NIH Public Access
Author Manuscript
Child Dev Perspect. Author manuscript; available in PMC 2010 August 1.

Published in final edited form as:
Child Dev Perspect. 2009 August 1; 3(2): 103–105. doi:10.1111/j.1750-8606.2009.00087.x.

Seeing the world through a third eye: Developmental systems theory looks beyond the nativist-empiricist debate

John P. Spencer[1], **Larissa K. Samuelson**[1], **Mark S. Blumberg**[1], **Bob McMurray**[1], **Scott R. Robinson**[1], and **J. Bruce Tomblin**[2]
Delta Center University of Iowa Iowa City, Iowa 52242

[1]Department of Psychology University of Iowa Iowa City, Iowa 52242

[2]Department of Communication Sciences and Disorders University of Iowa Iowa City, Iowa 52242

Abstract

In response to the commentaries on our paper (Spencer et al., 2009) we summarize what a developmental systems perspective offers for a twenty-first century science of development by highlighting five insights from developmental systems theory. Where applicable, the discussion is grounded in a particular example—the emergence of ocular dominance columns in early development. Ocular dominance columns are a paragon of epigenesis and are inconsistent with the nativist view. We conclude with optimism that developmental science can move beyond the nativist-empiricist debate armed with both modern technological tools and strong theory to guide their use.

Lively debate is the lifeblood of good science, and we thank all the individuals who took the time to write commentaries in response to our paper (2009). Our central theme was that it is high time to move beyond the nativist-empiricist debate and the dichotomous thinking that epitomizes it. Several of the commentaries illustrate how difficult this will be. For example, Landau (2009) argues that *even we nonnativists* must posit "building blocks" and "primitives"; she cannot imagine the construction of a developmental theory without them. Marcus (2009), by contrast, assigns us to the empiricist camp, as, to a degree, does Karmiloff-Smith (2009), despite explicit statements in our essay to the contrary. In Marcus's view, "To really advance the debate, each side will need to recognize the insights of the other." But, again, we are not trying to advance the debate. We are trying to dismantle it. We are advocating a shift in thinking away from dichotomies toward an appreciation of the full complexity of developmental process at multiple levels and time scales.

Spelke and Kinzler (2009) suggested that our view of the future is rather bleak and that we are rejecting the "empirical tools of psychology and cognitive neuroscience." We do not reject these tools, but we do contend that they are only as good as the theories that motivate their use. For instance, comparative approaches have been used to argue for innateness when some ability is *unique* to humans (e.g., Hauser, Chomsky, & Fitch, 2002), as well as when an ability is *shared* among humans and other animals (see Spelke & Kinzler; Landau). It appears, then, that comparative work is not diagnostic of innateness. Indeed, comparative work provides a compelling illustration of how the modern nativist position is too encompassing. For example, Spelke and Kinzler posit that "innate means not learned," whereas the *Oxford English Dictionary* defines innate as "existing in a person (or organism) from birth; belonging to the original or essential constitution (of body or mind)." Spelke and Kinzler's preferred definition is a clever way to catch all characteristics within the nativist bucket when it appears that learning (in the conventional sense) can be ruled out. The problem is that the characteristics being "caught"— including short arms, social systems, biological inheritance, nonbiological inheritance—are simply too complex and interesting to be stuffed into one impressively large container.

To move toward greater theoretical rigor, and beyond sound bites and seemingly intuitive concepts like "primitives," we summarize here what a developmental systems perspective is and the vision that this perspective offers for a twenty-first century science of development. In particular, we highlight five insights from developmental systems theory[1]. Where applicable, we ground our discussion in one final example—the emergence of ocular dominance columns in early development. We picked this example because ocular dominance columns are often used by nativists to support their views (see Marcus; Spelke & Kinzler). Dominance columns, however, are produced through competitive interactions between retinal ganglion cells--even in the absence of patterned visual stimulation by light--and the effects of these interactions on downstream neural circuits. Thus, these features of the visual system are paragons of epigenesis—and epigenesis is not, regardless of what nativists wish to believe, compatible with nativism (Blumberg, 2005;Gottlieb, 1997;Michel & Moore, 1995;Moore, 2001;Oyama et al., 2001).

1. Processes live at multiple levels from culture to genes

Everyone knows that children learn French easily when immersed in French culture (see Spelke & Kinzler) and that gene expression is extremely complex and can be triggered by often nonobvious influences (Johnston & Edwards, 2002; Keller, 2000). But these "facts" are routinely ignored when researchers look at phenomena at one level and assign "cause" at another. For instance, Marcus cites Horton and Hocking (1996) as finding that "ocular dominance columns form in the complete absence of visual input." This is technically correct, but only if we restrict the definition of "visual input" to light. In fact, spontaneous activity within the retina and the lateral geniculate nucleus provides structured visual-system input in the absence of light (Wong, 1999; for review, see Shatz, 2002). From the perspective of a neuron in the thalamus, the retinal ganglion cell is the critical local environment; thus, it does not matter to this neuron whether it has been stimulated by a retinal ganglion cell that has fired spontaneously or one that has been stimulated by light (via photoreceptors). Both kinds of input provide critical experience to a thalamic neuron. This is exactly the kind of experience, broadly defined, that Lehrman highlighted over fifty years ago (Lehrman, 1953) and that modern nativism routinely overlooks[2].

