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CHILD DEVELOPMENT PERSPECTIVES

Preaching to the Converted? From Constructivism to Neuroconstructivism

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ABSTRACT—*Xx xxxxxx.*

KEYWORDS—*xxx; xxx; xxx; xxx; xxx; xxxxx.*

Spencer and colleagues (p. xxx) have produced an article that all students of developmental neuroscience should read. Their ideas resonate with Piaget's constructivism (Piaget, 1967) and more recent versions of neuroconstructivism (Bates et al., 1998; Elman et al., 1996; Johnson, 2001; Karmiloff-Smith, 1992, 1998, 2007; Karmiloff-Smith, Plunkett, Johnson, Elman, & Bates, 1998; Mareschal et al., 2007). Even though I believe that Piaget was wrong about stages (Karmiloff-Smith, 1992), his was truly a middle-ground epistemological position, which stressed that nativism was a theoretical cop-out—he was particularly critical of Plato, Descartes, and Kant—and that the search for a start state was a static enterprise giving rise to infinite regress because, in the deepest sense, there is no absolute "beginning" (Piaget, 1967). And neuroconstructivists have consistently argued for Spencer and colleagues' central theme—for an epigenetic process that entails cascades of interactions across multiple levels of causation from genes to environments (e.g., Cornish, Scerif, & Karmiloff-Smith, 2007; Elman et al., 1996; de Haan, Humphreys, & Johnson, 2002; Johnson, 2001; Johnson, Halit, Grice, & Karmiloff-Smith, 2002; Johnson & Morton, 1991; Karmiloff-Smith, 1998, 2006, 2007). Although the converted will agree with much of the content of Spencer et al. interesting position, the article may seem obvious to them, and it may come across as frustrating to the as-yet-unconverted because, although it rightly criticizes others' claims of innateness, it runs the risk of appearing to nativists as yet another example of empiricism in disguise. Indeed, despite its accent on dynamical systems and its excellent discussions of examples from ethology and human psychology, the article seems to end up opting for two domain-general learning mechanisms of equivalent status: statistical learning and associative learning. Are these the only mechanisms that enable a system like the brain to reach its emergent adult state through the dynamic processes of development?

Other human examples might have strengthened Spencer et al. case. For example, nativists have frequently used genetic disorders in children to bolster their claims (e.g., Baron-Cohen, 1998; Castles & Coltheart, 1993; Duchaine, 2006; Gopnik, 1997; Leslie, 1992; Temple, 1997; Young & Ellis, 1989). The notion that the mind/brain comprises relatively independently functioning modules may be to some extent true for the adult brain once it has become fully specialized, a position illustrated by cases of acquired domain-specific deficits when focal damage has occurred. However, the extension by nativists of this type of thinking to typically and atypically developing infants in terms of innately specified, intact, or impaired modules, is unwarranted. Despite this, many researchers in the field of genetic syndromes continue to explain developmental disorders in terms of the "boxology" model of adult neuropsychology, in which the brain's functioning is represented by a series of boxes and arrows, with impaired boxes crossed through. Uneven neuropsychological profiles are divided into separated boxes for number, face processing, space, semantics, syntax, and so forth, each processed within a purported specialized region of the brain. This ignores the dynamic processes of development—how the adult brain *becomes* the way it is. In line with Spencer et al. arguments, it is clear that human intelligence is not a state, that is, not a collection of static, built-in modules that start out intact or impaired, but a process, that is, the emergent property of dynamic multidirectional interactions between genes, brain, cognition, behavior, and environment (see discussion in Karmiloff-Smith, 1998).

