

The Development of Attachment: Integrating Genes, Brain, Behavior, and Environment

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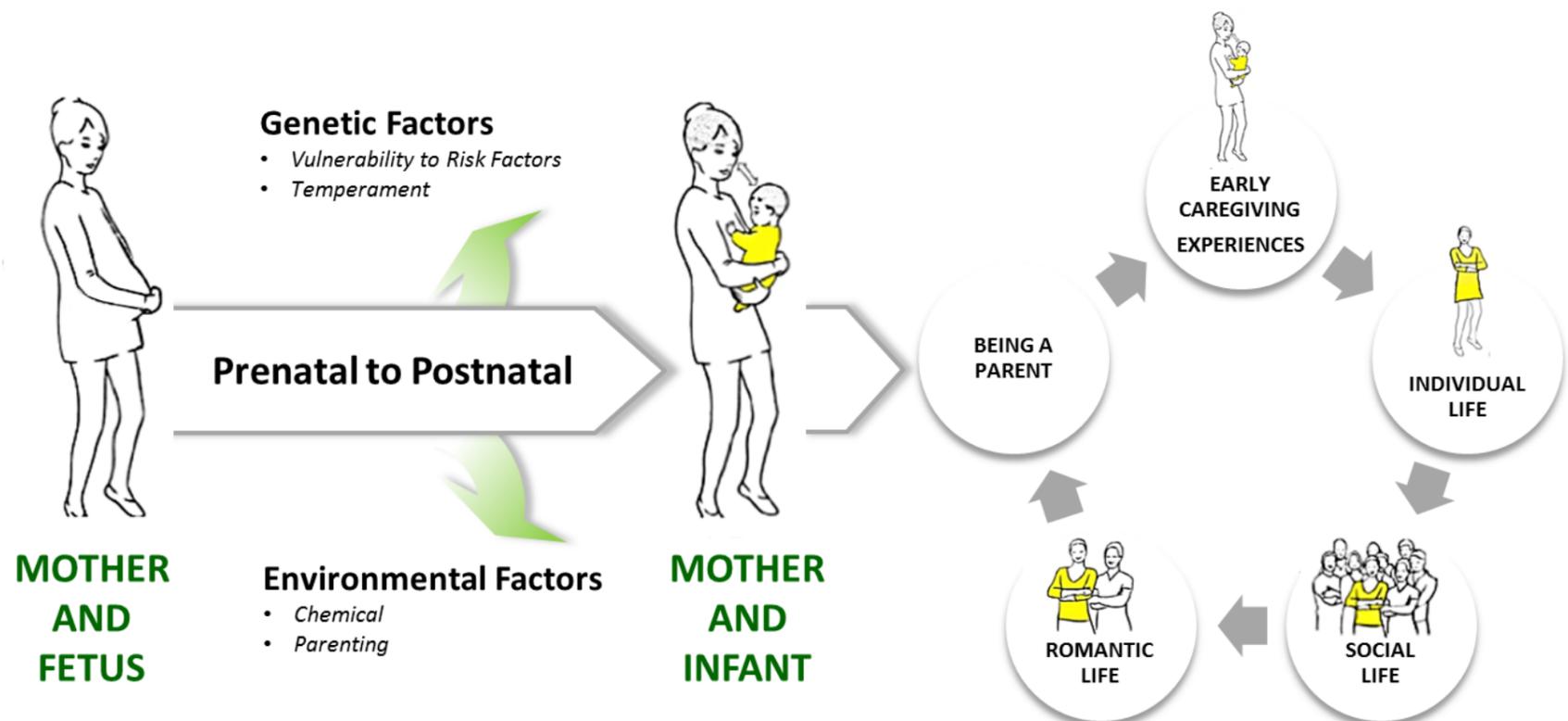
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Graphical Abstract



Abstract

In humans, as in other animal species, early caregiver-infant interactions influence physiological and psychological processes by modulating brain sensitivity. Furthermore, early social interaction between caregiver and infant influences infants' cognitive and socioemotional development, and subsequently the development of social, familial, and romantic relationships later in life. Here, we have collected longitudinal and cross-sectional empirical studies as well as review and perspective articles that focus on human or non-human mammals with the aim to investigate how genetic, hormonal, behavioural, and environmental factors, as well as cultural contexts, regulate early interactional experiences, and how these experiences translate into social and non-social competences later in life (see Graphical Abstract).

