

Adolescent development: From neurobiology to psychopathology

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Barbara Braams is currently an associate professor at the Vrije Universiteit Amsterdam. Her research focuses on adolescent neuro-cognitive development and decision-making. She is especially interested in the underlying mechanisms of increased risky decision-making in adolescence. She uses a variety of methods in her research, such as fMRI, hormone assessments, and daily diaries. Her research has been published in top peer-reviewed journals in the field, including the *Journal of Neuroscience*, *Child Development*, and *Developmental Science*. Her contributions to the field were acknowledged with the Dutch Neuroscience Meeting Young Talent Prize (2018) and the J.C. Ruigrok Award (2019).

Adolescence is the transitional period between childhood and adulthood. It is an important time of development on different levels. In this special issue, we present a collection of papers focusing on the newest insights into neurobiological development, psychological development, social development, and psychopathology, including delinquency, in adolescence.

Neurobiological development

The development of magnetic resonance imaging (MRI) allows researchers to study the development of the brain in healthy, human participants. Since the early MRI studies in the 1990s, we gained tremendous insight into brain development on the structural and functional level from childhood to adulthood. On the structural level, new analysis techniques and larger samples have led to detailed models of group-level changes in brain structure from childhood to adulthood. The establishment of these group-level models paved the way for more detailed studies on individual differences in brain development and a focus on which external factors shape an individual's brain development (Fershman). On the functional level, early fMRI studies focused on identifying the involvement of brain regions in cognitive, affective, and social processes. However, the brain does not function in isolation, but it is an intricate network of connected areas. Exciting new work identified network hubs. Hubs are local regions of the brain that are especially well-connected to other regions. These hubs play an important role in the functioning of brain networks. Brain networks start to form in late pregnancy, and these connections continue to develop through childhood and adulthood (Oldham). Lastly, understanding the interplay between structural and functional development requires the use of large, longitudinal, and phenotypically rich datasets. The Open Science Revolution has largely increased the availability of these types of datasets for reuse (Kievit).

Psychological development

Adolescence is a time of major psychological development in the cognitive, affective and social domains. Development in these domains can also show interactions with each other. One way these interactions between these domains becomes apparent is in the form of risk taking behavior in adolescence. Compared to children and adults, adolescents show

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Lydia Krabbendam is a full professor of Developmental Neuropsychology and the head of the Department of Clinical, Neuro-, and Developmental Psychology. Her research focuses on the development of social cognition and self-regulation in adolescence. She is specifically interested in the bidirectional relationships between social context and (social) cognitive development. In her work, she applies different methods, including experimental tasks, ecological momentary assessment, social network analysis, and functional neuroimaging.

increased risky decision making. An example of risk taking behavior is substance use, including smoking and the use of e-cigarettes ([Huizink](#)). A leading explanation for risk taking behavior has been an increase in reward sensitivity in adolescence. However, adolescents also show differential processing of risk compared to children and adults. A focus on risk processing could broaden the perspective on adolescent risk taking behavior ([van Duijvenvoorde](#)).

An important aspect of adolescent psychological development is the development of a set of skills and functions for goal-oriented behavior, including emotion regulation and executive functions. Although emotion regulation increases for most individuals during adolescence, there are individual differences in the extent to which this capacity develops. Caregivers play an important role in the development of emotion regulation skills and might account for interindividual differences in emotion regulation development. Furthermore, considering the influence of the social context is an important future direction for emotion regulation research ([Silvers](#)). Executive functions develop from early childhood into adulthood. Robust associations have been found between early-life executive functions and later well-being. Improvement of executive functions has been studied extensively, but with limited success. Potential future avenues for improvement of executive function interventions may be based on a value-based framework of executive functions ([Ganesan](#)).

A key developmental task for adolescents is the development of a coherent identity. Adolescents who succeed in this task report better mental health and well-being. New research shows that the development of identity occurs through day-to-day interactions rather than life transitions and major life events ([Branje](#)). Although most of the work in this special issue focuses on the development of human adolescents, we should recognize that adolescence is a phenomenon also observed in other species, including rodents. Adolescent and adult rodents show distinct differences in affective and cognitive processes. An exciting new avenue for research is to investigate how these behavioral differences support rodent survival in the wild ([Lin](#)).

