Cultivating Cognitive Foundations: A Review of Brain Development, Caregiver Roles, and Socioeconomic Influences on Early Communication in Infants

A literature review for the
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Abstract

This literature review offers a comprehensive analysis of peer-reviewed research pertaining to the science of brain development and its implications for healthy child development. The review delves into three key aspects: (1) the science of brain development in infants below 18 months, (2) the pivotal role of parents/caregivers in communication development and attachment, and (3) the influence of immersion and technoference on infant-caregiver relationships and early childhood development. Examining socio-economic influences and other factors influencing child development, the review emphasises the necessity for a preventive and early intervention approach to infant mental health, attachment, and communication development. Additionally, it addresses the impacts and challenges posed by technoference. By critically exploring the caregiver's role and the significance of nurturing relationships in speech and communication, the paper highlights sensory and linguistic play in infant communication development. This research underscores the importance of caregiver-infant interactions for designing effective interventions, particularly for families facing heightened challenges such as low socioeconomic status.

Introduction

The foundational period of infant development predominantly occurs within the home environment and is primarily influenced by the quality of caregiving provided. Within the first 18 months, cognitive and socio-emotional skills undergo crucial formative processes. Recent strides in research have significantly augmented our comprehension of the factors influencing the maturation of the developing brain. These encompass, but are not limited to, parental sensitivity and consistency, the prevailing home environment, socio-cultural elements, community support structures, and overarching public policies (Scott & Brito, 2022). This review paper explores various dimensions of infant development, with a particular focus on brain development, early childhood experiences, communication, caregiver roles, relationships, attachment, and the phenomenon of technoference. Beginning with an overview of brain development from birth to early childhood, the paper discusses the critical role of positive interactions with caregivers and essential contributors to optimal brain development such as sleep, play, nutrition, and interaction. Subsequently, it delves into the impact of early childhood experiences on lifelong health, behaviour, and learning outcomes, emphasising the importance of enriched environments and play in fostering robust development. The paper also examines effective communication, caregiver roles, and the significance of secure attachment relationships in shaping children's development and well-being. Finally, it addresses the concept of technoference and its potential adverse effects on parent-child interactions and emotional bonding. Through this exploration, the paper aims to shed light on the complex interplay between caregiving, environmental influences, and developmental outcomes, highlighting the profound significance of early experiences in shaping human development trajectories.

Brain Development and Communication in Children under 18 Months

The science of brain development is vital for comprehending the complexities of the human mind and has far-reaching implications across various domains. It provides insights crucial for understanding early childhood development, informing tailored educational practices, and preventing and addressing mental health issues and neurological disorders (Gilmore et al., 2018). This knowledge plays a pivotal role in shaping public policies and social services, ensuring effective support for individuals with developmental challenges and promoting overall well-being across the lifespan. During the first 18 months of life, infants experience a period of rapid expansion and maturation of the brain which forms the foundation for future learning, behaviour, health and overall development. This period is characterised by the formation of neural connections and pathways, which are influenced by a child's experiences and interactions with their environment (Tierney & Nelson, 2009).

The body's main control centre is the brain, and its functionality is driven by the intricate connections among the neurons present from birth (Stiles & Jernigan, 2010). All the neurons it will ever possess are already present in newborn infants, and it is these connections that enable various activities such as movement, thinking, and communication. It is during this developmental phase that approximately one million new synaptic connections are crafted per second within the brain, marking the most prolific period of such growth (Cao et al., 2017) and underscoring the significance of the early years in shaping the intricate neural network that governs the brain's functioning.

The brain's development is influenced by both genetic factors and environmental experiences (Brito et al., 2020). Distinct brain regions cater to specific functions, including motor skills, language comprehension, and emotional responses, each evolving at a unique pace. As development progresses, these connections interweave, fostering more intricate cognitive abilities and behaviours. These early connections shape the architecture of the brain, with environmental inputs such as stimulation from caregivers or teachers, nutrition, and exposure to trauma playing significant roles in this process (Tierney & Nelson, 2009). Neural pathways flourish through enriching interactions with parents, caregivers, and the environment. It is the quality and quantity of nurturing, stimulation, and engagement during these early phases that profoundly shape a child's neural development (Bick & Nelson, 2016), demonstrating the interplay between nature and nurture (Stiles & Jernigan, 2010).

