

Short Arms and Talking Eggs: Why We Should No Longer Abide the Nativist–Empiricist Debate

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ABSTRACT—*The nativist–empiricist debate and the nativist commitment to the idea of core knowledge and endowments that exist without relevant postnatal experience continue to distract attention from the reality of developmental systems. The developmental systems approach embraces the concept of epigenesis, that is, the view that development emerges via cascades of interactions across multiple levels of causation, from genes to environments. This view is rooted in a broader interpretation of experience and an appreciation for the nonobvious nature of development. This systems approach is illustrated here with examples from studies of imprinting, spatial cognition, and language development, revealing the inadequacies of the nativist–empiricist debate and the inconvenient truths of development. Developmental scientists should no longer abide the nativist–empiricist debate and nativists’ ungrounded focus on origins. Rather, the future lies in grounding science in contemporary theory and developmental process.*

KEYWORDS—*developmental systems; nativism; empiricism; imprinting; spatial cognition; language development*

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Spelke and Kinzler (2007) recently described developmental science as a struggle between two dichotomous groups. On one end sit the “blank slaters,” who view the brain as an unconstrained general learning device; on the other sit the evolutionary psychologists who view the brain as an amalgam of special-purpose learning devices (see also Pinker, 2002). Although Spelke’s nativist views typically align with those of evolutionary psychologists (e.g., see Spelke & Newport, 1998), Spelke and Kinzler propose a middle ground according to which “humans are endowed neither with a single, general-purpose learning system nor with myriad special-purpose systems and predispositions” (p. 89). Instead, they suggest “that humans are endowed with a small number of separable systems of core knowledge. New, flexible skills and belief systems build on these core foundations” (p. 89).

We applaud Spelke and Kinzler’s (2007) move to a middle ground, but we cannot meet them in this particular place. As we argue here, developmental scientists should no longer embrace “endowments,” “primitives,” “core knowledge,” “essences” (Gelman, 2003), or other static concepts that devalue developmental process. After all, “endowments” are bestowed, not developed. Similarly, “primitives” are *not developed or derived from anything else*. These nativist concepts originated in the rationalist tradition of Plato, Descartes, and Kant (Spelke & Newport, 1998), and thus nativists assume that relationships between developmental antecedents and consequents are rational and transparent (Blumberg, 2005; Johnston, 1987). This leads, in turn, to nativists’ overly narrow conception of experience (Lehrman, 1953).

We wish to locate developmental science in new territory, where we invoke only grounded processes to explain the remarkable transformations of development. To move in this direction, we must accept some inconvenient truths—inconvenient in the sense that they make our task as scientists considerably more difficult. First, development is often a nonobvious process that does not easily conform to our intuitions or rational expectations (Gottlieb, 1997). For example, what rationalist analysis would

have predicted that the quantity of stimulation provided by a mother rat to her pups would affect gene expression (Weaver et al., 2004), brain development (Liu, Diorio, Day, Francis, & Meaney, 2000), and adult sexual behavior (Moore, 1995)? Such examples should broaden our conception of what qualifies as relevant experience.

Second, we cannot sidestep the complexity of development by invoking evolutionary causation. The nativist appeal to endowments and primitives is an attempt to move beyond the here-and-now to an evolutionary past that prescribes adaptive outcomes. We, too, embrace evolutionary theory, but the fact that organisms evolved does not remove the need to explain developmental process, because brain and behavior are shaped through development, not programmed before development (Blumberg, 2009; West-Eberhard, 2003). In Gottlieb's words, evolution involves "selection for the entire developmental manifold" (Gottlieb, 1997, p. 76).

Third, although the nativist–empiricist debate has been rich and scholarly at times, too often nativist stories persist even when their supporting studies are demonstrably flawed (see Blumberg, 2005). And, critically, the lessons that nativists should learn when these interpretations turn out to be insufficient fail to temper the next round of nativist claims. Rather, nativists routinely extrapolate well beyond the data, making bold claims about time points not directly under investigation. For instance, Marcus (2001) described a habituation study with 4-month-olds, concluding "it seems likely that at least some of the machinery that infants use in this task is innate" (p. 370), but he presents no evidence to support this claim. Indeed, he goes further: A "reason for believing that something is innate is that there may be no other satisfying account for how a given piece of knowledge could arise" (p. 371). We contend that more satisfying accounts can be found through rigorous developmental analyses that embrace process, complexity, and evolutionary history (see Lehrman, 1953; Oyama, Griffiths, & Gray, 2001). We take up this charge in the present article.

The following sections focus on three areas of research—imprinting, spatial cognition, and language development—that justify our negative appraisal of nativism and the nativist–empiricist debate and illustrate the value of a developmental systems perspective. Our examples span low- and high-level cognition with humans and nonhuman animals, and they represent domains that have been central to nativist accounts. We could have chosen additional examples or reviewed important critiques of nativist claims (e.g., Clearfield & Mix, 1999; Haith, 1998; Jones, 1996), but such choices would not have altered our central theme: Development is an epigenetic process that entails cascades of interactions across multiple levels of causation, from genes to environments (Johnston & Edwards, 2002). Many factors routinely shape development, from the ordinary—such as the length of a child's arm—to the extraordinary—such as the vocalizations an embryonic duck produces within its egg. Our hope—and our challenge to young scientists

reading this article—is that one day we will achieve a science that is firmly grounded in developmental process.

IMPRINTING

Imprinting is widely viewed as an iconic example of an innately specified behavior (e.g., Spelke & Newport, 1998). As Lorenz (1935) and other classical ethologists described it, filial imprinting is a rapid form of learning that involves the establishment of perceptual and social preferences after a brief exposure to visual cues during early development. For example, when a duckling is exposed to its mother immediately after hatching, the duckling approaches and follows her. Similarly, if the hatchling is exposed to a red wooden box on wheels, it directs its approach and following responses toward the box. Beyond its significance for the young bird, imprinting has a much broader impact on species recognition and social preferences (ten Cate, 1994).

