect measures of those representations. In the case of the inductive inference task, in particular, infants' behavior may be the result of associations between the perceptual features of objects and what they have previously seen done with similar objects, rather than a link between a particular object and a particular outcome. Indeed, the neurological data suggest such behavior could incorporate their accumulated knowledge about what infants have themselves done or seen someone else do with similar objects in the more distant past (i.e., not the here-and-now of the current experiment). This could include accumulated sensorimotor representations of, for example, squeezing other soft things or other spheres. The representations that support behavior in these tasks may be of the form that some would label "conceptual," but note then, that this "conceptual" knowledge is intimately tied, indeed inseparable from, its perceptual and sensorimotor past. G&D attempt to discount this conclusion in their general discussion of their study. In particular, they suggest it is unlikely infants were simply generalizing properties on the basis of shape similarity without any need to invoke notions of kinds or categories, because other research using the identical inductive inference paradigm indicates infants make purposive generalizations based on kind-relevant cues. However, many of these studies are subject to the same task analysis presented here. As an example, G&D highlight a study by Keats and Graham (2008) as providing supporting evidence. The critical manipulation in that experiment was the addition of various naming or highlighting events, such that the exemplar and test objects were either named with the same count noun or highlighted with a flashlight, for example, before infants' actions with the test objects were measured. Infants who heard the exemplar named with a count noun performed an equal number of actions on high similarity (similar in shape and texture, different in size and color) and low similarity (different in shape, color and size) test objects, but infants in non-referential count noun conditions performed the target actions on high similarity test objects more than low similarity ones. G&D (and Keats & Graham, 2008) conclude, then, that the difference in infants' performance in the presence of a category cue (count noun in referential context) versus absence of such a cue, means the inductive inference task requires categorization by kind. Once again, however, no test that infants expected a *particular* nonobvious property to be elicited by a *particular* action was provided. Thus, all that can be concluded is that count nouns and high similarity—especially similarity in shape—promote generalization of an action from an exemplar to a test object. Again, we see such results as an important contribution to the literature. But we do not believe they reflect infants' conceptual understanding that shape is a reliable cue to object kind.

With respect to Ware and Booth's (W&B) article in this issue, prior research has demonstrated the importance of object shape in children's novel noun generalizations and vocabulary development (Smith, 2001). Over the course of early vocabulary development children come to preferentially attend to shape when generalizing novel nouns—a phenomenon known as the "shape bias". Furthermore, young children provided extensive experience with nominal categories well organized by shape similarity in short-term longitudinal experiments develop a precocious shape bias and show accelerations in vocabulary development (Samuelson, 2002; Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002). W&B ask whether the link between word learning and attention to shape is driven by conceptual information about function.

Using a short-term longitudinal design, W&B provided young children with experience with categories organized by function. In the critical condition, the stimuli in each category were all the same shape and all shown to perform the same function. In contrast to prior studies, however, no names were provided. The critical result is that when the functions were causally linked to the shape of the objects, children subsequently demonstrated a marginal bias to attend to shape in a noun generalization task. In contrast, children not given experience with the functions, or given experience with functions not causally related to the shapes of the object, did not show evidence of a shape bias. W&B conclude that function is instrumental in establishing a shape bias and that it does so via conceptually-based processes.

Although W&B claim that the effect of their function training on the emergence of a precocious shape bias was comparable to that seen in prior studies," this is not the case. Prior studies in which names, rather than functions, were paired with novel object categories led to strong biases to attend to shape. The proportion of shape choices with novel solid objects reported by Samuelson (2002) was .68, and by Smith et al. (2002) was .70, both significantly different from chance. In contrast, children given function training in W&B's study generalized novel nouns by shape similarity at much lower levels—.39 in a three-item task, a level that is only marginally different from chance (.33). When W&B look only at the first few trials in this task, that percentage goes up to .53; however, their analysis of the blocked data shows no interaction between condition and block, indicating that this proportion does not differ from that of the no-function condition. Furthermore, none of the children in any of W&B's conditions demonstrated an acceleration in word learning following the training—an acceleration that has been replicated in multiple noun training studies (Perry, Samuelson, Malloy & Schiffer, 2009; Samuelson, 2002; Smith et al., 2002).