At birth, the average baby's brain is about a quarter of the size of the average adult brain. Incredibly, it doubles in size in the first year. It keeps growing to about 80% of adult size by age three and 90% – nearly full grown – by age five. The brain is the command centre of the human body.

Newborns, within hours of birth, exhibit a distinct preference for their mother's voice, indicating the remarkable receptivity of their brains to specific communicative cues. This responsiveness is facilitated by the phenomenon of 'parentese,' a form of communication that serves as a vital link between infants and their caregivers. Termed Child-Directed Speech (CDS), also referred to as 'motherese', this mode of infant directed communication is the way adults/ caregivers talk to babies and young children (Wermelinger et al., 2019). It involves deliberate use of simpler words, clear pronunciation, and exaggerated pitch and intonation. CDS supports language acquisition in infants by making concepts easier to understand and engaging them in communication through repetition, gestures, and facial expressions. The distinguishing feature of CDS is its adaptation specifically for young children's linguistic and cognitive abilities. It aims to facilitate language acquisition and development by providing linguistic input that is tailored to the child's current level of understanding and cognitive processing capabilities (Schwab & Lew-Williams, 2016). This form of speech helps infants and young children to comprehend language more easily, facilitates their language learning process, and strengthens the bond between the child and caregiver through interactive communication. Early experiences of dyadic synchrony such as mutual gaze, complimentary vocalisations and expressions between mother and infant play a significant role in influencing brain development and shaping the bond between infants and their caregivers (Dissanayake, 2008; Trevarthen, 2001).

CDS extends beyond its role as a linguistic tool; it possesses arousing properties with a direct connection to cognitive development. These early dyadic interactions, characterised by synchrony and turn-taking, progress into exploratory vocal play between four and six months, evolving further into repetitive babbling from seven to 11 months. This babbling acts as a precursor to more complex linguistic developments, including variegated babbling where the infant starts to combine different sounds and syllables, leading to the emergence of early words around nine to 13 months (Kuhl, 2004). As linguistic behaviours advance, parent-infant interactions increasingly involve vocalisations and gestures to convey emotions and initiate exchanges, representing a crucial phase in the development of effective communication between caregivers and infants (Guevara-Rukoz et al., 2021; Krasotkina & Veraksa, 2019).

Research has demonstrated that infants' concurrent use of gesture and speech during social interactions is predictive of later language development (Alfonso et al., 2015). These findings point to the significance of early social interactions, language acquisition, and neural processes in shaping communication abilities in children under 18 months of age. Joint attention, a fundamental

developmental milestone, involves an infant's capacity to share attention with another individual towards a common focal point or object. This cognitive achievement arises from a dynamic interplay of attention, gaze-tracking, and mutual understanding between the infant and their caregiver, laying the groundwork for various advanced cognitive and socio-emotional competencies, including language acquisition, social cognition, and interpersonal relationships (Mundy & Newell, 2007; Szufnarowska et al., 2019).

Positive early experiences, particularly interactions with caregivers, are crucial in shaping neural connections and brain architecture. Essential factors for young brain development include sleep, play, nutrition, and social interaction.

Similar to CDS, joint attention facilitates interactive communication and aids in language acquisition among infants and young children. Caregivers engage in joint attention episodes by directing the infant's focus towards relevant stimuli and participating in reciprocal exchanges, thereby providing opportunities for observational learning and imitation of social cues, gestures, and communicative behaviours, which are essential for language development and social interaction (Morales et al., 2018). Furthermore, joint attention contributes significantly to the formation of secure attachment between the infant and caregiver (Bigelow et al., 2018; Donald et al., 2020). By actively engaging in joint attention activities, caregivers demonstrate responsiveness and sensitivity to the infant's needs, fostering a sense of trust and security within the relational bond. This secure attachment serves as a foundation from which infants explore their environment, regulate their emotions, and develop autonomy (Mundy & Newell, 2007). Caregivers play a crucial role in scaffolding infants' understanding of the social world through shared attentional experiences, thereby fostering language acquisition, nurturing secure attachment relationships, and facilitating the development of advanced socio-cognitive skills (Alfonso et al., 2015).

Socioeconomic Influences

The effects of socioeconomic status (SES) start even before birth, with the economic and educational status of parents influencing the brain development of the foetus. Neuroscientific investigations with a focus on infants show that those from wealthier backgrounds have differences in their brain structures and how different parts of the brain connect and communicate with each other (McLoyd, 1998). Notably, SES during the prenatal phase influences both foetal (Lu et al., 2021) and neonatal brain structures (Nolvi et al., 2023).

