Early Childhood: Key Factors in Healthy Brain Development & Adjustment

Olivia Lu

Abstract

Early childhood is a key period in life in which significant neurological, cognitive, social, and emotional development occur. This literature review works to discuss two related and innovative theories of childhood brain development, known as the developmental systems approach and experiential canalization, applying these theories to interpret the essential roles of socioeconomic status and caregiving and its attachment relationships on early childhood brain growth. Specific studies, literature reviews, and recent innovative research on childhood development is included in order to further discussions of current implications and connections, as well as possible future research. By analyzing results and applying the mentioned developmental theories, this review provides a new perspective for poverty and adverse experiences, discussing new potential avenues for new interventions involving caregiving, environmental changes, and adaptive trade-offs, to bring about poverty reduction and mitigate early caregiving adversity.

Keywords: early childhood brain development, developmental systems approach, experiential canalization, socioeconomic status, attachment, caregiving

Introduction

The brain is a vast and complex structure that controls behavior and how one perceives the world. Early childhood (birth to 2 years) is a particularly crucial time in development during which the brain is especially malleable and adaptable, allowing for the opportunity of formation of a variety of crucial connections and pathways that directly contribute to language, learning, behavior, and other mental processes that last for the rest of one's life. Essential processes in brain development, including cell proliferation and migration, synaptic growth and pruning, and myelination, occur with such rapidity that 90% of brain development is complete before the age of 5. Furthermore, during this time, the infant brain's greatly increased capacity to change and adapt, known as neuroplasticity, crucially depends on key experiences and environmental inputs during critical time periods of development. Indeed, failure to receive appropriate exposure to essential stimuli within a sensitive or critical time-window for a certain fundamental skill or trait can make it difficult or, in some cases, impossible to develop associated functions later in life (such as certain language capacities). By employing the theories of developmental systems and experiential canalization and reviewing existing studies, this paper works to inform and identify new perspectives and potential areas of research related to the impact of socioeconomic status and caregiving on developmental trajectories.

Literature Review

I. The developmental systems approach & experiential canalization

The developmental systems (DS) approach promotes a holistic perspective that considers the intricate interplay of genetic, environmental, and individual factors in understanding how individuals develop over time. It argues that individual development is hierarchically organized into multiple levels (i.e., genes, cell, organ system, behavior, etc.) that can mutually influence each other (Moore, 2016). In effect, the theory challenges the nature vs. nurture dichotomy, instead highlighting the need to consider the complexity and dynamics of the developmental system as a whole, and its collective role in shaping phenotypic outcomes through spontaneous, real-time interactions (Moore, 2016). According to Moore (2016), proponents of this approach agree that all behaviors simultaneously reflect the following:

> "(1) an individual's current environmental context, (2) the individual's genetic state (i.e., the sequence of nucleotide bases in the DNA as well as the presence and state of numerous epigenetic factors that influence genetic expression), and (3) the individual's developmental/experiential history (because that history has contributed to the structure and chemistry of the individual's nervous system as well as to numerous other anatomical, physiological, and behavioral features of the individual)." (pp. 253-254)

Further, the DS theory argues that there can be no true, evidenced distinction between "inherited" and "acquired" behaviors, as all behaviors are formed in real time, and cannot be predetermined; rather, they are the direct result of interactions between different components of the system (genetic, environmental, cellular, etc.) (Moore, 2016). As such, spontaneous interactions in the developmental system must be considered in any behavioral analysis; an experiment that attempts to account for inherited or acquired behaviors by isolating or regulating the environment is inherently flawed, as it is impossible to identify preceding experiences that led to observed behaviors without the full context of a person's history.

Experiential canalization is one theory that stems from the DS approach, and describes specifically the influence of experience on brain growth. Blair and Raver (2012) define experiential canalization as the joint influence of biology and experience on development, which entertains the idea that promotion of specific abilities, as well as prevention of atypical contingencies, can occur as a result of recurring experiences. It is important to distinguish that this theory is not suggesting that experience will prevent atypical development no matter the circumstance, but rather that it has the ability to do so in certain contexts.