Timing also plays a critical role in the cascading, interacting processes that characterize gradual developmental change. For example, infants and toddlers with Williams syndrome (WS) are very impaired early on in planning saccadic (quick and

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simultaneous) eye movements (Brown et al., 2003), which affects their subsequent ability to follow pointing (Laing et al., 2002), which in turn reduces their ability to use parental referential pointing to learn vocabulary. So, although later in development their language becomes proficient (not "intact," Karmiloff-Smith et al., 1997; as some claim), language in toddlers with WS is initially extremely delayed with an atypical developmental trajectory (Annaz, Karmiloff-Smith, & Thomas, in press; Paterson, Brown, Gsodl, Johnson, & Karmiloff-Smith, 1999). Thus, a problem with the *visual* system, together with other contributing factors (Masataka, 2001; Nazzi, Paterson, & Karmiloff-Smith, 2003), dynamically influences the way in which *auditory* stimuli are acquired. Because a critical vocabulary mass is necessary before syntax can take off, this in turn seriously delays grammatical development. Moreover, the failure to plan efficient saccadic eye movements affects more than just the early acquisition of language. Individuals with WS also turn out to be predominantly featural processors, which is obvious from both brain and behavioral studies (Grice et al., 2001, 2003; Karmiloff-Smith et al., 2004; Mills et al., 2000). A possible explanation for this is that, in the typical case, rapid configural processing emerges from REM planning, whereas, in the atypical WS case, the fact that infants remain fixated on stimuli such as faces leads to a focus on featural detail.

In addition to supporting their claims of core knowledge and built-in modules with atypical development of genetic origin, nativists also depend on data from early typical development. Indeed, when researchers detect a behavioral proficiency in typically developing infants within the first few months of life, they rarely seek an explanation in terms of an early capacity for learning. Rather, they claim that infants are born with innately specified core knowledge or domain-specific principles for that particular competence: number (Gelman & Butterworth, 2005), face processing (Duchaine, 2006), language (Pinker, 1999), spatial cognition (Hermer & Spelke, 1996), knowledge of the constraints governing the physical world (Spelke, 2005), and so forth. Some (e.g., Piatelli-Palmarini, 2001) totally deny that learning has any explanatory power. For others (e.g., Spelke & Kinzler, 2007), learning does occur, but it is highly constrained and can take place only if it is based on earlier core, domain-specific *knowledge*, or what we have elsewhere termed "representational innateness" (Elman et al., 1996). Yet, as Spencer and colleagues' article eloquently shows, detection of statistical regularities and learned associations from processing the input can go a long way toward getting a system off the ground without the need for specific, built-in knowledge.

Unlike Spencer and colleagues, I personally find it difficult to congratulate Spelke and Kinzler (2007) for having moved to a middle ground. After all, Spelke and Kinzler continue to argue for a nativist stance, that is, "domain-specific separable systems of core knowledge" (p. 257), even if the number of these innately specified core knowledge systems is now small. However, with their dichotomous reading of current theories (either a blank slate or innate core knowledge; see also Pinker, 2006), we might forgive Spencer et al. for judging Spelke and colleagues' position to be one that actually embraces a form of empiricism: Two dual learning mechanisms of equivalent status (statistical and associative learning) invoked to explain all learning. Has nothing changed over evolutionary time or across species? Does the human infant start out with no biases that could lend themselves to differential processing of different types of input? Is ontogenesis entirely unchanneled?