Imprinting clearly involves learning during early development, but is it necessary to invoke a special, innate learning mechanism? Although early ethologists emphasized the uniqueness of imprinting and went to great pains to distinguish it from other forms of learning, subsequent research has softened this stance. Today, researchers no longer view it as fundamentally different from other forms of perceptual learning (Bateson, 1966; Bolhuis, 1991; Klopfer, 1973). For example, we now know that the once-rigid critical period during which imprinting must be established varies in duration and depends on contextual factors both within and outside of the learning environment (Bolhuis & Honey, 1998; Horn, 2004). Most investigators now refer to a *sensitive* period in which the quantity and quality of sensory experience has a strong influence on the strength and reversibility of the imprinted preference (Bolhuis & Trooster, 1988).

But the modern understanding of imprinting goes well beyond issues of timing *toward a deep understanding of developmental process*. Analysis of neural mechanisms suggests that imprinting entails two distinct processes, one involving generalized learning of stimulus features of an imprinted object, and the second involving a predisposition to approach novel objects of the same general form as members of the same species (Bolhuis & Honey, 1998; Horn & McCabe, 1984). The notion of a predisposition might seem to fit neatly within the nativist ethos. Indeed, it is true that a chick reared in total darkness is still predisposed to approach a stuffed hen, thereby ruling out a necessary role for visual experience. However, chicks reared in total darkness develop the predisposition only if they receive one of several nonspecific experiences, such as running in a wheel or exposure to the hen's maternal assembly call (Bolhuis, Johnson, & Horn, 1985). In other words, *nonspecific, nonvisual* factors—factors outside the realm of what is typically considered relevant postnatal experience—can promote development of a *visual* predisposition, even though there is no obvious relationship between the predisposition and the nature of the experience. This example highlights how a "predisposition," like any other characteristic of an animal, must *develop*, and it is important to study the process through which this occurs.

Perhaps the strongest nativist claims about imprinting have been based on the preference expressed by naïve hatchlings for the maternal call of their species. As Gottlieb (1997) relates, ducklings hatched from eggs incubated in isolation show a species-appropriate preference toward the maternal call of their species, and this auditory bias facilitates imprinting to associated visual cues. Lorenz was quick to attribute this preference to innate, species-specific auditory recognition governed by genes. Gottlieb, however, experimentally demonstrated that the preference was not expressed by hatchlings that were incubated in isolation *and* devocalized, and therefore deprived of all prenatal auditory experience (i.e., maternal and sibling vocalizations as well as their own vocalizations). Indeed, self-stimulation from embryonic vocalizations tunes the auditory system and establishes a bias that shapes the later preference for the maternal call (Gottlieb, 1997). In this way, embryos—so-called talking eggs—help create their own species-typical environment.

Although the hatchling's auditory preference depends on prior experience, a nativist might argue that the embryonic vocal behavior that shapes auditory development is innate. This, of course, poses a problem of infinite regress for any explanation of developmental process, and it does not represent a logically valid source of evidence for innateness. Rather, as Gottlieb's work beautifully illustrates, it always remains for further empirical work to resolve the factors—genetic, neural, organismal, environmental—that contribute to the ontogeny of each attribute of the organism at each point in developmental time.

The study of imprinting has revealed the nonobvious nature of development: Behaviors are constructed through a cascade of developmental interactions, including influences of the environment that are both inherited and constructed (Goldstein, King, & West, 2003; Jablonka & Lamb, 2005; West, King, & Arberg, 1988). In light of our accumulated knowledge about imprinting and the broader view of experience that Lehrman (1953) and Gottlieb handed down to us that goes far beyond the notion of *relevance* (see also Oyama et al., 2001), the nativist focus on abilities that “are observed in the absence of any visual experience in newborn humans, infants, or newly hatched chicks” (Spelke & Kinzler, 2007, p. 89) is out of line with the empirical record and is uninformed by the lessons of the past (see Blumberg, 2005).

SPATIAL COGNITION

Our examination of imprinting highlights the benefits of a developmental systems view. Here, we demonstrate how nativist claims within the domain of spatial cognition extend beyond the data and fail to appreciate the subtlety of developmental process.

Dead Reckoning

Dead reckoning is a navigational process that establishes one's current location based on past locations and movement history. According to Spelke and Newport (1998), dead reckoning is a

core, innate ability whose developmental appearance does not rely on postnatal experience. Although a few studies appear to support this claim, a careful review reveals otherwise.

One study that proponents of nativism cite (even though the study's author did not advance a nativist interpretation) concerns young alpine geese navigating homeward from a distance of 40–100 meters (von Saint Paul, 1982). Because these goslings had never left the home area, Spelke and Newport (1998) claimed that they “do not learn to dead reckon by trial and error” (p. 312) and that their navigational ability must, therefore, be innate. But does this mean the geese had been deprived of all relevant experience that might support learning? These birds were 35–40 days old when tested, they took daily walks before testing within a 30 × 500 m home range, and they were trained to return to the nest across distances of several meters. Such experience seems relevant to us.

A second study limited the role of postnatal experience by testing 2-day-old chicks (Regolin, Vallortigara, & Zanforlin, 1995). Researchers placed chicks in the central corridor of an apparatus facing an object on which they had imprinted (visible through a window) and were free to walk around. When chicks left the corridor, they showed a strong preference to walk into rooms that were closer to the imprinted object even though the object was not visible. Although chicks learn a lot in the first 2 days after hatching (see, e.g., Hailman, 1967, 1969), it is not clear what accounts for their performance. Regolin et al. (1995) suggested that chicks might use “inborn” knowledge, but they also suggested that chicks might adopt a simple perceptual-motor strategy: “if you turned right (left) before the goal disappeared, then turn right (left) to find it again” (p. 198). Spencer and Dineva (2009) tested this possibility using a computer simulation of a random walk process with one constraint: As the simulated chick exited the virtual corridor—but while the object was still in view—it got a small “push” toward the goal. The best-fitting run of this simulation reproduced results from Regolin et al., showing that a detailed consideration of simple processes can obviate the need for inborn knowledge.