Limited research has explored the intricate interplay between prenatal challenges and SES in shaping the brain development and functions of infants. However, a notable study by Ramphal et al. (2020) revealed that infants born into higher SES backgrounds exhibited heightened neural connections in specific areas of the prefrontal cortex and reduced connections between other brain regions, irrespective of their gestational term. The prefrontal cortex is involved in high-order cognitive functions such as decision-making, executive control and social cognition, therefore potentially leading to advantages in academic achievement and socioemotional functioning later in life (Gao et al., 2015). This suggests that SES may exert an influence on the neural connectivity of newborns, particularly those born prematurely. In contrast to the scarcity of neuroscience findings, numerous studies have demonstrated that a higher SES contributes to enhanced cognitive development in prematurely born or low-birth-weight children (Beauregard et al., 2018; Lean et al., 2018). Some studies have even underscored the potential protective benefits of a higher SES, countering the adverse effects of premature birth on early cognitive functions, encompassing language abilities and executive skills (Beauregard et al., 2018; Benavente-Fernandez et al., 2019; Bilsteen et al., 2021; Mallinson et al., 2019; Richards et al., 2015). Given the association between low birth weight, prematurity, and lower SES, it's important to consider these factors in the context of early brain development and their potential implications for cognitive outcomes. Infants with low birth weight or born prematurely are already at risk for additional developmental challenges, and, when combined with socioeconomic disparities, this can lead to a compounded impact on neural connectivity patterns and cognitive functioning (McKinnon et al., 2023; Tomalski et al., 2013). Understanding the neural correlates of socioeconomic disparities in early brain development can inform targeted interventions and policies aimed at promoting equitable access to resources and opportunities for children from diverse socioeconomic backgrounds (Cantiani et al., 2019). Early interventions that provide enriching experiences and support for families from disadvantaged backgrounds could potentially mitigate some of the observed differences in neural connectivity patterns.

In infancy, SES correlates with variations in brain structure and maturation (Betancourt et al., 2016; Hanson et al., 2013) and functional neural connectivity (Gao et al., 2015; Ramphal et al., 2020). For instance, infants from higher SES backgrounds tend to exhibit increased cortical volume, particularly in the frontal and parietal regions, and augmented subcortical grey matter volume (Betancourt et al., 2016; Hanson et al., 2013). Increased cortical volume suggests that infants from higher SES backgrounds may have more extensive neural networks or larger brain regions associated with cognitive processes such as decision-making, attention, language, and spatial processing. Subcortical grey matter structures, such as the thalamus, basal ganglia, and hippocampus, play important roles in various functions including sensory processing, motor control, emotion regulation, and memory (Betancourt et al., 2016; Romeo et al., 2018). A higher SES, encompassing factors such as family income and parental education, emerges as a strong determinant for enhanced cognitive development and improved mental well-being in children (Duncan et al., 2017; McLoyd, 1998). This advantage can also be seen in the actual structure of the brain, whereby children from higher SES backgrounds exhibit larger brain structures, such as the hippocampus (Spann et al., 2020; Triplett et al., 2022).

Further corroborating this, a Randomised Controlled Trial (RCT) conducted by Troller-Renfree and colleagues in 2022, demonstrated that early-life poverty alleviation through unconditional financial assistance led to a significant increase in EEG (Electroencephalogram) power in the high-frequency bands of the infants' brains. Increased EEG power indicates enhanced neural activity or connectivity in the brain (Troller-Renfree et al., 2022). The conclusion drawn from this study is that addressing early-life poverty has a positive effect on infant brain functionality, reinforcing the pivotal role of socioeconomic conditions in shaping early brain development. This finding adds to the existing understanding of how external factors, such as poverty alleviation measures, can play a central role in shaping cognitive outcomes in early childhood. Understanding these differences in brain structure related to SES is crucial for identifying potential avenues for intervention and support, with equitable access to resources and opportunities, to promote optimal brain development and cognitive outcomes for children from diverse socioeconomic backgrounds.

Environments rich in stimulating experiences, such as language exposure, interactive play, and exploration, are crucial for healthy brain and child development. Responsive caregiving and nurturing environments during early childhood support language development and communication skills, helping to bridge developmental gaps related to socio-economic disparities.