Keywords: Attachment, Bonding, Gene, Environment, individual life, social life, romantic life, cultural attachment

Humans, like other animal species, have an innate, evolutionarily driven, biological predisposition for social interaction. Infants actively and instinctively seek and maintain their caregiver's proximity and care. Caregivers also instinctively seek and respond to their infants. These early caregiver-infant interactions give rise to caregiver-infant attachment, which influences physiological and psychological processes by modulating brain sensitivity. Furthermore, early social interaction between caregiver and infant influences infants' cognitive and socioemotional development, and subsequently the development of social, familial, and romantic relationships later in life.

Caregiver-infant attachment shapes neural pathways involved in socio-emotional regulation. These patterns of socio-emotional regulation are thought to remain relatively stable over an individual's lifetime, suggesting important links between early caregiver-infant attachment and health related physiological processes (e.g., stress) and vulnerability to risk-factors (e.g., the capacity for managing stress-related metabolic demands). Attachment formation is influenced by multiple systems, including environmental factors, such as prenatal chemical signals from the mother to the fetal brain, as well as parenting and genetic factors, such as vulnerability to risks and temperament. Current approaches to the study of caregiver-infant attachment should consider its multi-level nature.

In this Special Issue we have collected longitudinal and cross-sectional empirical studies as well as review and perspective articles which focus on humans and non-human mammals (i.e. mice and domestic chicks) that aim to investigate how genetic, hormonal, behavioural, and environmental factors, as well as cultural contexts, regulate early interactional experiences, and how these experiences translate into social and non-social competences later in life (see Graphical Abstract). The 23 articles from Europe, America, and Asia represent different expertises ranging from molecular biology to linguistics to human neuroimaging. The articles are grouped in four sections: (i) basis and mechanisms; (ii) modulation of social interaction; (iii) effect on language and culture; and (iv) atypical trajectories.

In the first section "Basis And Mechanisms", we focused on both filial [1] and parental responses [2] during caregiver-infant interactions as well as the cortical and subcortical circuitry regulating social attachment and relationships [3]. Furthermore, Amano and colleagues [4] show how maturation of the synaptic terminal in the bed nucleus of the stria terminalis (BSTrh) may mediate adaptive change from parental to infanticidal behavior in male mice. In another paper, the basic recognition system behind mother-infant bonding in mice is described by Mogi and colleagues [5]. While a social bond is defined as affiliative behaviors toward a specific partner, controversy remains concerning whether mouse pups can distinguish between their own mother from an alien mother, and whether mothers can differentiate their own pups from alien pups. Mogi and colleagues' results support the existence of mother-infant bonding in mice and suggest that pup ultrasonic vocalizations (USVs) contribute to pup recognition by mothers.

In the second section "Modulation Of Social Interaction", we have grouped together studies that show how early interaction and bonding experiences influence hormonal and physiological responses in early childhood[6] and adulthood[7]. In very different cultural contexts such as Italy and Japan, bonding experiences interact with genetics (such as the oxytocin receptor gene polymorphisms rs2254298 [7] and rs53576 [8] and the serotonin transporter gene polymorphism (5-HTTLPR,[8][9]) to modulate affective attitude towards either own infant[9] or infants in general[8]. The final two papers of this section describe how environmental factors (e.g., socio-cultural level) as well as individual (e.g., genetic makeup) and interpersonal factors (e.g., caregiver-child relationships) play crucial roles in shaping the development of the personality [10] and how socio-economic status has a strong impact on modulating maternal brain mechanisms that regulate propensity toward own infants [11].