What about research with humans? Multiple studies have shown that infants' dead-reckoning abilities emerge gradually after the onset of independent locomotion (e.g., Cornell & Heth, 1979; Lepecq & Lafaite, 1989; Rider & Rieser, 1988). Indeed, this motor milestone has a profound influence on infants' navigation through space to find hidden objects (Bai & Bertenthal, 1992; Clearfield, 2004; Horobin & Acredolo, 1986), how they represent objects (Kermoian & Campos, 1988), and even how they represent socioemotional experiences (Bertenthal, Campos, & Kermoian, 1994; Campos et al., 2000). And experiments giving prelocomotor infants early locomotor experience in infant “walkers” have shown that experience contributes *directly* to these changes (e.g., Bertenthal, Campos, & Barrett, 1984).

Nevertheless, nativists often cite one study (McKenzie, Day, & Ihsen, 1984) as evidence of innate dead-reckoning abilities before the onset of independent locomotion (e.g., Spelke &

Newport, 1998), even though this study did not examine dead reckoning as it is normally defined because infants were not moved from one location to another. Instead, infants were trained only to *turn* toward a particular target marked by a distinctive cue (which 6-month-olds did at above-chance levels). Learning to track rotational movements is one component of dead reckoning, but dead reckoning requires more. That said, what enabled infants to track rotational movements in this study? One likely factor is their experience sitting with support and sitting independently, motor skills that develop between 1–5 and 4–7 months, respectively (Bayley, 2006). In this context, the results of this study do not support claims that dead reckoning (or even a component of dead reckoning) is innate because the ability in question emerges only after the onset of relevant motor experience.

Spatial Reorientation

Dead reckoning works well provided that one can track and update a representation of movement through the environment. What happens, however, if one is disoriented? It is now accepted that humans and nonhuman animals reorient using the geometry of a space (Cheng & Newcombe, 2005). According to Spelke and colleagues (Hermer & Spelke, 1994, 1996; Hermer-Vazquez, Spelke, & Katsnelson, 1999; Spelke & Kinzler, 2007), animals have this ability because they possess an innate, encapsulated geometric module.

Brown, Spetch, and Hurd (2007) examined whether use of geometry for reorientation is innate by rearing fish in a circular space but testing them in a rectangular space. When there were no distinctive featural cues, fish used the geometry of the rectangular space to search for an exit in the corners diagonally opposite one another. This means fish do not need exposure to a rectangular space *during rearing* to orient using geometry. But is it the case that no experience is needed? Brown et al. (2007) cannot answer this question because the fish had 8–12 days of training *in the rectangular space* before testing. Chiandetti and Vallortigara (2008) investigated whether 3-day-old chicks reared in either rectangular or nonrectangular spaces use geometry when first placed in a rectangular space. Chicks did not show statistically robust geometric biases until after 50 training trials (C. Chiandetti, personal communication, January 26, 2008), suggesting that *some* experience is necessary.

What about the second aspect of the geometric module claim: Is reliance on geometry “encapsulated”? This claim stems from evidence that animals, children, and adults fail to use unambiguous nongeometric information (such as the color of a wall) to reorient under some conditions (Hermer & Spelke, 1994, 1996). Studies show, however, that fish and birds use nongeometric information to reorient (Brown et al., 2007; Cheng & Newcombe, 2005), and young children and adults do as well, provided the room in which the task is conducted is large and the nongeometric cues provide stable landmark information (Hupbach, Hardt, Nadel, & Bohbot, 2007; Hupbach & Nadel, 2005; Learmonth, Nadel, & Newcombe, 2002; Ratliff & Newcombe, 2008).

Recently, Lee, Shusterman, and Spelke (2006) argued that an associative strategy could explain many of these findings. They provided several tests of this claim; however, all tests used small-scale geometric cues and small, movable hiding containers. When researchers conducted a variant of the Lee et al. experiment in a large space with stable landmarks, people once again reorient using nongeometric cues (Newcombe, Ratliff, Shallcross, & Twyman, 2009).

In summary, there is no compelling evidence to support nativist accounts of spatial cognition. Rather, this domain offers numerous examples of emergence and developmental change (see Plumert & Spencer, 2007). Indeed, research showing the direct influence of locomotor experience on infants’ spatial understanding provides some of the strongest evidence that perception, action, cognition, and emotion codevelop in infancy (for discussion, see Bertenthal & Campos, 1990).

LANGUAGE DEVELOPMENT

As they have with imprinting, researchers have emphasized the uniqueness of language and the need for special capacities and constraints to guide the learner to correct linguistic structure (Chomsky, 1959). Such constraints are often described as innate, fixed factors, external to the learning system. By treating constraints as innate and fixed, however, researchers oversimplify their developmental origins, and by treating them as external, they ignore the interactivity of learning systems. In addition, approaches based on innate constraints rely too heavily on a rationalist analysis of language that overlooks the cascade of mutually dependent processes that affect learning and development (see Christiansen, Dale, Ellefson, & Conway, 2002; Elman et al., 1996). Although a systems view does not posit that learning is unconstrained, “constraints” in this framework are not fixed initial conditions. Rather, they arise out of the complex systems that codevelop with language.

Phonology, Grammar, and Domain-General Learning

Work on language learning was stymied for decades by claims that general-purpose learning mechanisms were insufficient for language development. The landscape shifted, however, when Saffran, Aslin, and Newport (1996) demonstrated that after only brief exposure, 9-month-olds implicitly acquire surface statistics that are useful for segmenting words. We now know that infants and adults can learn a range of statistics that underlie phonetic categories (Maye, Weiss, & Aslin, 2008; Maye, Werker, & Gerken, 2002), phonology (Newport & Aslin, 2004; Saffran & Thiessen, 2003), and grammar (Gómez, 2002; Mintz, 2002, 2003; Saffran, 2003; Thompson & Newport, 2007). Such computations are not limited to language, suggesting a domain-general mechanism (Creel, Newport, & Aslin, 2004; Fiser & Aslin, 2002a, 2002b).

Statistical learning provides a clear alternative to nativist views, yet nativist ideas continue to permeate debates about this

form of learning. Nativist arguments stem from a rationalist analysis of statistical learning that assumes that learners count statistics independently and accurately (e.g., Remez, 2005). This results in a huge set of possible statistics and many units over which they could be computed. Thus, statistical learning must be *constrained* to consider appropriate statistics (Marcus & Berent, 2003; Newport & Aslin, 2004; Saffran, 2003; Yang, 2004). Some assume that such constraints are fixed, endowed, and language specific (Spelke & Newport, 1998; Yang, 2004).