We believe the reason W&B's function training did not produce results comparable to prior studies is that their experimental design rests on two critical assumptions that are unwarranted: (1) function is a conceptually-based object property and (2) infants' perceive and represent the relation between objects and their functions. More specifically, the function events presented to infants by W&B can be redescribed in the same way as the stimulus events presented to infants by G&D, that is, as actions on objects that produce outcomes. How objects are acted on and the outcomes that acting on objects produce are features that can vary independently and are encoded in different regions of the brain, as noted earlier. Infants' ability to encode the feature relations in the events used by W&B, like those used by G&D, was not directly tested, and evidence suggests they do not develop in parallel (Elsner & Aschersleben, 2003; Perone et al., 2008; Perone & Oakes, 2006). However, the evidence reviewed here suggests that the relation between actions and objects is encoded earlier in development than relations between actions and outcomes or objects and outcomes. This is not surprising given the indications that appearances of manipulable objects and how those objects are acted on are inseparable components of object representations in the brain.

Together, these facts suggest that infants' ability to encode the relation between objects and actions facilitated infants' general representation of the link between shape and action, which, in turn, supported the use of shape to categorize novel objects in W&B's Experiment 1. In Experiment 2, however, infants' use of shape to categorize novel objects was not facilitated by the training events because the relations among object shape, how objects were acted on, and the outcomes produced were not plausibly related to each other (e.g., using a container to push couscous) as they were in Experiment 1 (e.g., using a container to scoop couscous).This manipulation by W&B suggests that the types of relations among actions, objects, and outcomes that infants experience is a crucial component of how infants acquire knowledge about the meaningful relationships between those features. Moreover, these findings fit with recent demonstrations by Smith (2009; Smith & Pereria, in press) that early name learning, the development of object perception, and children's explorations of objects are linked. Thus, W&B's data *do* fit with process-based accounts of the development of the shape bias (Smith, 2001; Smith & Samuelson, 2006). It is not clear, however, how accounts that rely on kinds or W&B's "conceptually-based mechanisms" would treat the links between the development of object perception, word learning, and exploratory play. Further, it is not clear what explanations based on conceptual understanding of "kind" ultimately contribute to our understanding of development. What Does "Kind" or "Conceptually-Based" Buy Us?