The Role of Caregiver Speech in Supporting Child Development

The role of caregiver speech, that is the way in which parents or caregivers communicate and interact with their infant, to support child development has been a subject of extensive research. In the 1990s, seminal studies by Hart et al (1997) and Huttenlocher and colleagues (1991) demonstrated the significant impact of caregiver speech on children's language skills. These studies found that infants exposed to more caregiver speech during early life, exhibited better language skills later in life. Furthermore, these studies highlighted the influence of SES on the amount and quality of caregiver speech, with children from higher SES families being exposed to more language-rich environments. Quality caregiver speech encompasses various linguistic and interactional features that contribute to a rich and supportive language-learning environment for children. These features go beyond simple word count and involve aspects such as vocabulary diversity, syntactic complexity, narrative skills, responsive interaction, positive reinforcement, and cultural relevance. Longitudinal studies revealed that the quality, rather than the quantity, of linguistic input from caregivers at 18 months correlated with children's language abilities at three years old. Specifically, directing utterances (i.e., those which served to direct the child's behaviour or actions, such as 'Look right here') were found to contribute significantly to variations in child language outcomes (Ambrose et al., 2015). This research is more recently supported by studies undertaken by Ying and colleagues who acknowledge the prevalence of lower levels of verbal interaction between caregivers and toddlers in low-income households compared to higher-SES households (Ying et al., 2023). However, the significance lies in the quality of the interactions, encompassing factors such as the range of vocabulary, complexity of utterances (represented by the average length of utterances) and verbal interaction style (direct vs responsive), as these elements predict language outcomes in higher-SES households (Masek et al., 2021).

Research exploring the types of caregiver speech that best support language skills across different stages of child development, emphasise the importance of speech quality in supporting infant language skills. A central concept in this context is the 'word gap', denoting disparities in language exposure and interactions during infancy, particularly between different socioeconomic backgrounds (Greenwood et al., 2020). Such disparities refer to differences or inequalities in the frequency, quality, and nature of verbal interactions between caregivers and infants across various socioeconomic contexts. By age three years, children from lower SES families will have heard approximately 30 million fewer words than their higher SES counterparts. This discrepancy contributes to variations in vocabulary size, school readiness, and long-term educational and health outcomes (Greenwood et al., 2020).

The impact of the word gap extends beyond word quantity, encompassing the quality of responsive interactions, thus emphasising the importance of understanding both aspects in fostering optimal language development (Hart et al., 1997).

While subsequent research has generally supported the existence of the word gap, some studies have questioned the magnitude identified by Hart et al (1997). Methodological differences between studies have contributed to the debate surrounding the word gap, underscoring the need for a nuanced understanding of language development factors. Overall, the evidence highlights the crucial role of caregiver speech in shaping children's language development and the need to support parents in providing rich and responsive language environments for their children (Asada & Endo, 2015).

Addressing speech, language, and communication difficulties in children and families from low SES backgrounds is of paramount importance due to increased risk for language delay and subsequent school problems within this cohort (Greenwood et al., 2020), whilst mechanisms to minimise the factors that lead to these differences must also be established. The communication needs of vulnerable children and young people are often not consistently identified or addressed, highlighting the importance of involving speech and language therapists and earlier intervention within health, education, and social services (Clegg, 2021). Upskilling of those who engage with babies, infants, and their carers, so that they can both support a language rich home learning environment and identify additional needs, is also central to an effective approach.

Collaborative practices and interprofessional/multi-agency interventions have proven effective in supporting young children with speech, language, and communication needs in inclusive early childhood education and care (Langner and Fukkink, 2022). Targeted pre-school interventions focusing on language development and enhancing parental interaction, have been shown to be cost-effective in alleviating the societal impact of children with low levels of speech, language, and communication (Frizelle et al., 2021). A systematic review found that there is a relatively high degree of trustworthiness in language intervention research with low-SES children, but a low degree of readiness for scale-up among professionals and parents to reach a broader population (Greenwood et al., 2020). Early intervention and parental involvement in treatment have proven beneficial for pre-school children experiencing language development difficulties, particularly in disadvantaged areas (Gibbard & Smith, 2015). These interventions not only enhance social and educational capacities but also contribute positively to overall child development.