Such views do not accurately characterize realistic learning systems, however. Connectionist networks can capture statistics of sequences and contextual dependencies (e.g., Elman, 1990) and are capable of computing multiple statistics simultaneously. Subtle statistical relationships work together to permit learning of abstract notions (such as verb class; Christiansen & Monaghan, 2006). Additionally, learning can happen in fits and starts, showing dramatic nonlinearities over development (Abbs, Gupta, Tomblin, & Lipinski, 2007) that are exquisitely sensitive to the developmental history of the system (Altmann, 2002; MacDonald & Christiansen, 2002).

Nativist analyses of statistical learning also oversimplify the content being learned, assuming a one-to-one mapping between statistics and linguistic structure. But statistics can show intricate dependencies, such as when variation in one class of statistics points learners to a second class of statistics. For example, relationships in grammars jump over embedded elements, such as number marking on verbs. In English, verb tense must agree with the preceding noun (e.g., “She walks” but “they walk \emptyset ”), but the tense marker always appears *after* the verb—the relationship between nouns and tense marker must skip the adjacent verb. Classical analyses suggest that this poses difficulty for association learning, because the adjacent statistics (e.g., noun–verb and verb–marker) are not useful—the learner must disregard adjacent relationships and discover the appropriate nonadjacent relationship. How can the system choose the correct class of statistics without prior knowledge? Gómez (2002) used artificial grammars to show that adults and infants can identify the correct nonadjacent statistics if adjacent transitional probabilities are variable, and therefore undependable, cues (for related results, see Rost & McMurray, 2009; Yu & Smith, 2007). Thus, rather than noise, variability is critical to learning statistics in context.

Other factors, such as social context, also play a key role in focusing the learner on particular statistics. For example, infant-directed speech changes the statistics of word segmentation (Kempe, Brooks, & Gillis, 2005) and vowel categories (Kuhl, Andruski, Chistovich, & Chistovich, 1997), a natural consequence of speaking clearly and simplifying the vocabulary (Cutler & Butterfield, 1990; Krause & Braid, 2003). These examples highlight that the learner does not require an innate push toward specific statistics—the rich social milieu can provide a scaffold for language development (Deacon, 1997; Goldstein et al., 2003).

Nativists also claim that statistics alone cannot account for the patterned representations of language; algebraic rules are also necessary. Algebraic rules operate over symbols, rather than specific perceptual or linguistic items (over which statistics are computed). Marcus, Vijayan, Bandi Rao, and Vishton (1999) attempted to demonstrate algebraic rule learning in human infants when surface statistics were unavailable. Because infants learned the rule, Marcus et al. claimed that rule learning must be innate and linked specifically to language (see Marcus, Fernandez, & Johnson, 2007). On the basis of unsuccessful modeling, they further argued that rule learning cannot emerge from a statistical learning device. But their pessimism was premature: Statistical learning models such as simple recurrent networks can do the trick (Altmann & Diennes, 1999; Seidenberg & Elman, 1999). Altmann (2002), for instance, found that a model given prior experience with language (similar to infants’ experiences in the home) showed rule-like behavior.

The only other support for innate rule learning comes from Peña, Bonatti, Nespor, and Mehler (2002), who demonstrated that adults extract rule-like nonadjacent statistics under some conditions. However, Perruchet, Tyler, Galland, and Peereman (2005) analyzed in detail the stimuli Peña and colleagues used and found that *adjacent* statistics supporting the apparent rule-learning are available. This redundancy of statistics at surface and deeper levels is a feature of real language (e.g., Monaghan, Chater, & Christiansen, 2005) and represents a nonobvious source of developmental change.

The examples above reveal the step-by-step, dynamic nature of statistical learning. In this context, we contend that innate constraints are unnecessary and fixed constraints of *any* kind are unlikely because the kinds of things that modulate learning develop along with language. For example, some think that perceptual systems provide fixed constraints for statistical learning, allowing the learning of certain statistics and the prevention of others (Creel et al., 2004; Fiser, Scholl, & Aslin, 2007). For this to work, however, perceptual systems must be stable during language development. They are not: In cases where perceptual processes affect statistical learning, the hypothetical perceptual “constraints” themselves develop (Johnson, Amso, & Slemmer, 2004; Sussman, Wong, Horvath, Winkler, & Wang, 2007).

Word Learning

Another classic rationalist argument for specialized language mechanisms originated with Quine (1960), who proposed that a child presented with a visual scene and a novel word faces an infinite number of possible interpretations. Thus, children must be innately constrained to consider only some of the possible meanings of a novel word.

Recent work suggests, however, that general cognitive processes and a cascade of developmental processes move children step-by-step from slow and deliberate to fast and efficient word learning. For example, Yu, Smith, Christensen, and Pereira (2007) examined Quine’s problem, not from the perspective of

an outside adult observer but from the child's own perspective using head-mounted cameras. The result: The child's view is much more focused than previously thought, with only one object in view at any given moment. This narrow focus occurs because the child's smaller body and shorter arms keep objects close to the eyes. This fresh look at Quine's problem suggests that language-specific constraints are unnecessary: The problem is greatly simplified through the physical constraint of short arms!

They can get children to the correct referent, but they cannot build a lexicon with categories that span individual instances. For that, nativists argue that children need constraints and innate knowledge to help them carve up the world (Markman, 1991; Soja, Carey, & Spelke, 1991). But do they? Work on the development of one well-studied word-learning bias—the shape bias—shows that becoming an effective word learner is an emergent product of basic attentional learning.