Previously, experience was generally considered (described by developmental geneticist Waddington) to be a "perturbation" of a metaphorical "ball" rolling down the "epigenetic landscape" (Gottlieb, 1991, p. 6). This phrase describes experience ("perturbations") as disrupting or causing deviations in the expected course of an individual's typical development (the "ball"), which is supposedly only influenced by epigenetic factors (the "landscape").

Canalization itself was defined by Waddington as the process of self-correction from these supposed perturbations, enabled by genes, allowing the usual phenotype to remain present through buffering of the normal developmental pathways (Gottlieb, 1991). As time progressed, and canalization was studied further, it was soon realized that canalization is not only a characteristic of genetic activity, but is also contained within other levels of development (environment, behaviors, neural activity, etc.), which each influence each other.

Gottlieb (1991) speaks of his accompanying empirical report to portray experiential canalization's functioning in a specific setting. To do so, he studied the impact of environmental stimuli on the development of young mallard ducks' ability to recognize their mothers' calls. Through his research, he revealed that while recognition of a maternal call is instinctual behavior, the underlying properties of that recognition are malleable through experience; in mallard ducks, this species-specific development was found to be canalized by the hearing of their own voices. Researchers have extrapolated these findings to humans to conclude that development is not predetermined by DNA or the environment, but rather that the two work in tandem to determine behavioral and psychological development.

This theory led researchers to develop the Developmental Psychobiological Model of Experiential Canalization (DPMEC). Using this model, Blair & Raver (2012) outline how poverty-related adversity can affect emotionally supportive parenting, which in turn influences how children self-regulate stress physiology and behavior. To expand on the underlying principles of the DPMEC model, the following sections of this paper will outline the specific ways in which caregiving and attachment can influence brain development, as well as the effects of poverty-related adversity on brain development.

II. Early attachment and culture

While the caregiver-child relationship undoubtedly provides basic necessities to the child, such as food, housing, and safety, the relationship also greatly impacts the development of language, how the child views the world and future relationships, and countless other neurological developments. The caregiver-child relationship serves as a sort of template for a child's understanding of others; this is formally termed the internal working model (IWM): a mental representation created by the child, through which specific mental responses according to their caregiver's behavior are internalized, contributing to their views of themselves, their caregiver, and the world more broadly (Pietromonaco & Barrett, 2000). From this, the child customizes their external responses, or attachment behaviors, towards their caregiver in the ways that they believe would best maintain their proximity.

The caregiver child relationship and attachment behaviors were studied in depth in the 1970's by Mary Ainsworth. Ainsworth was the designer of the Strange Situation Procedure: a paradigm continually utilized to assess the quality of attachment relationships (Ainsworth & Bell, 1970). From this experiment, four types of attachment styles were derived to provide a categorical system taking into account both positive and negative models of the self and of others: secure, preoccupied (also called ambivalent/anxious), dismissing-avoidant, and

fearful-avoidant (Pietromonaco & Barrett, 2000). The more secure an attachment with the caregiver is perceived, the likelihood that the caregiver is properly attentive and provides adequate protection to the child is also proportionally increased.

Further studies upon these behaviors have suggested that romantic relationships that occur later in life may also be influenced by the same attachment behavior and internal working models that are originally developed between child and caregiver. Hazan and Shaver (1987) are credited as being the first to attempt to view adult relationships as partial reflections of attachment behaviors developed as children. The two accomplished this by conceptually corresponding adult's evaluations of their own attachment to children's behavioral patterns; from this, they created parallels between adult relationships and child-caregiver relationships that provided evidence that romantic love is one of the many properties of the attachment behavioral system. The implications of this study, and further studies which followed it, can extend in both ways. It both implies that we can likely estimate the security of child-caregiver relationships that an individual had based on their current adult attachments, and that the type of child-caregiver relationship that a child has may very likely influence their view of relationships in adulthood; both in relation to the self and in the perception of others.