Effective communication encompasses both verbal and nonverbal elements, including gestures, facial expressions, tone of voice, and body language. Frequent verbal interaction with babies accelerates their learning and speech development. Studies show that babies who are regularly spoken to know approximately 300 more words by age 2 compared to those who are less frequently engaged in conversation.

The Role of Nurturing Relationships in Early Childhood Development

In the crucial first years of life, the significance of nurturing relationships cannot be overstated, as they play a pivotal role in optimal brain development. The primary influencers on a child's brain development are the relationships they forge with adults. Affectionate, responsive bonds with consistent caregivers lay the groundwork for robust brain development.

Winston and Chicot (2016) stress that while the initial bond is cultivated within the family, it extends to encompass educators, community members, and other influential figures. These relationships not only provide the necessary sensory stimulation for neural growth but also establish the foundation for important cognitive and socio-emotional skills (Winston & Chicot, 2016). Social cognition in infant children is influenced by a combination of both neurocognitive maturation and environmental factors, including parental responsivity and children's language skills (Corlett, 2008).

Responsive caregiving, which involves attentiveness to a child's cues and needs, fosters secure attachment and healthy development. As primary role models, caregivers significantly influence children's behaviours, beliefs, and values through observation and imitation.

Early parent-infant interaction is highlighted as a key factor in fostering productive dyadic relationships. Hasan & Hazam (2022) emphasise the importance of communication, bonding, and responsiveness to cues in these interactions. Additionally, the interplay between environmental, social, and genetic factors is identified as a significant factor influencing language development in infants and toddlers, with social class and family history playing a substantial role in predicting language development (AlHammadi, 2017; Odoom, 2020).

From infancy, children actively seek engagement through various expressions, including gestures, vocalisations, coos, smiles, and cries. Engaging in conversations from infancy is crucial, aligning with the inherent biological predisposition of babies to establish social connections essential for survival (Shonkoff & Phillips, 2000). This reciprocal exchange between infant and caregiver, termed "serve and return," is foundational to the effective development of neural pathways in the brain and subsequent child development (Fisher et al., 2016). Caregivers who attentively respond to these cues play a crucial role in shaping the child's neural pathways. Therefore, engaging with infants through conversation, songs, stories, and play from their earliest days is deemed imperative, fostering exploration, and ensuring children thrive in safe, nurturing environments (Bick & Nelson, 2016; Hirsh-Pasek & Golinkoff, 2018).

At birth, infants can discern their mother's language from others', indicating pre-verbal neural engagement. Before uttering their first words, infants actively establish neural connections by absorbing the linguistic environment, seemingly practising the intricate sounds for future articulation (May et al., 2011). Babies display innate responses to parental communication, and the unique phenomenon of turn-taking in human discourse becomes a foundation for subsequent attachment and language acquisition (Trevarthen, 2001). This process of contingent communication, present from the beginning, serves the purpose of 'containment'. Parents signal their interest and readiness to understand and appropriately respond to the infant's feelings, ranging from providing comfort to eliciting excitement. This conversational duet unfolds within the emotional overlap of 'primary intersubjectivity', established through the biological imperative of physical closeness in attachment dynamics. This 'potential space' becomes the harmonious link between baby and mother, reinforcing the emotional bond and often leading to secure attachment (Trevarthen & Aitken, 2001). Nurturing and responsive interactions continually shape the developing brain of the infant.

Infant Mental Health focuses on the emotional and social well-being of infants and young children, particularly in the context of their early relationships, attachment, and interactions. In terms of communication development, infant mental health highlights the crucial role of a secure attachment between caregivers and infants, emphasising responsive caregiving to promote positive communication experiences (Clinton, 2016). The concept underscores the significance of emotional regulation, language development, and social engagement for a child's overall well-being. Babies' effective early interactions with others are crucial for their first social experiences and the rapid development of communicative and socio-cognitive skills (Dunster-Page, 2023). The assessment of infant mental health should encompass characteristics of caregiving relationships, such as the capacity for emotion regulation, the ability to communicate feelings to caregivers, and active exploration of the environment (Gratier & Devouche, 2017). By recognising and addressing potential challenges in communication early on, infant mental health theories advocate for interventions that support healthy development, acknowledging the interconnectedness of social and emotional factors in shaping effective communication skills during the early years of life. By promoting behaviours such as social engagement, turn-taking, expressive language, and emotion regulation, caregivers and educators can foster positive outcomes in socio-emotional competence, school readiness, and academic and social performance (Kaur & Sharma, 2022).