The “shape bias” refers to children's (and adults') tendency to generalize a novel name for a novel solid object to other solid objects on the basis of similarity in shape (Landau, Smith, & Jones, 1988). Smith, Jones, Landau, Gershkoff-Stowe, and Samuelson (2002) have proposed that the shape bias develops out of statistical regularities among the words and categories in the early noun vocabulary via general processes of attentional learning. Languages present regularities among linguistic devices, object properties, and perceptual category organization. For example, English distinguishes between objects that are countable and those that are not via the use of different determiners: Countable things are preceded by *a*, *another*, and number words, whereas uncountable things are preceded by *some* and *more*. Moreover, there are consistent associations between classes of nouns and object properties: Count nouns generally refer to rigid objects that have solid surfaces, straight edges, and sharp corners and are organized into categories based on object shape, whereas mass nouns usually refer to nonsolid substances with irregular shapes that are organized into categories based on material similarity (Samuelson & Smith, 1999). Thus, as children begin learning a vocabulary of individual words, they are also regularly exposed to, and learn, a rich set of statistical regularities among words, object properties, and category organizations (Samuelson & Smith, 1999; Smith, Colunga, & Yoshida, 2003).

These regularities are the basis for learned associations between naming contexts and object properties that come to mechanistically shift children's attention to the correct features of novel referents (Smith, 1999; Smith & Samuelson, 2006). The shape bias, then, simplifies the word learning situation and thereby aids vocabulary development (Samuelson, 2002; Smith et al., 2002), but it is not innate. Rather, it is the emergent product of a step-by-step cascade in which children move from individual name-referent pairings, to generalizations within categories, to generalizations that span similarities across categories. And, importantly, this cascade is grounded in general processes—detection of statistical regularities and learned associations.

In summary, nativist accounts of language development rely heavily on rationalist arguments for specialized learning mechanisms. Contemporary theory illustrates, however, how these arguments underestimate the computational power of even simple mechanisms (see McMurray, 2007), particularly when they are embedded within a developmental history.

CONCLUSIONS

As developmental scientists who work in a variety of domains and have been trained in diverse traditions, we share a profound dismay that our field has been consumed for so long by the nativist–empiricist debate. We hope to spur our colleagues and the next generation of scholars to seek new ground—not by compromising on the quantity and quality of “core knowledge systems” and “primitives” (Spelke & Kinzler, 2007) but by demanding an end to ungrounded claims about origins. This requires that we jettison the false dichotomies of the past (Johnston, 1987) and embrace a truly modern view of developmental process and developmental systems (Elman et al., 1996; Gottlieb, 1997; Oyama et al., 2001; Thelen & Smith, 1994).

We reemphasize that a developmental systems view is not the classical counterpoint to the nativist program—we are not arguing for a return to empiricism and notions of a “blank slate.” After all, the notion of a “blank slate” is just as poorly grounded as claims about “primitives” and “essences.” Rather, developmental science should acknowledge that development does not begin at birth; that it is a complex, historical process; and that the relationship between cause and consequence is often nonobvious. There is no easy way around such inconvenient truths. Viewing the topic through this lens, researchers can have legitimate interests in characterizing the abilities of newborns—they are certainly fascinating!—but such characterizations do not provide privileged insight into origins. Human infants have attained certain abilities at birth, just as they have attained other abilities 1 day prior to birth and 1 day after. To lose sight of this fact is to lose sight of development itself.

What is the way forward? First, we should hold each other to a higher standard when evaluating claims about origins without direct evidence. Some of us may examine fetuses, others newborns, still others toddlers, adolescents, adults, and the aged. We can justify any choice. But what we cannot justify is studying one time point and then making unsubstantiated—or worse, unsubstantiable—claims about prior points in time. One may think such claims are justified when there appear to be no relevant prior experiences that can account for the observed behavior. But the overly narrow conception of experience that nativists offer withers away in light of evidence that nonobvious experiences critically shape the development of behavior (Gottlieb, 1997).

Second, we must invest in the future. Today's young developmental scientists have at their disposal an incredible array of sophisticated tools that form the backbone of cutting-edge,

interdisciplinary research. However, these tools cannot replace the need for equally sophisticated training in contemporary developmental theory. For the sake of this generation, it is time to retire the nativist–empiricist dialog and encourage a new dialog that is forward looking and grounded in a modern view of developmental process.