One concept within attachment that is essential to consider, but has yet to be further explored, is the impact of culture; in other words, unique cultural deviations that may alter exact definitions of "secure attachment". Despite its broad application, current attachment theory based on Ainsworth's Baltimore study (Ainsworth et al., 1978) has notable limitations, including the narrow cultural context in which it was developed. Keller and Bard (2017), for example, identify differences in the distribution (or prevalence) of different attachment classifications depending on the population being studied; in particular, two studies by Grossmann et al. (1985) in Northern Germany and Takahashi (1986) in Japan become relevant. The two discovered numerous variations in attachment distribution: Grossmann et al. (1985), studying 49 North German mother-infant pairs, found an unusually high recorded number of avoidant infants at 49% (compared to Ainsworth's 26%); and Takahashi, through assessing 60 pairs of Japanese mother-infant pairs, discovered that the Japanese insecure group (32%) consisted of only ambivalent, and no avoidant. Each of these discoveries correspond, to some degree, to the parenting styles and cultural norms of each specific group. The results of the German study were interpreted as a result of greater parental pushes towards a child's independence (Grossmann et al, 1985), while Japan were interpreted as a consequence of underexposure to strangers. Japan also has heavy emphasis on a close mother-child bond (Takahashi, 1986), which may be a contributor to excessive separation stress during the experiment. Keller and Bard (2017) state these two experiments display important evidence of the lack of cultural integration within attachment theory. Keller and Bard (2017) also put forward that there are many other instances of cultural and anthropological literature that suggest considerable variance in learning environments and socialization strategies both across and within cultures. Therefore, attachment theory and related assessments, policies, and practices should be informed by culturally sensitive studies that integrate unique societal and cultural norms (i.e.,

acceptable and common parenting practices, learning environments, etc.). This idea is also supported by the DS approach, in that development can vary according to exposure to different environments as a result of altered interactions between systems. Keller and Bard (2017) suggest that attachment may be so individually tailored that, even within a single culture, a wide spectrum of family types and compositions must be surveyed to accurately depict attachment and security.

III. Caregiving and its mediating effects on development

Only in the last decade have researchers begun to understand the impact of attachment relationships and caregiving on brain development in greater depth. A notable example of such research is a study conducted by Nim Tottenham (2015) examining the development of the human amygdala-mPFC (medial prefrontal cortex) circuit in association with caregiving. The amygdala is a brain structure highly associated with emotional processing, and also with the regulation of fear and anxiety responses, while the mPFC is a crucial cortical region related to cognitive processing, integration of information, and, most importantly, regulation of emotions. As such, the mPFC is crucial to modulating the amygdala's activity, and thereby the circuit between the two is chiefly responsible for self-regulation and stress. It is worthy to note that, across different age groups, the relationship between amygdala and mPFC greatly varies. Adults showcase an anticorrelated pattern indicating high levels of emotional regulation, while children and infants showcase positive connectivity, in which activity within the amygdala is correlated with activity in the mPFC (and vice versa) (Tottenham, 2015). This implies a stabilization over time in terms of emotional regulation and stress response as the brain develops and creates stronger connections and pathways. Tottenham (2015) found that there exists a significantly long sensitive period for this circuit during childhood, including a time when amygdala functioning is critically dependent on the parent, who acts as a buffer to amygdala reactivity. During this time, a parental presence was evidenced to have strengthened connectivity between the mPFC and the amygdala, helping to facilitate the beginning of the formation of the anticorrelated pattern and therefore increased stress regulation (Tottenham, 2015). Contrastingly, the absence of a parent was found to be correlated with aversive learning and a more hyperactive and less self-regulated amygdala. In other words, the relevant strength of regulation and connectivity is directly moderated by the level of attachment security between caregiver and child (Tottenham, 2015).

This was furthered by Tottenham's findings revealing that when a child experiences chronic stress or trauma, their stress-reactive system can become extremely sensitive, leading to amygdala hyperactivity. Referred to as stress acceleration, this hypothesis advances that exposure to stressful life events appears to accelerate the development of stress-reactive systems as a result of developmental adaptations to meet immediate needs (Tottenham, 2015). Therefore, early caregiving adversity also appears to impact pacing of development, with greater adversity associated with earlier formation of the amygdala-mPFC circuit. Its materialization in this context ultimately leads to lower plasticity in the amygdala, abbreviation of

the sensitive period of the circuit, and greater anxiety levels later in life. This research suggests that caregiving is invaluable to the development of the amygdala-mPFC connection and self-regulation. It also indicates that to promote proper development, it is important to not only support the child, but also the family charged with their care.