Babies and toddlers are essentially dependent on caregivers' sensitive and responsive behaviours within the context of the development of attachment patterns. Maternal perinatal depressive symptoms, occurring during both pregnancy (prenatal) and after childbirth (postnatal), have been demonstrated to influence different facets of infant socio-emotional development. Disturbances in parental attention can have a negative impact on attachment-related interactional processes between parents and children and on child developmental outcomes. Playing together offers parents and their toddlers a unique opportunity for language-rich interactions and emotional engagement (Ginsburg, 2007; Hirsh-Pasek & Golinkoff, 2018; Yogman et al., 2018). Furthermore, there is evidence that the quality of such early parent-child interactions is a powerful predictor of socio-emotional, cognitive, and linguistic child development and the parent-child bond (Ainsworth, 1979; Landry et al., 2006; Tamis-LeMonda et al., 2001). Socio-emotional development in early infancy is primarily influenced by the infant's relationship with their primary caregiver. This relationship is described as bi-directional, with the infant's behaviour also impacting the caregiver-infant relationship. Maternal responsivity is identified as a key factor in children's social-cognitive development, mediated through language skills (Gerlach et al., 2022).

Drawing particular attention to the involvement of fathers, it is widely accepted that mothers engage in more verbal communication with their young children than fathers do, particularly with girls over boys. Mothers tend to employ more supportive speech, while fathers often adopt a more directive and informative approach (Shapiro et al., 2021). However, it is crucial to recognise that these patterns may be influenced more by contextual factors such as culture, access, and role within the family than solely by gender. Research indicates that fathers are inclined to use "parentese" more when they are aware of its significance (Ferjan Ramírez et al., 2022).

Caregivers who promptly respond to an infant's cues contribute to building a sense of security and trust, positively influencing the development of the infant's brain circuits associated with emotional regulation and stress response. Furthermore, the quality of the caregiver-child relationship during the early years has lasting effects on cognitive, social, and emotional development. By providing a responsive and supportive environment, caregivers play a critical role in promoting secure attachments and laying the groundwork for healthy development in infants (Zimmer-Gembeck et al., 2022).

Healthy attachment relationships promote the development of interpersonal skills such as empathy, communication, cooperation, and conflict resolution, essential for building and maintaining relationships.

Sensory and Linguistic Play for Infant Development

In tandem with infant-caregiver relationships, sensory stimulation and exploration play a pivotal role in infant brain development. Britto et al. (2017) highlight the importance of sensory activities in shaping neural pathways during infancy. Infants actively engage with their surroundings through sensory experiences, crucial for organising and refining neural networks. Caregivers can support this developmental stage by introducing age-appropriate sensory activities. These may include supervised tummy time, gentle massage, and exposure to toys and books with varying textures, sounds, colours, and patterns. The integration of sensory stimulation and exploration have been found to further enrich the developmental landscape (Ilyka et al., 2021). Recognising and maximising these dynamics is vital for shaping effective interventions and support systems to ensure children receive the linguistic and sensory inputs necessary for optimal growth and future success.

'Serve and return' interactions with babies and toddlers involve engaging in back-and-forth exchanges through conversation, expressions, and sensory and linguistic play, helping to nurture their social and emotional development.

The Lego Foundation conducted a review to assess the relationship between learning through play and children's holistic development, identifying the need for further understanding in this domain (Zosh et al., 2017). Despite the inclusion of more than 300 studies on this topic, the review highlights the absence of conclusive evidence establishing a causal or directional relationship. The challenge lies in determining whether learning through play actively supports skill development or if the observed link is merely correlational. The review emphasises the necessity to systematically evaluate the strength of evidence both in favour of and against a causal relationship. Additionally, it advocates for the formulation and rigorous testing of potential mechanisms that may underlie such a relationship (Zosh et al., 2017). The interactions, through play, between caregivers and babies/infants are identified as a key avenue for the development of essential self-regulatory skills. As children grow, adult engagement in play continues to reinforce the development of coping strategies that children carry with them throughout their lives (Whitebread et al., 2017).

