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Review article

Leveraging Neuroscience to Inform Adolescent Health: The Need for an Innovative Transdisciplinary Developmental Science of Adolescence

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See Related Editorial p. 233

A B S T R A C T

In this article, we consider how to leverage some of the rapid advances in developmental neuroscience in ways that can improve adolescent health. We provide a brief overview of several key areas of scientific progress relevant to these issues. We then focus on two examples of important health problems that increase sharply during adolescence: sleep problems and affective disorders. These examples illustrate how an integrative, developmental science approach provides new insights into treatment and intervention. They also highlight a cornerstone principle: how a deeper understanding of potentially modifiable factors—at key developmental inflection points along the trajectory toward clinical disorders—is beginning to inform, and may eventually transform, a broad range of innovative early intervention strategies to improve adolescent health.

IMPLICATIONS AND CONTRIBUTION

A deeper and more integrative understanding of developmental neuroscience can enhance early intervention efforts by identifying modifiable targets, establishing greater precision in the timing of these processes, and using these insights to inform new strategies.

Adolescence is filled with paradoxes. It is both the healthiest period of the lifespan with respect to the most measureable aspects of physical health and a maturational period marked by surges in overall morbidity and mortality. Moreover, many types of behavioral and educational interventions appear to be relatively ineffective during adolescence, leading some to argue that this is the worst developmental period to try early intervention and prevention efforts [1]. Yet, there is growing evidence that adolescence is a dynamic period of learning and adaptation [2–4]. How can developmental science help to reconcile aspects of these paradoxes? It can do so by helping us to deepen our understanding of adolescence as a dynamic developmental period that creates vulnerabilities and unique opportunities for early intervention and prevention. For example, adolescence appears to create a sensitive period for some kinds of flexible learning and adaptation in ways that contribute to rapid downward spiraling toward some negative health trajectories (e.g., emotional and substance use disorders) as well as upward spirals toward positive developmental trajectories [2].

We believe that recent advances in developmental neuroscience—integrated within a larger transdisciplinary developmental science perspective on adolescence—can provide a new framework for these apparent contradictions. Specifically, we are looking at ways in which understanding the

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neurobiological trajectory of adolescence, including identifying key inflection points such as the onset of puberty, can help to refine and enhance our intervention approaches. Ideally, this can inform how to match the right kinds of behavioral interventions to opportune windows of learning and adaptation. To provide one concrete example, Bryan et al. [5] recently highlighted how a developmentally informed strategy to improve healthy eating (framing educational messages in a way that taps into adolescents' sensitivity to social status and desire for respect and autonomy) had a positive impact on adolescents' food selections, in sharp contrast to traditional educational efforts that typically have no effect (or a negative effect) on eating behavior. The point here is not to imply any simple solution to a complex problem like changing eating behavior but rather to illustrate an example of how developmental science can transform a relatively ineffective intervention into a promising approach. A second point focuses on the value of understanding the developmental neuroscience underpinnings (such as the role of pubertal testosterone effects on neural systems involved in adolescents' increased sensitivity to social status and desire for respect and autonomy). That is, a deeper and more mechanistic understanding as to why an intervention that honors adolescents' sensitivity to status (e.g., as in the study by Bryan et al.) can provide insights which can inform the targets, developmental timing, and other strategies for improving early intervention approaches.

Developmental Neuroscience Informs Developmental Science of Adolescence

On one hand, developmental neuroscience has led to rapid progress in understanding multiple aspects of neurodevelopmental changes in childhood and adolescence. Some of these advances appear promising in their capacity to inform pragmatic issues, adolescent health and well-being. On the other hand, we do not see developmental neuroscience as providing any simple mechanistic answers for treating the complex behavioral, emotional, and social problems that emerge in adolescence. Rather, we believe progress in understanding the interactions among social, emotional, psychological, behavioral, and neurodevelopmental processes that provides insights into both sides of the paradox. These include insights into the vulnerabilities for difficult-to-change negative spirals of health-harming risk behaviors and opportunities to establish positive spirals for health protective behavior [2]. In some cases, a deeper and more mechanistic understanding of these spirals, including their neuroscience underpinnings will map onto existing knowledge about the psychological and social development. In other cases, the developmental neuroscience provides fundamentally new insights and discoveries that help to identify modifiable factors early in the pathways leading to clinical disorders and advance and refine the precision of optimal timing or targets of modifiable factors. We believe that these advances will increasingly inform innovations to improve, and may eventually transform, early intervention approaches.

We will not attempt to summarize comprehensively the incredible range and depth of research that converge in the transdisciplinary developmental science of adolescence. Instead, our goals in this article are (1) to provide a brief, high-altitude overview of several areas of scientific progress in developmental neuroscience that point to leverage points for specific modifiable factors in adolescence and (2) to provide two specific examples to help illustrate how this type of integrative developmental science approach can provide promising opportunities for translational advances.

Developmental Neuroscience, Neuroplasticity, and Specialized Learning

Developmental neuroscience has achieved incredible progress in understanding the cellular and molecular underpinnings of a wide range of early prenatal and postnatal neurodevelopmental processes. Increasingly, researchers are emphasizing the role of early experience and learning in actively shaping neurodevelopment. There is now a nearly universal recognition of the positive opportunities created by early plasticity in developing neural systems—in ways that have major implications for policy, health, education, and national, as well as global, priorities [6].

There is also growing recognition that neuroplasticity is not limited to the first few years of life or even to the childhood years [6]. Broadly, the term neuroplasticity encompasses a wide range of synaptic and nonsynaptic processes that underpin the brain's capacity to instantiate learning, along with the concept of "sensitive windows" for specialized learning. Simply put, this means that many developmental factors influence the brain's capacity to learn, including the fact that the brain may be particularly receptive to specific types of learning at key times. Research into the molecular processes and mechanisms of neuroplasticity underlying sensitive periods of brain development has progressed rapidly (see reviews by Werker and Hensch and Hensch [7,8]). Researchers can now experimentally manipulate the molecular mechanisms underpinning plasticity. For example, in laboratory studies, researchers have successfully removed the molecular "brakes" to reopen critical developmental learning windows for visual processing in animal models [9] and have pharmacologically reopened critical periods for learning precise musical pitch in adult humans [10]. Efforts to manipulate plasticity, however, must be considered with great caution because there is growing recognition that normal brain development involves a changing balance of plasticity (patterns of neural connection that are flexible and adaptive to learning) and stability (neural circuitry that has achieved a relatively stable state of development) [11].

The period of brain development beginning with the onset of puberty and extending through adolescence may represent a unique combination of stability and plasticity—in ways that create an important window of opportunity for learning and experience to actively shape developing neural networks in enduring ways [11–13]. A deeper understanding of how this plasticity creates sensitive periods for learning specific to adolescence can provide important insights for translational advances in adolescent health.

To highlight a key principle relevant to these translational advances, it can be helpful to consider plasticity using an "experience-expectant" framework [14,15]. The infant brain, for example, "expects" some kinds of visual experiences that are necessary to organize and tune the visual systems. By 2 months of age, a typical infant has executed more than 2.5 million eye movements that have fundamentally shaped the relevant neural circuitry [16]. Similarly, the infant brain "expects" language and social experiences during this window of development. The analogous question for adolescent researchers is: How have