Trends in
Cognitive Sciences

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Spotlight

When do sensitive periods emerge later in development?

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Although plasticity is often heightened early in life, innovative modeling from Walasek and colleagues demonstrates that sensitive periods may emerge later in development when the reliability of environmental cues increases across ontogeny. In doing so they provide novel mechanistic insight into empirical observations of heightened environmental influences during adolescence.

Experiences that take place early in life can have a profound and lasting effect on brain and behavioral development, particularly when they occur during sensitive periods of heightened plasticity. Recent years have witnessed transformative discoveries about the neurobiological mechanisms that control the onset and closure of sensitive periods, as well as the insight that sensitive-period processes are themselves malleable [1]. Despite these advances, much has remained unknown about the evolution of sensitive periods.

In parallel to empirical research, a growing area of mathematical modeling has elucidated the conditions under which evolution may select for sensitive periods. In these models, organisms use environmental cues to construct a phenotype that is optimized to meet the demands of their environment [2]. Consistent with the gradual nature of behavioral development, models that allow for incremental specialization of phenotypes have demonstrated how environmental cues can have more or less impact on phenotypic development at different times in ontogeny [2]. In other words, these models allow sensitive periods to emerge. By manipulating specific variables, researchers can then explore how environmental conditions and experiences relate to the key features (e.g., timing, duration) of sensitive periods. In general, these models suggest that individuals who have more consistent experiences lose their plasticity earlier in development, allowing greater investment in phenotypic specialization when uncertainty is low [2]. These predictions fit with empirical findings, such as evidence for a more gradual decline in plasticity among bilingual infants [3].

Although sensitive periods of heightened plasticity often occur early in life, growing empirical evidence suggests that experiences can also have heightened effects later in development. Indeed, adolescence has been proposed as a sensitive period for a range of processes such as socioemotional development [4]. Formal modeling has not been able to account for the phenomenon of later sensitive periods. In an innovative new study, Walasek and colleagues [5] explore the conditions that favor sensitive periods at later developmental stages. Crucially, unlike previous models, the reliability of cues – the probability of receiving a particular cue given that the organism is in a corresponding environmental state – can vary across ontogeny in their model. The researchers tested conditions in which cue reliability increased, decreased, or increased and then decreased. Sensitive periods were only favored early when cue reliability decreased across ontogeny. By contrast, sensitive periods emerged later in development only when cue reliability increased across some portion of ontogeny. Notably, the findings were robust across various manipulations, suggesting that the occurrence of later sensitive periods when cue reliability increases across ontogeny is likely to generalize across a broad array of paradigms for sensitive periods that are often used in empirical research.

The current findings could lend valuable mechanistic insight into several phenomena that have been observed in brain and behavioral development. Although the idea that adolescence represents a sensitive period for various processes has gained traction, much remains unknown about the precise nature of plasticity during adolescence. For example, under some environmental conditions or for particular functions, adolescence may be a discrete period of heightened plasticity (e.g., if cue reliability peaks mid-ontogeny). In other cases, a continuous sensitive period may span childhood and adolescence (e.g., when cues are unreliable early in life but become more reliable across development) (Figure 1) [4]. Alternatively, plasticity may decline gradually (and linearly) across childhood and adolescence, as in cases when cue reliability is high early in life and declines across development. Each of these three models would have different implications for the influence of experiences on brain and behavioral development. Moreover, the current work may explain some of the marked heterogeneity that has been observed in brain and behavioral development following early-life adversity [6]. Walasek and colleagues show interindividual differences in the extent of heightened plasticity during sensitive periods that occur mid-ontogeny [5]. Organisms with more uncertainty when they entered a period of higher cue reliability had higher peaks of plasticity during mid-ontogeny sensitive periods. These findings highlight ways in which the environmental conditions experienced by an organism can shape the trajectories of plasticity.

Innovations in modeling the evolution of sensitive periods present rich opportunities for synergy between fields that often operate in isolation. As one example, growing empirical evidence suggests that early adversity can accelerate the pace of development [7,8], possibly to facilitate reproduction in the context of a

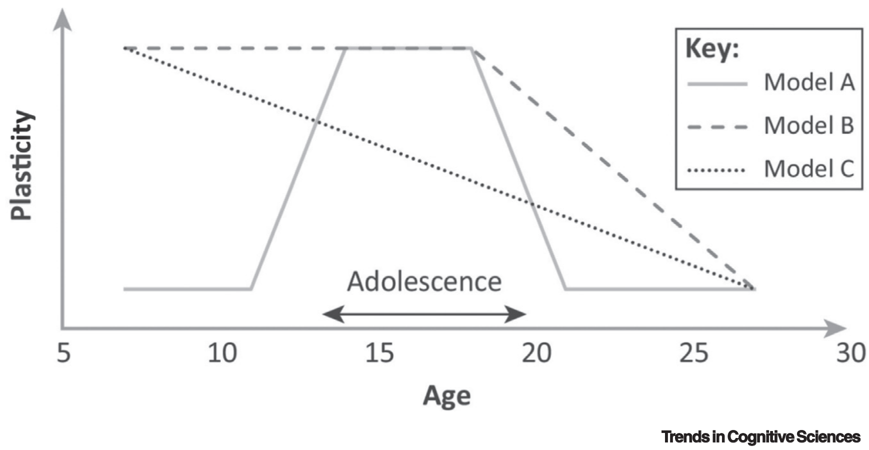

Figure 1. Models of Plasticity in Adolescence. Depending on the environmental conditions and the specific cognitive, behavioral, or neural process at hand, plasticity in adolescence could take different forms: (A) a discrete period of heightened plasticity during adolescence; (B) a continuous sensitive period that spans childhood and adolescence; (C) continuous decline across childhood and adolescence. Reprinted, with permission, from [4].

foreshortened lifespan [7] or to meet the affective demands of a harsh environment [8]. However, other studies show delays or no differences in the pace of maturation following adversity [9], and much remains unknown about the conditions in which alterations in the timing of development may arise. Future models that examine the evolution of sensitive periods when the length of ontogeny is uncertain (e.g., owing to mortality risk) could provide novel insights and help to refine hypotheses about the mechanisms by which adversity influences the pace of brain development. Second, recent longitudinal evidence suggests that puberty may confer greater plasticity and opportunities for recalibration of the hypothalamus–pituitary–adrenal (HPA) axis following early childhood adversity. Adolescents exposed to caregiver deprivation in infancy and who were later adopted into stable, supportive family environments showed shifts toward more typical cortisol stress reactivity with pubertal development [10]. With strategic manipulations (e.g., allowing the environmental state to vary over time), future models could provide a means to explore the conditions under which a shift to a significantly more favorable environment in adolescence could facilitate adaptive reshaping of the HPA axis following early adversity. Taken together, the work of Walasek and colleagues provides novel insight into when sensitive periods may emerge later in development, and opens up new avenues for developmental scientists to test key predictions from leading conceptual models of early adversity.

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Declaration of interests

The author declares no competing interests.

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