2.There are cascading, nonlinear, and often nonobvious interactions among levels

The existence of complex processes at multiple levels creates one set of complications, but even more complications arise when we consider interactions among levels: how genes affect neurotransmitter release; how neurotransmitters modify the activity of neurons; how the activity of populations of neurons are coordinated through time; how this population activity can in turn change gene expression; how behaviors are generated, producing new patterns of stimulation that drive change at lower levels. In our original paper, we highlighted the nonobvious nature of these interactions and emphasized how one cannot

[1]Interested readers are referred to the collection of more specific theoretical approaches that, in our view, fall within a developmental systems framework (dynamical systems theory, see Thelen & Smith, 1994; developmental psychobiology, see Oyama et al., 2001; connectionist approaches to development, see Elman et al., 1997; neuroconstructivism, see Mareschal et al., 2007).

[2]A similar critique can be levied against Marcus's treatment of findings from Verhage et al. (2000). He contends this paper shows that the brain is formed even when "experience is precluded altogether." But Verhage et al. more modestly claim that, for early brain development, "spontaneous activity must act by a mechanism that does not require neurotransmitter release" (p. 868).

understand the emergence of a new behavior merely by thinking about it rationally. In a similar vein, Karmiloff-Smith points to the cascading processes that characterize development in children with Williams syndrome.

3. No one (level) is in control

Although it is tempting to favor one explanatory level over another, we urge caution. Such favoring can lead to a mischaracterization of developmental process. For instance, Marcus writes, “The role of genes is not just to create the brain and body of a newborn, but to create an organism that is flexible enough to deal with an ever-changing world. …” But, in fact, genes don't create anything, let alone brains, bodies, and flexibility. Genes participate in the production of proteins and in the regulation of other genes. The building of brains, bodies, and flexibility involves a cascading developmental process in which genes and their products interact within their local environment to create the substrates for further development.

4. These nested interactions propagate over multiple time scales

Developmental processes unfold over time, and therefore cannot be viewed in isolation. Rather, the real-time activity of a child in context lays the foundation for integrated experiences occurring over days, weeks, months, and years (for discussion, see Adolph et al., in press). And these processes that live at longer time scales provide the fuel for cultural and biological evolution. Thus, when we put our experimental foot down somewhere in time, we must be ever mindful that the processes we just caught by the tail have a history that extends backward in time and will have a future that extends beyond the time scale of our experimental patience.

5. Nested interactions can lead to the emergence of new patterns of organization in context

One of the central insights of a developmental systems view is that *new forms can emerge over time*, that is, something fundamentally new can be created over development (for discussion, see Spencer & Perone, 2008; see also, Smith, 1999). As an example, Constantine-Paton and Law (1978) artificially created frogs with three eyes and were thereby able to demonstrate the emergent nature of ocular dominance columns in a species that does not typically produce them.

Are ocular dominance columns in three-eyed frogs innate? Some might argue that the building blocks must have been there to allow for this pattern to emerge (see Landau). In our view, however, there is no need for building blocks because, as noted earlier, ocular dominance columns are built through competitive interactions among spontaneously firing retinal ganglion cells and their effects on downstream neural circuits. Positing innate building blocks does not inform our understanding because, as Moore (2009) correctly points out, building blocks must themselves be built. Of course, researchers should state the initial conditions required for new forms to emerge within the systems they study, be those conditions particular cell types, patterns of connectivity among cells, or something else. But such initial conditions should not be confused with innate building blocks. By carefully drawing this distinction, we purposefully leave a parenthesis open, promoting the view that more remains to be explored and discovered about the processes that created the initial conditions. A developmental systems view, therefore, promotes a greater understanding of the phenomena and fosters more, not fewer, lines of research (contra Spelke & Kinzler).

Putting all these critical insights together results in a theoretical approach that focuses on developmental process “all the way down”—from neighborhoods to neurons—and at all time scales from milliseconds to minutes to days to years to eons. Although some may find the challenges of a developmental systems perspective daunting, we are optimistic that our science can move in the right direction, armed with modern empirical and technological tools. But we reiterate: these tools are only as good as the theory that guides them. For this and all the other reasons that we have enumerated, we remain confident in our judgment that the nativist-empiricist debate should no longer be abided.

Acknowledgments

This work was supported by NSF HSD 0527698 awarded to John P. Spencer, an Independent Scientist Award (MH66424) from the National Institute of Mental Health awarded to Mark S. Blumberg, and NICHD 045713 awarded to Larissa K. Samuelson. To join the discussion of this paper and associated commentaries, visit the Delta Center's Facebook page: www.facebook.com/home.php#/group.php?gid=20773264989

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