I and my colleagues have been advocating a position that is, in our view, a truly middle ground (Elman et al., 1996; Karmiloff-Smith, 1992) that the infant brain is neither a learning device of equivalent status nor one containing a number of built-in, domain-specific, core knowledge systems. Rather, beyond the common six-layer structure across regions of cerebral cortex, we argue for tiny regional differences in type, density, and orientation of neurons, in neurotransmitters, in firing thresholds, in rate of myelination, lamination, ratio of gray matter to white matter, and so forth. These differences make certain networks of the brain somewhat more relevant to the processing of certain types of input than others (Elman et al., 1996; Karmiloff-Smith, 1998). In our view, many cortical regions initially attempt to process all incoming inputs. With time—with repeated processing—some networks turn out to be more proficient than others and start to fine tune and specialize in processing a particular input type. Our argument is now borne out by empirical data from typically developing infants showing that the whole cortex starts out being much more active in attempts to process incoming input, but gradually some areas show reduced activity and others increased activity as processing becomes more localized and specialized in the fine-tuning of the type of inputs processed. Of course, there are many examples of activity across the whole cortex even in adults, but the issue here is developmental *change* in the differing levels of activity across different regions of cortex. Indeed, infant brains start out displaying more widespread activity when processing, say, faces, than those of older children whose brains, with development, *become* increasingly localized and specialized (Cohen-Kadosh & Johnson, 2007; Giedd et al., 1996, 1999; Huttenlocher & Dabholkar, 1997; Johnson, 2001; Johnson et al., 2002; Karmiloff-Smith, 1998). In other words, what was "domain relevant" to processing faces *becomes* domain specific as a result of repeated processing of certain types of input like faces, as competition between regions wins out over developmental time. It is not the mere fact that the infant brain initially shows widespread activity in response to a certain type of input that demonstrates progressive cortical specialization. It is the developmental changes that occur over time. And it is precisely this form of progressive developmental localization and specialization of cerebral function that is lacking in some syndromes in which brains continue to show widespread activity across both hemispheres even in adulthood, despite the existence of proficient overt behavior (Karmiloff-Smith, 1997, 2007).

Indeed, rather than invoking impaired and intact built-in core knowledge, genetic syndromes point to altered constraints on neural plasticity in a *developing* organism, often affecting plasticity itself (Karmiloff-Smith, 1998; Karmiloff-Smith & Thomas, 2003). Although some see plasticity as a response solely to injury (Wexler, 1996), for others it is the rule for development, normal or atypical (Bates et al., 1998; Cicchetti & Tucker, 1994; Elman et al., 1996; Huttenlocher & Dabholkar, 1997; Johnson, 2001; Karmiloff-Smith & Thomas, 2003). For instance, visual cortex processes visual input, but it is not predestined solely to do so. Several experiments with the blind reveal that primary visual cortex can process tactile input (Braille reading) or auditory input (Sadato et al., 1998). Moreover, the ventral and dorsal pathways play different roles in cerebral processing, but these differences could have emerged from development. A demonstration in principle is provided by a neural network model that fed identical inputs to two pathways with identical architecture except for a small difference in the rate of activation changes. After repeated processing of inputs, the slower pathway ended up processing the features of objects (the “what channel”) and the faster pathway ended up processing the location of objects (the “where” pathway) (O’Reilly & McClelland, 1992). In other words, this model showed that differences like those in the ventral and dorsal pathways could in principle emerge from a developmental process as long as (a) there were tiny domain-relevant differences in their start state, and (b) the environment provided species-typical stimuli like objects and their movements across space. If the tiny difference in activation levels is not part of the initial state of, say, an atypical brain, a single mechanism may attempt to process both where and what objects are, but may do so less efficiently than brains endowed with that small difference in firing thresholds. Once the two systems emerge developmentally, they can be subsequently dissociated in adult brain injury, without the dissociation automatically implying innately specified specializations (Karmiloff-Smith, Scerif, & Ansari, 2003). But plasticity is of course not totally unconstrained, and developmental disorders may turn out to be very informative about the constraints on plasticity.

Finally, what about the issue of evolution and core knowledge systems? I agree with Spencer et al. criticism of the school of evolutionary psychology that compares the human brain to a Swiss army knife, each tool exquisitely fashioned and dedicated to carrying out very circumscribed tasks, passed on by evolution from our hunter-gatherer ancestors (Duchaine, Cosmides, & Tooby, 2001). Instead, I would argue that evolution seems to have endowed species with increasing flexibility for learning rather than increasing complexity of built-in domain-specific core knowledge. However, in my view it continues to be worth exploring the intricate balance between prespecification and plasticity for learning (Karmiloff-Smith, 1992). In fact, the degree of prespecification varies in nonrandom ways across species (Quartz & Sejnowski, 1997), with the highest degree of prespecification in animals most distal from humans and the lowest degree of prespecification in our closest relative, the chimpanzee. Yet, a high degree of prespecification allows for some adaptive learning, and a low degree of prespecification does not necessarily mean no biases whatsoever in a system. In other words, it is worth exploring the extent to which ontogenesis channels development to some extent via the dynamic competition between domain-relevant learning mechanisms and the highly structured species-typical inputs that they process, such that over developmental time, domain specificity becomes an emergent rather than built-in property of the human cognitive system.

