Trends in Cognitive Sciences

Letter

No evidence for discontinuity between infants and adults

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Based on studies of infant gaze, developmental psychologists have ascribed abstract cognitive functions to young infants. In their thought-provoking article, Blumberg and Adolph (B+A) [1] consider the implications of developmental neurobiology for these claims. Abstract cognitive functions in adults depend on cortical circuits; however, B+A hypothesize that the developing cortex is too immature to drive gaze in the youngest infants. If this is true, then subcortical regions must be driving all observed gaze behavior in young infants. If infants' gaze relies on entirely distinct neural mechanisms from those underlying abstract adult cognition, B+A argue, 'claims of developmental continuity between infant and adult cognition are suspect' ([1], p. 233). We challenge this line of reasoning, and instead argue that the available, though admittedly limited, neural data from young infants suggests remarkable continuity between infant and adult minds and brains.

First, B+A hypothesize that all looking behavior in young infants is driven by subcortical mechanisms, which they use to argue that young infants cannot be engaging in abstract cognition. However, B+A themselves acknowledge that all cognitive processes in adults rely on systematic and recursive loops between cortical and subcortical regions ([1], p. 243, see also [2]). For example, numerical cognition in adulthood evokes activity in the parietal cortex, but also in the subcortex [3]; visual categorization is accomplished in the ventral temporal cortex, but also in the superior colliculus [4]; and cognitive control evokes activity in frontoparietal cortical networks, but also in the periaqueductal gray and other midbrain nuclei [5]. Cognition, and the behavioral outputs of cognition, are not exclusively driven by the cortex in people of any age. Thus, the strong reverse inference made by B+A, from subcortically mediated behavior in infants to noncognitive, or less abstract cognitive processes, is unjustified.

Second, the essential part of the argument of B+A for developmental discontinuity is the absence of cortical control over eye movements in infancy. In adults, multiple cortical brain regions project to the superior colliculus, the primary midbrain structure controlling eye movements (Figure 1A). B+A claim that these projections from the cortex to subcortex are not yet functional in early infancy. Note that B+A grant the flow of information between the same structures in the opposite direction: subcortical structures process and relay information to the cortex. This flow of information is structurally organized similarly to that in adults, as early as has been measured. Neuroimaging of human infants aged ≤6 months has found systematic topological organization [6] and task-driven activation of all the major cortical networks [7], including by high-level vision [8], language [9], social cognition [10], and control of attention [11]. Despite this remarkable consistency of the network organization between infancy and adulthood, B+A suggest that, before infants are 3–6 months old, this functionally organized cortical activity is epiphenomenal, and plays no causal role in infants' behavior such as eye gaze. Cortical activity, they argue, occurs in young infants *only* to organize neural representations that will be useful for driving behavior later in development, and thus is qualitatively discontinuous with adult abstract cognition.

We see no support for such a categorical shift from early to late infancy. Instead, the same data are consistent with gradual, continuous change (Figure 1B). Cortical functional organization and connectivity patterns do undergo protracted development over the first year of life, altering the tuning, speed, and precision of neural activity. However, the starting state for this development is architecturally and functionally similar to adult brain organization. Thus, another possible explanation for the same observations is that the balance of influence shifts continuously during the first year within a developmentally stable architecture of cortical–subcortical loops. Initially, input from subcortical to cortical regions may dominate, driving learning. Over the first year, the balance of influence may shift to the cortical regions. This hypothesis, like the hypothesis presented by B+A, goes beyond existing data, and could be tested in future empirical studies, including those that link cortical activity to looking behavior in infants aged <6 months, following work in older infants [12].

In summary, the persistent role of the subcortex, and a gradually increasing involvement of the cortex, in generating behaviors would explain all of the data presented by B+A. However, this proposal also suggests that infants' cognitive abilities *are* the structural and functional precursors of adults' cognitive abilities. Thus, the existing behavioral and neural evidence is consistent with continuity between infant and adult minds.

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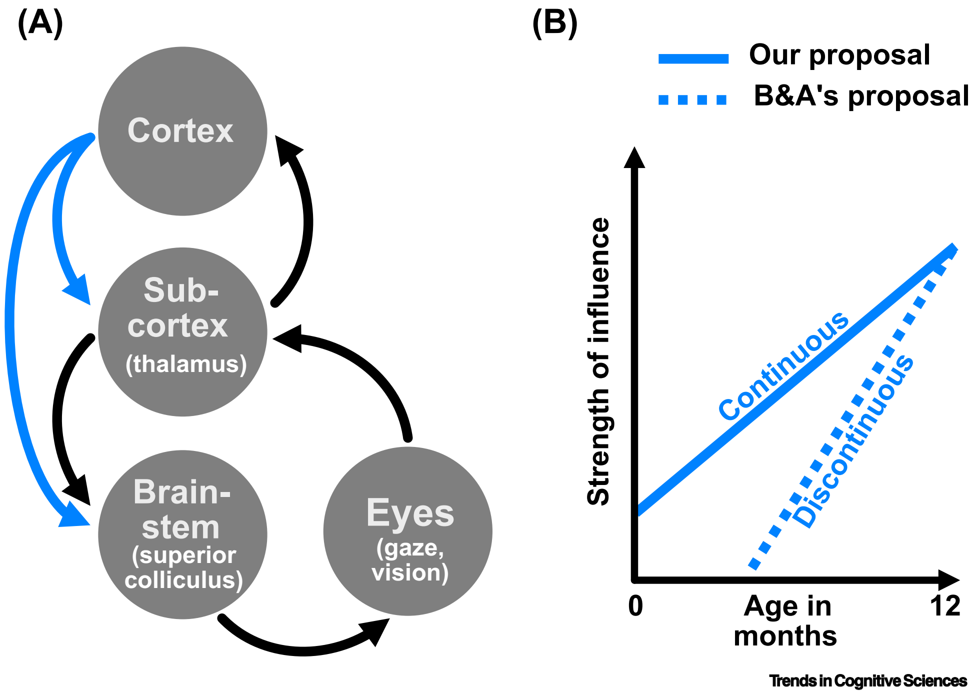

Figure 1. (A) Circuit underlying vision and gaze in infants and adults. Visual information flows from eyes to cortical regions in both infants and adults. The debate concerns when cortical regions begin to influence eye movements (blue arrows). (B) Alternative proposals for the strength of cortical influence over development. Blumberg and Adolph propose that cortical regions have no influence before age 3–6 months, and thus argue for developmental discontinuity in the neural basis of cognition. We propose that cortical regions begin with weak influence that gradually strengthens, consistent with continuity in the neural basis of cognition.

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