REFERENCES

- Abbs, B., Gupta, P., Tomblin, J. B., & Lipinski, J. (2007). A behavioral and computational integration of phonological, short-term memory and vocabulary acquisition processes in nonword repetition. In D. MacNamara & G. Trafton (Eds.), *Proceedings of the twenty-ninth annual conference of the Cognitive Science Society* (pp. 59–64). Austin, TX: Cognitive Science Society.
- Altmann, G. (2002). Learning and development in neural networks—The importance of prior experience. *Cognition*, *85*, B43–B50.
- Altmann, G., & Diennes, Z. (1999). Rule learning by seven-month-old infants and neural networks. *Science*, *284*, 875.
- Bai, D. L., & Bertenthal, B. I. (1992). Locomotor status and the development of spatial search skills. *Child Development*, *63*, 215–226.
- Bateson, P. P. G. (1966). The characteristics and context of imprinting. *Biological Review*, *41*, 177–220.
- Bayley, N. (2006). *Bayley Scales of Infant and Toddler Development* (3rd ed.). San Antonio, TX: Harcourt Assessment.
- Bertenthal, B., & Campos, J. J. (1990). A systems approach to the organizing effects of self-produced locomotion during infancy. In C. Rovee-Collier & L. Lipsitt (Eds.), *Advances in infancy research* (pp. 1–60). Norwood, NJ: Ablex.
- Bertenthal, B. I., Campos, J. J., & Barrett, K. (1984). Self-produced locomotion: An organizer of emotional, cognitive, and social developments in infancy. In R. Emde & R. Harmon (Eds.), *Continuities and discontinuities in development* (pp. 175–210). New York: Plenum.
- Bertenthal, B. I., Campos, J. J., & Kermoian, R. (1994). An epigenetic perspective on the development of self-produced locomotion and its consequences. *Current Directions in Psychological Science*, *5*, 140–145.
- Blumberg, M. S. (2005). *Basic instinct: The genesis of behavior*. New York: Thunder's Mouth Press.
- Blumberg, M. S. (2009). *Freaks of nature: What anomalies tell us about development and evolution*. New York: Oxford University Press.
- Bolhuis, J. J. (1991). Mechanisms of avian imprinting: A review. *Biological Reviews of the Cambridge Philosophical Society*, *66*, 303–345.
- Bolhuis, J. J., & Honey, R. C. (1998). Imprinting, learning and development: From behaviour to brain and back. *Trends in Neuroscience*, *21*, 306–311.
- Bolhuis, J. J., Johnson, M. H., & Horn, G. (1985). Effects of early experience on the development of filial preferences in the domestic chick. *Developmental Psychobiology*, *18*, 299–308.
- Bolhuis, J. J., & Trooster, W. J. (1988). Reveribility revisited: Stimulus-dependent stability of filial preference in the chick. *Animal Behaviour*, *36*, 668–674.
- Brown, A. A., Spetch, M. L., & Hurd, P. L. (2007). Growing in circles: Rearing environment alters spatial navigation in fish. *Psychological Science*, *18*, 569–573.
- Campos, J. J., Anderson, D. I., Barbu-Roth, M. A., Hubbard, E. M., Hertenstein, M. J., & Witherington, D. (2000). Travel broadens the mind. *Infancy*, *1*, 149–220.
- Cheng, K., & Newcombe, N. S. (2005). Is there a geometric module for spatial orientation? Squaring theory and evidence. *Psychonomic Bulletin and Review*, *12*(1), 1–23.
- Chiandetti, C., & Vallortigara, G. (2008). Is there an innate geometric module? Effects of experience with angular geometric cues on spatial re-orientation based on the shape of the environment. *Animal Cognition*, *11*, 139–146.
- Chomsky, N. (1959). A review of B. F. Skinner's verbal behavior. *Language*, *35*(1), 26–58.
- Christiansen, M. H., Dale, R. A. C., Ellefson, M. R., & Conway, C. M. (2002). The role of sequential learning in language evolution: Computational and experimental studies. In A. Cangelosi & D. Parisi (Eds.), *Simulating the evolution of language* (pp. 165–188). New York: Springer.
- Christiansen, M., & Monaghan, P. (2006). Discovering verbs through multiple cue integration. In K. Hirsh-Pasek & R. M. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 88–110). New York: Oxford University Press.
- Clearfield, M. W. (2004). The role of crawling and walking experience in infant spatial memory. *Journal of Experimental Child Psychology*, *89*, 214–241.
- Clearfield, M. W., & Mix, K. S. (1999). Number versus contour length in infants' discrimination of small visual sets. *Psychological Science*, *10*, 408–411.
- Cornell, E. H., & Heth, C. D. (1979). Response versus place learning by human infants. *Journal of Experimental Psychology: Human Learning and Memory*, *5*, 188–196.
- Creel, S. C., Newport, E. L., & Aslin, R. N. (2004). Distant melodies: Statistical learning of non-adjacent dependencies in tone sequences. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*, 1119–1130.
- Cutler, A., & Butterfield, S. (1990). Durational cues to word boundaries in clear speech. *Speech Communication*, *9*, 485–495.
- Deacon, T. (1997). *The symbolic species: The co-evolution of language and the brain*. New York: Norton.
- Elman, J. (1990). Finding structure in time. *Cognitive Science*, *14*, 179–211.
- Elman, J., Bates, E., Johnson, M., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1996). *Rethinking innateness: A connectionist perspective on development*. Cambridge, MA: MIT Press.
- Fiser, J., & Aslin, R. N. (2002a). Statistical learning of higher-order temporal structure from visual shape-sequences. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*, 458–467.
- Fiser, J., & Aslin, R. N. (2002b). Statistical learning of new visual feature combinations by infants. *Proceedings of the National Academy of Sciences*, *99*, 15822–15826.
- Fiser, J., Scholl, B. J., & Aslin, R. N. (2007). Perceived object trajectories during occlusion constrain visual statistical learning. *Psychological Bulletin and Review*, *14*, 173–178.
- Gelman, S. A. (2003). *The essential child: Origins of essentialism in everyday thought*. Oxford, UK: Oxford University Press.
- Goldstein, M. H., King, A. P., & West, M. J. (2003). Social interaction shapes babbling: Testing parallels between birdsong and speech. *Proceedings of the National Academy of Sciences*, *100*(13), 8030–8035.