Our discussion suggests how explanations of early categorization behaviors that fail to fully examine what is revealed by behavioral measures can lead to unwarranted assumptions regarding infant's representations of those events. Such accounts are particularly problematic for our understanding of development because explaining infant behavior as resulting from an understanding of "kinds" or "conceptually-based processes" begs the question of where this deep conceptual knowledge comes from. Indeed, accounts that have posited that children's biased attention to shape in categorization and noun generalization tasks is based on conceptual understanding of kinds and conceptual processes, like those advocated by G&D and W&B, lack specification of how infants and children could acquire such abstract representations (Samuelson & Horst, 2008; Xu, Dewar & Perfors, 2009). In some cases, kind- and conceptually-based accounts of biased attention to shape actually resort to claiming that conceptual understanding of kinds could be acquired via associations between aspects of naming and categorization tasks and the relevant perceptual features of objects (Booth, Waxman, & Huang, 2005). However, other accounts of the same or similar phenomena, for example, proposals by Smith and colleagues as to the development of the shape bias from regularities in children's word learning environment (Colunga & Smith, 2008; Samuelson, 2002; Samuelson & Smith, 2006; Samuelson & Horst, 2008; Smith, Jones, Landau, Gershkoff-Stowe & Smith, 2002), are able to explain such developments without resort to conceptual representations of kind. Thus, it becomes unclear what the notion of kind buys us or what it truly means. The example of a word learning robot developed by Faubel and Schöner (2008) makes this point clear. This interactive autonomous robot learns names from a human user via correlated presentations of category exemplars and words. The basis of this learning—what this robot has in its head—is an associative neural network similar to the one used by Samuelson, Schutte, Horst & Dobbertin (2009) in their Dynamic Neural Field model of noun generalization and the development of the shape bias. Fauble and Schöner have shown that this robot can quickly learn to name and categorize objects that are novel to it, and that shape is important to this categorization. Thus, this robot takes input similar to that presented to children and learns a behavior similar to that used in laboratory tests of children's noun learning—generalization of a name to novel instances. We contend that if this robot were to perform the task presented to 15-month-olds in G&D's study, it too would generalize the nonobvious property according to shape similarity. Similarly, given the training presented to infants by W&B, the robot would learn the association between an object's shape and what can be done with it. Indeed, if the robot had prior vocabulary experiences in which naming events and count noun syntax were repeatedly associated with the importance of shape for property generalization (not just naming), it could also learn to use those context cues that point to the referential nature of the event as a basis for differential generalization, as did infants in a study by Keats and Graham (2008). The robot would show this behavior because shape, actions on objects, count noun syntax, and/or other context cues were the most relevant to the categorization tasks it has experienced. This is exactly the notion of kind or conceptual knowledge proposed by conceptual accounts. However, in this case the robot's, and by implication, the infant's, behavior cannot be separated from its learning history and experiences in the task, from the processes of attending, perceiving, and remembering that served as the basis for these behaviors, nor from the perceptible features of the objects that bring this longer history of experience to bear at the moment of categorization. Thus, there is no separation between the perceptual information by which nonobvious properties, prior naming events, actions, sounds, tactile sensations, and propreoceptive information are experienced, and the conceptual linking of these representations over time, events and current behavior. Again, we could label all this as the conceptual notion of "kind" and say that it served as the basis of the robot's behavior (as indeed it does), but it is not clear what the notion of "kind" contributes to this account. In this context, "kind" and "conceptually-based" are just a short-hand for the dynamic, context-sensitive link between object features, categorization tasks and current behavior. Implications and conclusions We have argued for a process-based, mechanistic account of infants' developing ability to use nonobvious properties and functions as a basis for categorization. At a mechanistic level, our position is similar to Rakison's (2003, 2005a) proposal that general associative learning can build complex representations to support inference of nonobvious properties out of learned connections between perceptible features. For example, he has suggested that infants may learn to associate one static feature (e.g., legs) with the presence of an intermittently available dynamic one (e.g., running), which then supports the expectation of the dynamic feature upon perception of the static one. In both our account and Rakison's, nonobvious properties such as the actions and sounds used in G&D's task or the functions used in W&B's task are nothing more than intermittently available perceptual features, which could, over time, be represented via their repeated association with perceptible features. Thus, particular features can be represented in the moment in a task (e.g., ribbed, blue spheres are squeezed), category specific relations can be learned over a longer time scale (e.g., balls bounce), and abstract representations of artifacts over yet a longer time scale (e.g., objects produce unobservable properties when acted on). This process-based account is context sensitive and can explain both task-related (e.g., keys "start" dogs) and knowledge-based (e.g., animals drink) property generalizations (Younger, Johnson & Furrer, 2007; Furrer & Younger, 2008), and developmental changes (Johnson, Younger, & Furrer, 2005; Rakison, 2007). Similarly, this account fits with data from other studies examining the integration and inseparability of perceptual and conceptual information in naming tasks previously thought to have a purely conceptual basis (Samuelson, Perry & Warrington, 2007; Colunga & Smith, 2001), as well as data demonstrating ties between early noun learning, pretend play, and object recognition (Smith, 2005, 2009).

More generally, this analysis of inductive inference and conceptual accounts of infant categorization suggests that an explanation of development should include an appreciation of three critical issues (Samuelson & Horst, 2008). First, empirical details matter. Behavior is made as the task and stimulus context make contact with the child's history—in a particular task and over development—and bring relevant aspects of that history to bear on current behavior. Thus, the details of the task determine how children's prior experiences create behavior in the current situation. Second, understanding mental states requires a rich understanding of behavior, because behavioral dynamics shape learning and are our means of assessing mental states (Bremner & Mareschal, 2004; Thelen, Schöner, Scheier & Smith, 2001; Smith, 2005; Spencer, Perone & Johnson, 2009). Third, development is created over time, and for this reason, a full explanation of any developmental phenomenon requires understanding how in-the-moment cognitive and behavioral acts accumulate to create developmental change (Smith & Thelen, 2003). Explanations that rely heavily on conceptual representations on the part of the infant lack clarity and specificity with regard to these critical elements.

For these reasons we believe we must move beyond the conceptual versus perceptual debate and toward a processed-based account of categorization grounded in developmental accounts of perception, action, learning, attention and memory. This fact is perhaps best illustrated by considering the extremes of behavior displayed in cases of atypical development. If a child does not show an expected behavior and our explanation for the typical production of that behavior is only at the level of "kinds" or "conceptual understanding," it is not clear how the theory applies (or, more importantly, how to help that child). In contrast, if our explanation of the typical course of behavior is grounded in the details of behavior in a moment and ties such behavior to the evolution of behavior over longer time scales, we can work to understand atypical patterns and how to influence them if warranted (Jones, 2003; Jones & Smith, 2005; Landry, Smith, Swank, & Guttentag, 2008; Perone, Spencer, Acarregui, Breitbach, Eastman, & Gordon, 2009.) Appealing to kinds instead of thinking about the details of cognitive and behavioral dynamics leads to an incomplete understanding of infant cognition and behavior.