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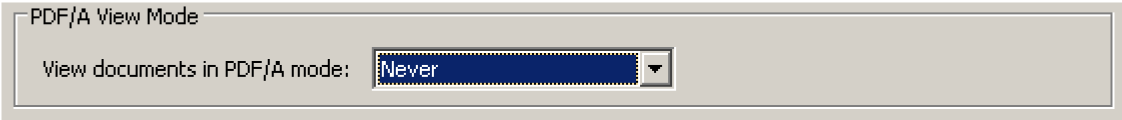

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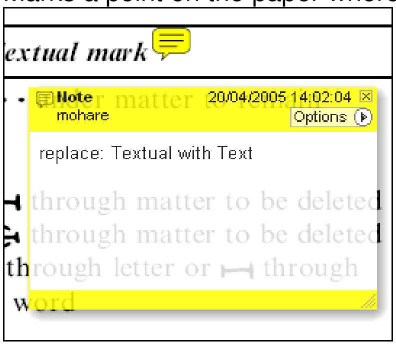

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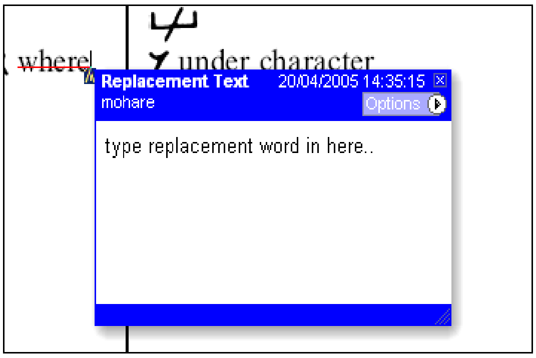

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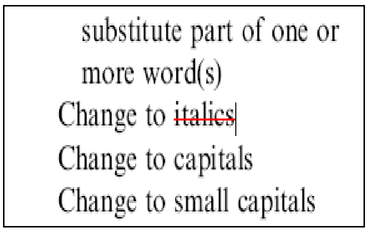

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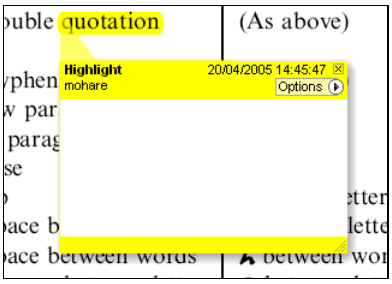

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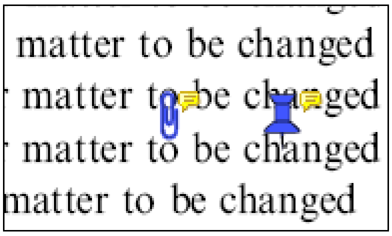

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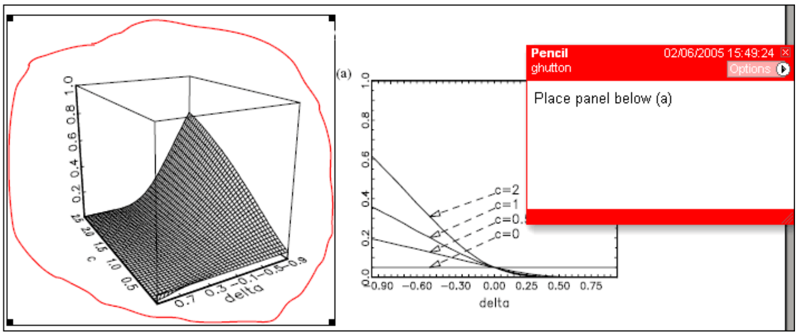

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