Screentime, Immersion and Technoference

When caregivers or parents become immersed in technology, such as constantly checking their smartphones or engaging in prolonged screen time, it can lead to a lack of attention and responsiveness to the needs of infants. Infants thrive on consistent and responsive interactions with their caregivers, as these interactions play a crucial role in their emotional, social, and cognitive development. Technoference refers to the interference or disruption in face-to-face interactions caused by the use of technology, particularly smartphones and other digital devices, and has garnered attention in the context of relationships and family dynamics (Mackay et al 2022; Odoom, 2020). In the realm of infant development, technoference introduces the concept of 'immersion' (Agrawal et al., 2019), where individuals become deeply engaged in technology to the detriment of interpersonal relationships (Komanchuk et al., 2023). Caregivers immersed in technology risk the infant experiencing attachment and bonding issues, language development delays, hindrances in social and emotional development, and challenges in attention regulation (Harding et al., 2022; Komanchuk et al., 2023).

Excessive screen time, especially in the presence of children, can disrupt parent-child interactions, leading to negative outcomes such as decreased responsiveness and emotional bonding.

Parental responsiveness is crucial for infants; in addition to the factors noted above, it nurtures the development of secure attachment, a vital component in their development. However, the pervasive influence of technology poses a risk to this responsiveness. When parents are immersed in their devices, this can impede their ability to connect with their infant and so hinder the formation of secure attachments and cognitive and emotional development. Socio-emotional development, encompassing the ability to self-regulate behaviours and emotions, begins during infancy (Scott & Brito, 2022) and is important for developing future emotional intelligence and resilience. In terms of socio-emotional development, infants learn by observing and engaging with their caregivers. Technoference, by diverting caregivers' attention away from the child, may deprive infants of essential social cues and emotional connections. This can impact the development of social skills and emotional regulation, with negative impacts on parent-child relationships and children's health and developmental outcomes (Hasan & Hazam, 2022; Kwok et al., 2022). Several studies have investigated the impact of technoference on infant-caregiver relationships and these realms of early childhood development. One study found that technoference, measured by the amount of time parents spend on their mobile devices and the number of audible notifications they receive, negatively predicted infant vocabulary. The study suggests that technoference

negatively predicts the development of infant vocabulary through its impact on parental directiveness; indicating that when parents are more distracted by their mobile devices, they may engage less in direct interactions with their infants (Corkin, et al., 2021). Another study found that frequent technoference was associated with less secure mother-child attachment as reported by children. It was also associated with decreased ratings by mothers regarding their child's socio-emotional functioning (Zayia et al., 2021).

Research on technoference and its effects on infant development is still evolving. Various factors, such as the frequency and duration of device use, the quality of caregiver-infant interactions, and individual differences, contribute to the complexity of the impact. Despite this, experts emphasise the need to strike a balance between technology use and face-to-face interactions to support healthy infant development. Excessive screen time and digital media use can lead to negative outcomes such as reduced parent-child interaction, language delays, and behavioural problems (Cunningham et al., 2021; Hasan & Hazam, 2022; Kwok et al., 2022).

Effective boundary management, such as establishing device-free times and spaces for meaningful interactions, is essential for mitigating the negative effects of technoference on relationships.

Conclusions

During the formative stages of infancy and early childhood, the brain undergoes an incredible and unparalleled period of growth and development. The quality and quantity of nurturing relationships and experiences encountered by infants during this period play a significant role in shaping their neural connectivity, and ultimately their cognitive, emotional, and social competencies. Substantive research consistently highlights the key role of positive, responsive associations with adults and caregivers in shaping optimal developmental outcomes. The evidence supports the premise that positive, responsive relationships during infancy provide the essential sensory stimuli for neural growth. These relationships also serve as the foundation for cultivating critical higher-order skills like motivation, self-regulation, and communication (Britto et al., 2017; Romeo et al., 2018).

Enriching interactions not only foster exploration but also ensure that children thrive in safe and nurturing environments, setting the stage for healthy, adept, emotionally secure and prosperous adults in the future. By responding to an infant child's cues and providing a supportive and nurturing environment through conversation, songs, stories, and play right from the earliest days carers can help shape the child's neural development and lay the foundation for lifelong learning and well-being. It is crucial for parents, caregivers, and society as a whole to prioritise and invest in promoting healthy relationships and providing supportive environments for young children.