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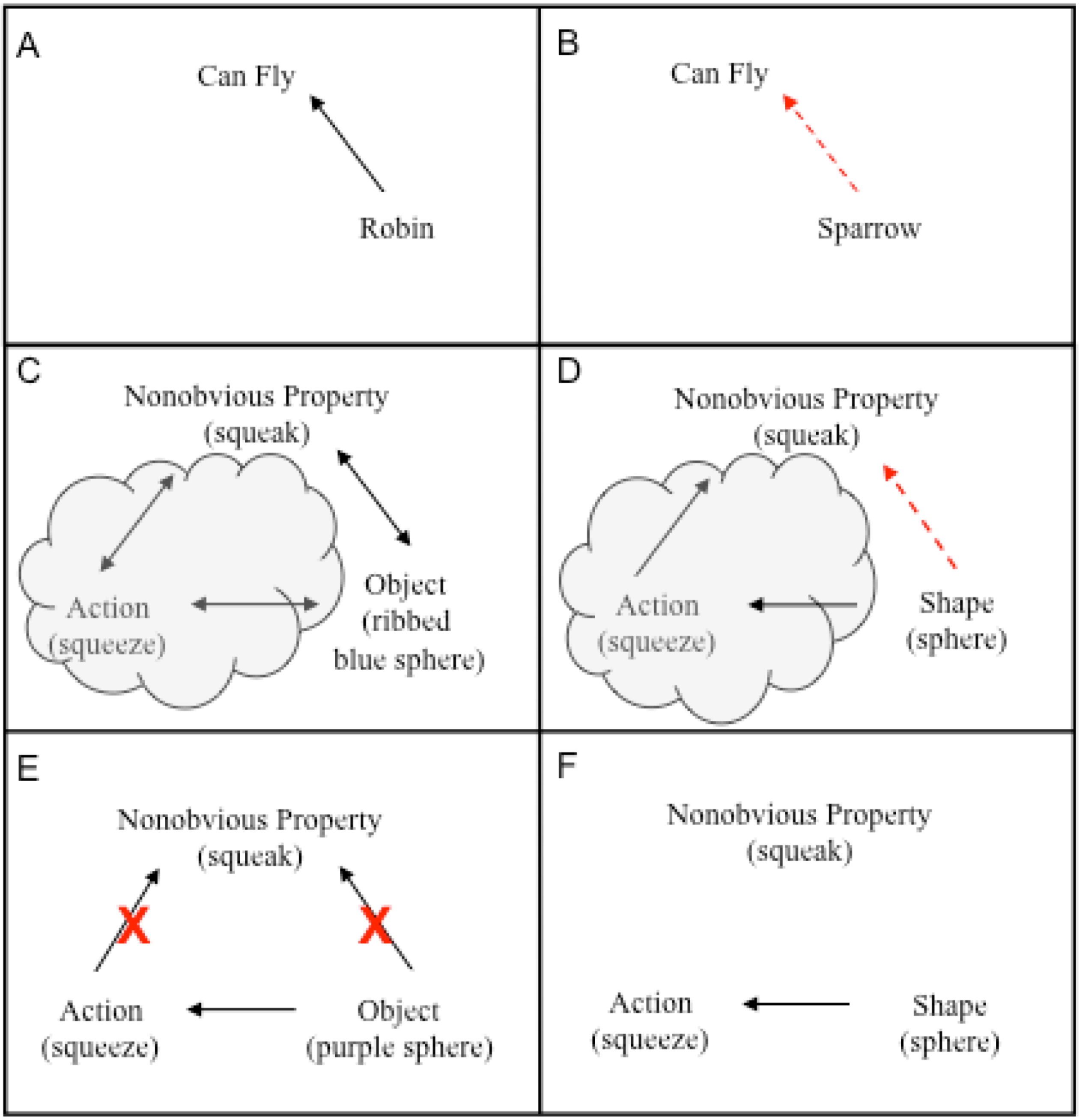

Figure 1.
Logic of inductive inference task (panels A & B). Possible represented links between the exemplar object, demonstrated action and nonobvious property (panel C) and test object, action and nonobvious property (panel D) of Graham and Diesendruck (2010). Summary of data from tests of represented links in Perone et al., (2008) (panel E) and hypothesis of basis for biased attention to shape in Graham and Diesendruck (this issue) and Ware and Booth (this issue) (panel F).