Further research upon this topic has suggested that caregiving may also have a role in mediation of adverse experiences; in particular, socioeconomic adversity. One paper presents findings from a longitudinal study in Melbourne that sought to establish whether positive parenting behaviors could moderate the negative impacts of socioeconomic disadvantage on adaptive functioning in adolescents (Whittle et al., 2017). It discovered that positive parenting did help mitigate the effects of the adversity of poverty by supporting development of thickness in both the dorsal frontal and lateral orbitofrontal cortices, as well as amygdala reactivity (supporting Tottenham). Similarly, as a part of a much longer investigation, Blair and Raver (2012) speak on this topic and argue that maternal behaviors may be a key mediator of poverty, particularly in self-regulation, with the ability to initiate a positive developmental impact across levels of development and increase flexibility of development through maintaining high levels of responsiveness, consistency, and warmth.

IV. Socioeconomic status and the adversity of poverty

Socioeconomic status (SES) is considered the economic and sociological measure of one's work, educational, and life experiences, and one's overall social position in relation to others. SES entails much more than one's salary, and also includes a person's ease of access to resources, education and parental education, and family relationships and sizes. Many politicians, psychologists, and neuroscientists have performed research and subsequently made inferences concerning the impact of SES on childhood and brain development. They have found that the challenges of living in poverty, or low SES, often decrease a family's ability to afford basic needs such as adequate access to nutritious food, utilities, safe housing, and health care. This struggle places parents at higher risk for stress and depression, which can then impair their ability to provide emotionally supportive caregiving and lead to higher incidences of harsh parenting (e.g., unpredictable, punitive, hostile, intrusive, and retaliatory behaviors). This is then reflected through their child through individual issues with self-regulation (see Tottenham, 2015; Blair & Raver, 2012). Interestingly, Whittle et al. (2017) discovered an association between neighborhood SES, but not family SES, in altered development, especially in the temporal lobes. This may be explained by the idea that one's entire environment contributes to development, not only home environments (suggested by Blair & Raver, 2012). It is crucial to distinguish that this paper is not suggesting or assuming that poverty necessarily or causally leads to worse parenting. Rather, this review works to point out the inexorable stressors applied to parents living with lower economic resources, and how these stressors, in turn, contribute to a child's development.

Blair and Raver (2012) suggest that, through the application of experiential canalization's concepts to poverty and its adversity, poverty can be characterized not with a deficit-oriented

model in which children are considered as lacking certain inputs, but rather with a model that accounts for the presence of alternative experiences that "actively shape development to meet a specific set of contingencies" (Blair & Raver, 2012, p. 310). By using these concepts, the impact of SES would then be considered across multiple levels of development (cellular, genetic, social, etc.) instead of the previous evaluation of a more simple, additive fashion (Blair & Raver, 2012). This is supported by the works of Gottlieb (1991) and Moore (2016) on the DS approach and its multi-level interactions.

This view allows new formations of explanations for poverty and its correlation to stunted or unhealthy development; in particular, an important concept of life span theory becomes relevant: selective optimization with compensation (for more, see Blair & Raver, 2012). Such a description for lifetime development involves the idea that an individual (usually a senior) and their brain can work to selectively shape and maintain certain abilities over others to compensate for a noticed decline in such abilities. In other words, development is a constant system of internal trade-offs and exchanges. This concept can be related back to experiential canalization: while the former may be a more conscious choice, the correlation exists in the idea that certain adverse experiences in childhood may canalize the unconscious selection and "optimization" of certain behavioral and neural developments by the infant brain in order to compensate for environmental adversity. In turn, this would allow for the creation of unique, short-term benefits based on contextually appropriate adaptation of perceived "proper" behaviors, but at the cost of other damage to one's well-being, health, and self-regulation. As a prominent example of such trade-offs, Wesarg et al. (2020) reviewed the effect of early adversity on the functioning of the HPA (hypothalamic-pituitary-adrenal) axis in children and found that, in instances of chronic stress, the HPA axis became increasingly overactive to cope with threats and prepare itself for continuous occurrences of stress. Particularly in low-resource and unpredictable caregiving environments, there were generally greater amounts of altered HPA responsiveness and hypervigilance to environmental cues to allow for rapid learning and response to highly threatening conditions (Blair & Raver, 2012). This relates back to stress acceleration, in which early adversity forces the faster development of stress-responsive systems for the sake of protection as a result of mistreatment or some form of chronic stress. In the short-term, the observed adjustments are adaptive and provide protective effects by preparing for energy demands associated with the recurring stressful events; but in the long term, they have detrimental effects such as sustained allostatic states and allostatic overload (Wesarg et al., 2020), and permanent hyporeactivity and altered functioning of the HPA axis later in life (Blair & Raver, 2012).