Parent-child communication emerges as a critical aspect of healthy child development, influenced by various factors, including marital relationships and family socioeconomic status (Carlone & Milan, 2021). There is a need for further research and professional development on the specific interplay of predictive factors, such as environment and social class on language development among infants and toddlers; the relationship between children's developmental delays and their communicative participation; and interventions aimed at addressing parental technoference. The complex interplay between genetic factors, brain development, and environmental influences is underscored, particularly in shaping communication skills in children younger than 18 months. Research consistently shows that early exposure to cognitive and linguistic enrichment, such as regular parental communication and interaction, access to toys and books at home, and regular reading sessions, benefits infants (Pace et al., 2017; Rodriguez & Tamis-LeMonda, 2011; Son & Morrison, 2010). Such enriching experiences not only help infants with their thinking and understanding abilities but also in their emotional and social growth. Essentially, a richer linguistic environment in early childhood can positively impact brain development, especially in the growth of neural pathways associated with language comprehension, attention, and self-regulation (King et al., 2021; Romeo et al., 2018; Pierce et al., 2021).

The early caregiver–infant relationship, particularly with the primary caregiver, significantly influences socio-emotional development in infancy. This relationship is bi-directional, meaning the infant's behaviour also impacts it. Maternal responsivity, crucial for children's social-cognitive development through language skills, is emphasised. Additionally, maternal perinatal depressive symptoms can negatively affect various aspects of infant socio-emotional development (Clinton et al., 2016). Therefore, promoting infant mental health through both antenatal and in postnatal services, and implementing specific screening for prenatal depression, are essential for fostering healthy communication development in children younger than 18 months (Zayia et al., 2021; Zeanah et al., 2008). Early attachment is highlighted as mitigating the impact of subsequent exposure to maternal depression on children's externalising symptoms. This underscores the potential benefits of interventions aimed at improving early parent–child relationships, especially in families at elevated risk (Gerlach et al., 2022).

Play fosters creativity, imagination, social skills, and cognitive abilities, helping children learn about themselves and their environment. Responsive caregiving and nurturing environments are essential for early language development and communication skills.

Research on technoference and its effects on infant development is described as ongoing and complex, indicating that scholars are actively studying this phenomenon and its implications. Factors such as the frequency and duration of device use, as well as the quality of caregiver–infant interactions, are highlighted as important considerations in understanding the impact of technoference. Excessive screen time and digital media use by either the caregiver or the infant are noted to have negative outcomes, which can include reduced parent-child interaction, language delays, and behavioural problems (Mackay et al., 2022). Despite these potential negative effects, experts emphasise the importance of striking a balance between technology use and face-to-face interactions to support healthy infant development. This balance should reflect the fact that while technology can have benefits, such as educational apps, it should not replace or overshadow the crucial role of in-person interaction in fostering infant development. Strategies such as limiting screen time, prioritising in-person interactions, using technology mindfully, creating tech-free zones, and modelling healthy tech habits can help mitigate immersion and the negative effects of excessive screen time and technoference while fostering strong parent-child relationships (Radesky, 2020).

In conclusion, the comprehensive synthesis of this paper underscores the critical role of nurturing relationships in early childhood development. From neural pathway development to emotional regulation and language skills, caregivers, educators, and community members all contribute to shaping the trajectory of a child's cognitive, social, and emotional well-being. Recognising the significance of these early interactions is vital for designing effective interventions, particularly in families facing heightened challenges such as maternal depression or low socioeconomic status. Agencies working in low SES areas are encouraged to understand the role of child development and attachment in caregiving, to use this knowledge to inform their work with families and to provide attachment-informed resources and interventions for parents (Zimmer-Gembeck et al., 2022). There is a need for more extensive trials and longer-term tracking of outcomes to definitively influence policy changes in language development interventions for children facing social disadvantages. The importance of accurately assessing communication needs in at risk children and providing evidence-based interventions is underscored. Future studies should concentrate on understanding the benefits of daily collaborative practices in early intervention for children with speech, language, and communication needs. Furthermore, there is a need for research to enhance the ecological validity, trustworthiness, and scalability of language intervention programmes for low socioeconomic status children, with attention to factors like infrastructure, community engagement, and progress monitoring/evaluation. Overall, fostering positive and supportive relationships in the early years lays the foundation for a child's lifelong well-being.

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CDI Childhood Development Initiative

TUSLA An Ghníomhaireacht um Leanaí agus an Teaghlach Child and Family Agency

Area Based Childhood Programme