- Gómez, R. L. (2002). Variability and detection of invariant structure. *Psychological Science, 13*, 431–436.
- Gottlieb, G. (1997). *Synthesizing nature-nurture: Prenatal roots of instinctive behavior*. Mahwah, NJ: Erlbaum.
- Hailman, J. P. (1967). The ontogeny of an instinct: The pecking response in chicks of the laughing gull (*Larus atricilla* L.) and related species. In *Behaviour, Suppl. XV*. Leiden: E.J. Brill.
- Hailman, J. P. (1969). How an instinct is learned. *Scientific American, 221*, 98–106.
- Haith, M. M. (1998). Who put the cog in infant cognition? Is rich interpretation too costly. *Infant Behavior and Development, 21*, 167–179.
- Hermer, L., & Spelke, E. (1994). A geometric process for spatial reorientation in young children. *Nature, 370*, 57–59.
- Hermer, L., & Spelke, E. (1996). Modularity and development: The case of spatial reorientation. *Cognition, 61*, 195–232.
- Hermer-Vazquez, L., Spelke, E., & Katsnelson, A. (1999). Sources of flexibility in human cognition: Dual-task studies of space and language. *Cognitive Psychology, 39*, 3–36.
- Horn, G. (2004). Pathways of the past: The imprint of memory. *Nature Reviews Neuroscience, 5*, 108–113.
- Horn, G., & McCabe, B. J. (1984). Predispositions and preferences: Effects on imprinting of lesions to the chick brain. *Animal Behaviour, 32*, 288–292.
- Horobin, K., & Acredolo, L. P. (1986). The role of attentiveness, mobility history, and separation of hiding sites on stage IV search behavior. *Journal of Experimental Child Psychology, 41*, 114–127.
- Hupbach, A., Hardt, O., Nadel, L., & Bohbot, V. (2007). Spatial reorientation: Effects of verbal and spatial shadowing. *Spatial Cognition and Computation, 7*, 213–226.
- Hupbach, A., & Nadel, L. (2005). Reorientation in a rhombic environment: No evidence for an encapsulated geometric module. *Cognitive Development, 20*, 279–302.
- Jablonka, E., & Lamb, M. J. (2005). *Evolution in four dimensions: Genetic, epigenetic, behavioral, and symbolic variation in the history of life*. Cambridge, MA: MIT Press.
- Johnson, S., Amso, D., & Slemmer, J. (2004). Development of object concepts in infancy: Evidence for early learning in an eye tracking paradigm. *Proceedings of the National Academy of Sciences, 100*(18), 10568–10573.
- Johnston, T. D. (1987). The persistence of dichotomies in the study of behavioral development. *Developmental Review, 7*, 149–182.
- Johnston, T. D., & Edwards, L. (2002). Genes, interactions, and the development of behavior. *Psychological Review, 109*, 26–34.
- Jones, S. S. (1996). Imitation or exploration? Young infants' matching of adults' oral gestures. *Child Development, 67*, 1952–1969.
- Kempe, V., Brooks, P., & Gillis, S. (2005). Diminutives in child-directed speech supplement metric with distributional word segmentation cues. *Psychonomic Bulletin and Review, 12*, 145–151.
- Kermoian, R., & Campos, J. J. (1988). Locomotor experience: A facilitator of spatial cognitive development. *Child Development, 59*, 908–917.
- Klopfer, P. H. (1973). *On behavior: Instinct is a Cheshire cat*. New York: J. B. Lippincott.
- Krause, J., & Braid, L. (2003). Acoustic properties of naturally produced clear speech at normal speaking rates. *Journal of the Acoustical Society of America, 115*(1), 362–378.
- Kuhl, P. K., Andruski, J. E., Chistovich, I., & Chistovich, L. (1997). Cross-language analysis of phonetic units in language addressed to infants. *Science, 277*, 684–686.
- Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical learning. *Cognitive Development, 3*, 299–321.
- Learmonth, A. E., Nadel, L., & Newcombe, N. S. (2002). Children's use of landmarks: Implications for modularity theory. *Psychological Science, 13*, 337–341.
- Lee, S. H., Shusterman, A., & Spelke, E. S. (2006). Reorientation and landmark-guided search by young children. *Psychological Science, 17*(7), 577–582.
- Lehrman, D. S. (1953). A critique of Konrad Lorenz's theory of instinctive behavior. *The Quarterly Review of Biology, 4*, 337–363.
- Lepecq, J. C., & Lafaite, M. (1989). The early development of position constancy in a no-landmark environment. *British Journal of Developmental Psychology, 7*, 289–306.
- Liu, D., Diorio, J., Day, J. C., Francis, D. D., & Meaney, M. J. (2000). Maternal care, hippocampal synaptogenesis and cognitive development in rats. *Nature Neuroscience, 3*(8), 799–806.
- Lorenz, K. (1935). Der kumpan in der umwelt des vogels. *Journal für Ornithologie, 83*, 137–213.
- MacDonald, M., & Christiansen, M. H. (2002). Reassessing working memory: Comment on Just and Carpenter (1992) and Waters and Caplan (1996). *Psychological Review, 109*, 35–54.
- Marcus, G. F. (2001). Plasticity and nativism: Towards a resolution of an apparent paradox. In S. Wermter, J. Austin, & D. Willshaw (Eds.), *Emergent neural computational architectures based on neuroscience* (pp. 368–382). Heidelberg: Springer.
- Marcus, G. F., & Berent, I. (2003). Are there limits to statistical learning? *Science, 300*, 53–54.
- Marcus, G., Fernandez, K., & Johnson, S. (2007). Infant rule learning facilitated by speech. *Psychological Science, 18*(5), 387–391.
- Marcus, G. F., Vijayan, S., Bandi Rao, S., & Vishton, P. M. (1999). Rule learning by seven-month-old infants. *Science, 283*, 77–80.
- Markman, E. (1991). The whole object, taxonomic and mutual exclusivity assumptions as initial constraints in word meaning. In J. P. Byrnes & S. A. Gelman (Eds.), *Perspectives on language and thought: Interrelations in development* (pp. 72–106). Cambridge, MA: MIT Press.
- Maye, J., Weiss, D. J., & Aslin, R. N. (2008). Statistical phonetic learning in infants: Facilitation and feature generalization. *Developmental Science, 11*, 122–134.
- Maye, J., Werker, J. F., & Gerken, L. (2002). Infant sensitivity to distributional information can affect phonetic discrimination. *Cognition, 82*, 101–111.
- McKenzie, B. E., Day, R. H., & Ihsen, E. (1984). Localization of events in space: Young infants are not always egocentric. *British Journal of Developmental Psychology, 2*, 1–9.
- McMurray, B. (2007). Defusing the childhood vocabulary explosion. *Science, 317*, 631.
- Mintz, T. H. (2002). Category induction from distributional cues in an artificial language. *Memory and Cognition, 30*, 678–686.
- Mintz, T. H. (2003). Frequent frames as a cue for grammatical categories in child directed speech. *Cognition, 90*, 91–117.
- Monaghan, P., Chater, N., & Christiansen, M. H. (2005). The differential role of phonological and distributional cues in grammatical categorization. *Cognition, 96*, 143–182.
- Moore, C. L. (1995). Maternal contributions to mammalian reproductive development and the divergence of males and females. *Advances in the Study of Behavior, 24*, 47–118.
- Newcombe, N. S., Ratliff, K. R., Shallcross, W., & Twyman, A. D. (2009). Young children's use of features to reorient is more than