Section three "Effect On Language And Culture" focuses on how attachment and interaction modulate the management of complex skills such as linguistic communication and cultural understanding. In the context of language for example, human babies possess cognitive skills that predispose them to learn. However, humans acquiring language requires socialised learning, scaffolded over years of prolonged and intense caregiver-child interactions [12]. Onnis's article suggests possible scenarios in which early infant-caregiver attachment may mediate or moderate the expression of human genetic systems for language [12]. A complex capacity such as language could be used to assess the quality of bonding. For example, Rasmussen and colleagues [13] report that

greater mother-child linguistic style matching, defined as a composite measure of the similarity of function word use in spoken or written language between two or more people, is associated with lower emotional reactivity (lower cortisol reactivity, reports of lower negative emotion) in children. Beyond the traditional concept of attachment is Yap and colleagues' study of emotional mechanisms that could explain how cultural symbols act as extensions of the prototypical attachment figures and confer the sense of security in the face of threat [14]. As much as a positive interpersonal attachment (often defined as secure) is a necessary condition to explore the "external world", caregiver and cultural attachments interact and modulate the ability to adapt in a novel environment. In line with this, Phua and colleagues [15] show how individuals' genetic predispositions significantly interact with maternal, paternal and cultural attachment and moderate the ability to adapt in a novel environment, as represented in young students that are sojourning overseas.

The final section focuses on "Atypical Trajectories." Provenzano and colleagues [16] discuss the importance of understanding genetic determinants of social behavior in mouse models for the development of novel therapeutic approaches to overcome social disturbances in complex disorders such as Autism Spectrum Disorders. Also related to ASD, but from the perspective of human studies, Vivanti and Nuske [17] outline a conceptual framework to show that dissociable pathways of child-parent bonding and social development in ASD are shaped by a dissociation between externally driven and internally driven attachment responses and atypical learning dynamics occurring during child-caregiver bonding episodes [17]. The next studies in this section focus on the influence of early attachment on health in infancy [18] as well as gene by environment effects in childhood for aggression [19], emotion regulation, and mood [20]. Among atypical trajectories, Swain and colleagues show how maternal depression alters maternal limbic system function and functional connectivity underlying parental motivations [21]. Depression may affect mothers by increasing baby-cry threat responses and deregulating associations between threat and healthy child-oriented parenting motivations [21].

Other papers address long-term effects that start early in development and have an impact of social interaction and cognition later in life. Beginning with recent studies that have focused on the role of early life (prenatal and postnatal) experiences in progression of late-onset sporadic Alzheimer's disease (AD), it has been shown that, although no single unfavorable environmental event is necessary nor sufficient for AD development, it is possible that the sum of several environmentally induced effects, over time, contribute to its pathophysiology through epigenetic mechanisms [22]. A number of papers describe the ontogeny and developmental trajectories of conditions that are the cause (or the effect) of poor social interaction. The final paper describes a model to prevent atypical development and improve parents' psychological well-being and child development. Ahlqvist-Björkroth and colleagues present an intervention program to improve staff skills in communicating and collaborating with parents in neonatal intensive care units (NICU) to increase parents' presence and participation in infant care, to improve parent-infant bonding, and to foster parents' psychological well-being and later child development [23].

Before concluding this Editorial, it is necessary to discuss potential avenues to continue our focus on how genes, brain, behavior, and environment modulate the development of social bonding and attachment. We think exploring three main domains will improve knowledge in the field. First, a number of the studies in this Special Issue highlight the importance of a multilevel assessment. Here we propose the need to approach the development of bonding using a physio-bioecological approach [24]. A bioecological perspective considers the reciprocal interactions of human development and the multiple environments in which it unfolds, which Bronfenbrenner [25] termed a microsystem, mesosystem, exosystem, macrosystem, and chronosystem. However, this perspective should be merged with a deeper understanding of the genetic and brain mechanisms underlying specific behaviors. Specifically, a physio-bioecological approach, embracing knowledge and techniques from different scientific domains (ranging from molecular biology to systems neuroscience to psychology) should aim to answer the following fundamental questions: (i) What are the physiological and biological mechanisms behind social bonding? (ii) How do physiological and biological characteristics interact with the external environment and impact the ontogeny of social bonding? The topic of the environment leads us to carefully consider the second of the three domains that should be better studied in future, viz. is the concept of environment. In particular, a greater emphasis should be given to the definition of the environment. How does the environment influence the genotype to phenotype transition? How and when does the environment constitute a constraint but become an actively sought after choice which reciprocally influences the person? Finally, the third domain relates to gaining a better understanding of individual developmental trajectories in lieu of focusing on group average phenomena.

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