Relating to these concepts, an innovative recent study by Troller-Renfree et al. (2022) examined whether an increase in monetary funds (poverty reduction) was effective in preventing harmful neurological trade-offs; the first of its kind in the United States. The interdisciplinary study functioned to provide randomized low- ($20) or high-cash ($333) gifts to 1,000 low-income mothers spanning across 4 metropolitan areas, measuring the impact of their children's development through EEG data collection. It found that, after just one year, there was a slight

correlation between the degree of poverty reduction and stronger and more dynamic brain activity patterns associated with higher cognitive, language, social-emotional scores. It is significant to note that the study did not place any restrictions on how the funds should be spent by the families, and the mothers were given full autonomy over its use. Despite this, most mothers did, indeed, spend the money on supporting their child and providing more resources. This study has drawn particular attention in realms of public policy, especially during a time of increased political action towards larger programs of subsidies for families and expanded child tax credits under President Joe Biden (DeParle, 2022). Such research evidently suggests that cash aids may be a plausibly effective strategy to target the disproportionate numbers of underdeveloped children due to poverty's adversity in the United States. Noble argued that, while income may not be completely encompassing of healthy development requirements, it may be the easiest to advocate for and implement as a sort of baseline investment to help ensure basic security for youth brain development (Noble, 2017). However, such policies still face criticism by those concerned that unconditional aid in such a form may discourage parents from joining the workforce (largely Republicans) (DeParle, 2022). As such, Noble's study has since been a constant topic of debate, while little to no progress is made to ever truly change public policy or even come to a consensus on this issue. Additionally, studies similar to Noble's have created a harmful stigma surrounding the idea of low-income mothers being less suitable caregivers, which was briefly addressed earlier in this section when discussing the distinctions between poverty and the causality of bad parenting.

Returning to ideas of the mediation of caregiving in socioeconomic disadvantage, it is clear to see how caregiving can be used to moderate the impacts of poverty; particularly in regards to facilitating healthy developments of self-regulation and stress reactivity (amygdala, HPA axis). Through correct applications, caregiving can be utilized to direct adaptational trade-offs towards a less detrimental route through proper attentiveness and presence in the general environment, or, as mentioned earlier, to increase flexibility of development and influence neural continuity. However, just as caregiving can influence the environment, as the DS approach would suggest, the environment and caregiving behaviors are mutually influential. Blair and Raver (2012) observed that environmental quality promotes certain caregiving behaviors that, in turn, initiate developmental cascades that lead to patterns of development appropriate for that specific environment. From all of the mentioned concepts, many more possible interventions and re-optimizations can arise; this was highlighted by Blair and Raver (2012, p. 313): "Just as the system is open to shaping and selective optimization in the face of high levels of disadvantage, so too might the system be reoptimized to meet changing environmental demands and conditions."

Conclusion

This paper provided an overview of the developmental systems approach and a related theory of experiential canalization to inform an analysis of the potential impacts of caregiving and socioeconomic status on brain development. Several key takeaways emerge from the

research reviewed. First, the research covered widely agrees that development can be understood in terms of a sequence of trade-offs across many levels of development that optimize for the current environment, sometimes at the cost of future behaviors and cognition. This, in turn, casts the impacts of poverty in a new light, in which the costs themselves are not viewed as true costs or detrimental ramifications, but rather the consequence or by-product of certain forced adaptations due to adverse experience. In other words, development in the face of socioeconomic adversity should not be considered inadequate development, but rather a process of continuity through adaptation necessitated by its context. This then allows for more opportunities for intervention; particularly in the form of reversing or re-optimizing harmful trade-offs by introducing and sustaining a more secure environment with healthier experiences to change and influence previous development. Second, in terms of context, cultural differences are essential to consider when it comes to attachment relationships between caregivers and children. By combining this concept with a caregiver's mediating abilities and the DPMEC, it then becomes clear that interventions and further research must be also appropriately customized to maintain a culturally-sensitive basis, avoid premature generalizations, and account for a caregiver's role.