- just associative: Further evidence against a modular view of spatial processing. *Developmental Science*, doi: 10.1111/j.1467-7687.2009.00877.x.
- Newport, E. L., & Aslin, R. N. (2004). Learning at a distance: I. Statistical learning of non-adjacent dependencies. *Cognitive Psychology*, *48*, 127–162.
- Oyama, S., Griffiths, P. E., & Gray, R. D., Eds. (2001). *Cycles of contingency: Developmental systems and evolution*. Cambridge, MA: MIT Press.
- Peña, M., Bonatti, L., Nespor, M., & Mehler, J. (2002). Signal-driven computations in speech processing. *Science*, *298*, 604–607.
- Perruchet, P., Tyler, M., Galland, N., & Peereman, R. (2005). Learning nonadjacent dependencies: No need for algebraic computations. *Journal of Experimental Psychology: General*, *133*(4), 573–583.
- Pinker, S. (2002). *The blank slate: The modern denial of human nature*. New York: Viking.
- Plumert, J. M., & Spencer, J. P. (2007). *The emerging spatial mind*. Oxford, UK: Oxford University Press.
- Quine, W. V. (1960). *Word and object*. Cambridge, MA: MIT Press.
- Ratliff, K. R., & Newcombe, N. (2008). Reorienting when cues conflict: Using geometry and features following landmark displacement. *Psychological Science*, *19*, 1301–1307.
- Regolin, L., Vallortigara, G., & Zanforlin, M. (1995). Object and spatial representations in detour problems by chicks. *Animal Behavior*, *49*, 195–199.
- Remez, R. (2005). Perceptual organization of speech. In D. Pisoni & R. Remez (Eds.), *Handbook of speech perception* (pp. 28–50). Oxford, UK: Blackwell.
- Rider, E. A., & Rieser, J. J. (1988). Pointing at objects in other rooms: Young children's sensitivity to perspective after walking with and without vision. *Child Development*, *59*, 480–494.
- Rost, G., & McMurray, B. (2009). Speaker variability augments phonological processing in early word learning. *Developmental Science*, *12*, 339–349.
- Saffran, J. (2003). Statistical language learning: Mechanisms and constraints. *Current Directions in Psychological Science*, *12*, 110–114.
- Saffran, J. R., Aslin, R. N., & Newport, E. (1996). Statistical learning by 8-month-old infants. *Science*, *274*, 1926–1928.
- Saffran, J. R., & Thiessen, E. D. (2003). Pattern induction by infant language learners. *Developmental Psychology*, *39*, 484–494.
- Samuelson, L. K. (2002). Statistical regularities in vocabulary guide language acquisition in connectionist models and 15–20-month-olds. *Developmental Psychology*, *38*, 1016–1037.
- Samuelson, L. K., & Smith, L. B. (1999). Early noun vocabularies: Do ontology, category organization and syntax correspond? *Cognition*, *73*, 1–33.
- Seidenberg, M., & Elman, J. L. (1999). Do infants learn grammar with algebra or statistics? *Science*, *284*, 434–435.
- Smith, L. B. (1999). Children's noun learning: How general learning processes make specialized learning mechanisms. In B. MacWhinney (Ed.), *The emergence of language* (pp. 277–303). Mahwah, NJ: Erlbaum.
- Smith, L. B., Colunga, E., & Yoshida, H. (2003). Making an ontology: Cross-linguistic evidence. *Cognitive Creier Comportament*, *7*(1), 61–90.
- Smith, L. B., Jones, S. S., Landau, B., Gershkoff-Stowe, L., & Samuelson, L. K. (2002). Object name learning provides on-the-job training for attention. *Psychological Science*, *13*, 13–19.
- Smith, L. B., & Samuelson, L. K. (2006). An attentional learning account of the shape bias: Reply to Cimpian & Markman (2005) and Booth, Waxman & Huang (2005). *Developmental Psychology*, *42*, 1339–1343.
- Soja, N. N., Carey, S., & Spelke, E. S. (1991). Ontological categories guide young children's inductions of word meaning: Object terms and substance terms. *Cognition*, *38*, 179–211.
- Spelke, E. S., & Kinzler, K. D. (2007). Core knowledge. *Developmental Science*, *10*, 89–96.
- Spelke, E. S., & Newport, E. L. (1998). Nativism, empiricism, and the development of knowledge. In W. Damon & R. M. Lerner (Eds.), *Handbook of child psychology: Vol. 1. Theoretical models of human development* (pp. 275–340). New York: Wiley.
- Spencer, J. P., & Dineva, E. (2009). *Taking a random walk through nativist claims about spatial cognitive development*. Manuscript in preparation.
- Sussman, E., Wong, R., Horvath, J., Winkler, I., & Wang, W. (2007). The development of the perceptual organization of sound by frequency separation in 5–11 year old children. *Hearing Research*, *225*(1–2), 117–127.
- ten Cate, C. (1994). Perceptual mechanisms in imprinting and song learning. In J. A. Hogan & J. J. Bolhuis (Eds.), *Causal mechanisms of behavioural development* (pp. 116–146). Cambridge, UK: Cambridge University Press.
- Thelen, E., & Smith, L. B. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press.
- Thompson, S. P., & Newport, E. L. (2007). Statistical learning of syntax: The role of transitional probability. *Language Learning and Development*, *3*, 1–42.
- von Saint Paul, U. (1982). Do geese use path integration for walking home? In F. Papi & H. G. Wallraff (Eds.), *Avian navigation* (pp. 298–307). New York: Springer.
- Weaver, I. C., Cervoni, N., Champagne, F. A., D'Alessio, A. C., Sharma, S., Seckl, J. R., et al. (2004). Epigenetic programming by maternal behavior. *Nature Neuroscience*, *7*, 847–854.
- West, M. J., King, A. P., & Arberg, A. A. (1988). The inheritance of niches: The role of ecological legacies in ontogeny. In E. M. Blass (Ed.), *Handbook of behavioral neurobiology* (Vol. 9, pp. 41–62). New York: Plenum.
- West-Eberhard, M. J. (2003). *Developmental plasticity and evolution*. Oxford, UK: Oxford University Press.
- Yang, C. (2004). Universal grammar, statistics or both? *Trends in Cognitive Sciences*, *8*, 451–456.
- Yu, C., & Smith, L. (2007). Rapid word learning under uncertainty via cross-situational statistics. *Psychological Science*, *18*, 414–420.
- Yu, C., Smith, L. B., Christensen, M., & Pereira, A. (2007). Two views of the world: Active vision in real-world interaction. In *Proceedings of the 29th Annual Meeting of the Cognitive Science Society*. Mahwah, NJ: Erlbaum.