Social development

Adolescence is a crucial period in life for social development. Compared to children, adolescents spend more time with their peers and social interactions become more important. As such, adolescence has been described as a sensitive period for social development. An essential skill for social development is perspective taking. Perspective-taking skills allow adolescents to navigate increasingly complex social interactions and are an important prerequisite for forming social relationships ([Hollarek](#)). Two of the most proximal social relationships for adolescents are peers and parents. Peers have a major influence on adolescent behavior across several domains. Peer influence can promote both undesirable behavior such as excessive risk-taking behavior as well as desirable behaviors such as prosocial actions and maintaining a healthy lifestyle. Peer-led interventions are increasingly utilized to promote desirable behavior and are promising given the inherent adolescent focus on peers ([Veenstra](#)). Although adult supervision decreases across adolescence, parents remain an important social relationship for adolescents. Population-wide studies show that warmth, structure, and autonomy are important parental styles to promote adolescent well-being. Interactions between adolescents and parents vary across days. Ecological momentary assessments provide in-depth information on day-to-day

interactions and as such are a promising avenue for future research (Keijsers).

The recent COVID-19 pandemic dramatically decreased opportunities for live social interactions. Although social interactions are important for all age groups, this is even more apparent for adolescents. Indeed, adolescents and young adults experience more negative effects of the restriction of live social interactions than other age groups, possibly with long-lasting results. However, the COVID-19 pandemic also provided new opportunities for prosocial actions (Crone). Social media occupies an ever-growing part of adolescents' social interactions. The effects of social media use on well-being are a topic of current debate. In general, it appears that online self-disclosure is less beneficial for social relationships than offline self-disclosure. However, research indicates that highly anxious individuals might benefit more from online self-disclosure (Townner). A person-centered approach could help parse out the effects of social media on individuals (Valkenburg). This is especially important, since maintaining healthy relationships could serve as a buffer for the development of psychopathology (Scheuplein).

Psychopathology and delinquency

Major changes in the neurobiological, psychological, and social domains support positive adolescent development. However, these rapid changes also render adolescents vulnerable for negative experiences and the development of psychopathology. The tendency to make risky and impulsive decisions that is typical of adolescence is even stronger in adolescents with attention deficit hyperactivity disorder (ADHD). It is less clear whether going through adolescence further exacerbates this tendency in individuals with ADHD, and more longitudinal studies are needed to investigate this (Dekkers). The development of antisocial behavior has been linked to aberrant structural and functional brain development, particularly in the prefrontal and (para)

limbic areas of the brain. Knowledge about these neurobiological and neuropsychological mechanisms is increasingly used to improve diagnosis and treatment (Jansen). Neurodevelopmental aspects also play an important role in the etiology of psychosis and psychotic symptoms. However, we should be careful not to pathologize experiences of psychosis in adolescents, since in many cases, these experiences are transient (Schultze-Lutter). Stress is a risk factor for psychopathology for all age groups, but it might pose even higher risks during adolescence (Sisk). Furthermore, early-life adversity is related to anxiety and depression during adolescence. One potential mechanism for this relationship is accelerated pubertal development (Colich). Adolescents can also experience major life events during adolescence, such as adolescent pregnancy. In sub-Saharan Africa, adolescent pregnancy poses serious socio-economic and health-related risks (Kumar). Mental health interventions tailored toward depression, anxiety, and self-harm show promising results (Campisi). A virtual treatment is becoming more widespread, although the effects of virtual treatment are unclear. Mental health services might benefit from a focus on prevention and early recognition, rather than treatment.

Future directions

The editors hope that this special issue will serve as a resource for scientists and provide an overview of the current state of a broad spectrum of adolescent research. Future work spanning multiple measurement levels and time scales and with a focus on individual development will help push forward our understanding of this transitional period of life.

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