The limitations of the research surveyed is greatly in the ambiguity of the concept of the DS approach. While the DS theory acknowledges that environmental and genetic factors combine to influence development, the actual biological mechanisms of interactions within the brain between these systems have yet to be explored in great depth. Very little has been found about where such interactions take place, how certain specific pairings of components (genetic, cellular, behavioral, etc.) may influence certain developments, or what factors trigger them to activate. While the approach itself contains credibility, the concepts behind its description lack necessary information and discernment, which may cause unreliable variations between studies that makes true correlations unclear.

In fact, such a theme has been observed among past studies and suggested approaches related to childhood brain development. Much research towards further understandings of developmental pathways and how they are formed lack clarity and/or specificity in terms of connections to previous findings or other components of childhood neural development. For example, the findings of both the Wesarg et al. (2020) and Blair and Raver (2012) studies lack specificity for the "adverse experiences" they reference, and do not attempt to make connections to other aspects of development. Wesarg focuses on dysregulated HPA functioning as a predictor for psychopathology in early childhood, but cannot address what exposure to specific adversity, such as poverty, does to the HPA axis, as hypo- and hyperactive functioning have both been observed. Blair and Raver, though they accomplished a synthesis of connections between systems, do not go into any further depth regarding them and also do not identify specific poverty related-adversity that may lead to specific developments. Especially as the majority of their work relies on the idea of experience shaping development coactively with genes, a lack of specific connections between particular experiences and adaptive developments becomes a clear limitation.

Currently, it appears that the solution that is best in terms of being mutually policy-effective and impactful upon childhood development is likely a design very similar to Noble's (2017). Her aforementioned statement contains undeniable truths about its ease of implementation, and while the support may not be incredibly specific, it is certainly widely comprehensive in terms of its possible effects on brain development. Especially in the case of childhood interventions, it is vital that we be, at least for the time being, pragmatic in addressing current issues and invest in what is proven to be effective. The DS approach would also arguably support Noble's design, though only as a temporary starting point, as income has the possibility to influence many different aspects that impact childhood development, including quality of environment, caregivers, and resources. Furthermore, with additional aid such as caregiving support and parental interventions, the reach and effectiveness of this study can be further increased, providing a temporary but realistic and effective solution.

However, in-depth research must not be neglected if we ever hope to further determine the specific types of adversity and adverse experience correlated to certain developmental pathways, and the most effective times and environments for intervention. Otherwise, any targeted interventions will be both difficult to implement, and have great likelihood of failure or of producing inconsistent results. No solidified consensus can be reached amongst policy makers without consistent and viable evidence to support one's claims, and therefore no change in policy can be made without further research. Much is still left to be discovered; for example, the impact of a study similar to Baby's First Years on development past infancy. Properly targeted interventions now have the possibility to have incredibly positive impacts on improving development; particularly with the new information this review has presented regarding experience and reversal of harmful, but conceivably temporary, adaptations. As such, this review hopes to instill urgency in conducting research to clarify our knowledge of developmental systems, the adverse experiences of poverty, and the complexities and interconnections of childhood development in order to deepen our understanding of the brain and design effective and easily enforceable interventions. As it is becoming increasingly evident that childhood brain development contains incredible levels of complexity, the only certain method to propel research continuously forward is by appropriately comparing to past findings and, more importantly, making connections to other (ideally all) developmental factors (including, but not limited to, attachment/caregiving, genetics, culture, and developmental systems). Where such connections cannot be made due to a lack of information (i.e. what specific type of adversity impairs a particular developmental pathway) then provides a clear pathway of where research must go next to deepen our understanding in the years ahead.

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