Associations between Home Literacy Environment, Executive Function, and Emergent Literacy among Four-Year-Old Children from Low-Income Families

by

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BEEd, Southville International School and Colleges, 2014

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We acknowledge and respect the Lək̓ʷəŋən (Songhees and Xʷsepsəm/Esquimalt) Peoples on whose territory the university stands, and the Lək̓ʷəŋən and W̱SÁNEĆ Peoples whose historical relationships with the land continue to this day.

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Abstract

Emergent literacy skills are a set of knowledge, skills and behaviors that serve as precursors to conventional reading and writing. Despite a wealth of research investigating the influence of the home literacy environment (HLE) on the emerging literacy skills of preschool children, findings across studies remain inconsistent. More recently, researchers have been interested in the role of executive function (EF) in school readiness skills, including emergent literacy, as well as its potential mediating role between the HLE and early literacy skills. However, their associations remain insufficiently understood, particularly among low-income preschool populations. Therefore, the present study sought to examine the direct effects of the different types of HLE activities (reading books, telling stories, and learning activities) on children's emergent literacy skills, as well as their indirect effects operating through EF among 4-year-olds from low-income families. The three HLE activities were examined separately to determine whether each would show a differential pattern of association with emergent literacy. Using secondary data from the Baby's First Years study, the path analysis revealed a significant direct association between EF and emergent literacy. In contrast, no significant direct and indirect effects were found between any of the three HLE activities and emergent literacy via EF. These findings underscore the important role of early EF in supporting the acquisition of early literacy skills prior to school entry.

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Acknowledgments

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Introduction

Early childhood is an important period of child development when brain growth is strongly influenced by the interaction between children's biological characteristics and their experiences within the environment (Hoffman, 2008). It is a period when many foundational skills for school and life success are established. However, in the United States (U.S.), a country known to have high economic and social inequalities, young children living in poverty often experience significant gaps in early learning experiences and opportunities that are essential in the promotion of these fundamental skills. These children are likely to get diagnosed with physical, cognitive, and other developmental delays, affecting their abilities to progress in school and life in general. In other words, poverty can affect children's overall development in many ways, including physical health, cognitive development, school readiness, and later academic achievement (Brooks-Gunn & Duncan, 1997; Evans, 2004; Wolf et al., 2017), pointing to the vital role of contextual factors on child development.

The home environment is a broad construct that encompasses, but is not limited to, the physical environment, the availability of learning resources and opportunities, parent-child interactions, and parental characteristics, beliefs, and expectations (Phillips et al., 2025). For most children, home serves as the primary context for their literacy and cognitive development in the early years. However, the home environment of children in poverty is often characterized by limited learning experiences and cognitive stimulation, reduced quality of interactions, and less supportive and nurturing relationships between the caregiver and the child that may negatively affect the development of cognitive domains, including language, self-regulation and executive function (EF) skills (Blair & Raver, 2015; Evans, 2004; Kalil & Ryan, 2020).

Theoretical and empirical evidence underscored the role that ecological influences may play, particularly the early home environment, in shaping children's early academic, cognitive and self-regulation abilities (Blair & Raver, 2015; Bronfenbrenner & Morris, 2006; Korucu et al., 2020; Rodriguez & Tamis-LeMonda, 2011). For example, a recent work points to the importance of the home literacy environment (HLE) in supporting school readiness skills, such as literacy, numeracy, and EF, during the preschool years (Korucu et al., 2020). Other studies also highlight some aspects of the HLE, including parental-child literacy interactions (e.g., shared book reading, teaching letters and sounds) as not only influencing children's language and literacy development (Rodriguez & Tamis-LeMonda, 2011; Sénéchal & LeFevre, 2002) but also providing opportunities for children to develop their EF skills (Korucu et al., 2020). Preschool children, typically ages three to five, growing up in low socioeconomic families are found to be more likely to exhibit gaps in emergent literacy skills, such as alphabet knowledge, print concepts and vocabulary (Cabell et al., 2011), as well as in their EF skills (Fitzpatrick et al., 2014) and that these deficits predict persistent disparities in early and long-term achievement (Blair & Raver, 2015; Duncan et al., 2007; Fitzpatrick et al., 2014).

Pre-academic abilities, such as emergent literacy and numeracy, as well as executive functions (e.g., attention skills), are well-known predictors of later achievement (Duncan et al., 2007). Emergent literacy, the main outcome variable of the study, is strongly linked to later reading achievement. Evidence shows that its components - early language (e.g., receptive and expressive) and early literacy skills (e.g., print concepts, alphabet knowledge, and phonological awareness) during preschool, predict school-age decoding and reading comprehension skills (Cabell et al., 2011; Storch & Whitehurst, 2002). However, despite these important findings, many children begin school lacking not only in pre-academic skills but also in abilities that

enable them to learn successfully in the classroom setting, such as self-regulation and EF (Blair & Raver, 2015). EF skills are cognitive processes that enable individuals to focus, sustain their attention, and ignore distractions to accomplish tasks (Miyake et al., 2000). These processes are important mechanisms that facilitate and support the acquisition of early skills (e.g., language, letter and sound recognition) during learning interactions. The development of academic and EF skills is dependent on both environmental and child factors (Blair & Raver, 2015). Therefore, these insights highlight the importance of early home experiences and the role of children in their own development.

Several recent studies have examined the influence of both the HLE and EF on children's school readiness skills, including emergent literacy skills, among preschool children (Davidse et al., 2011; Segers et al., 2016). However, these studies have found inconsistencies in the relationships between the HLE and emergent literacy skills, where differences in the conceptualization and measurement of the constructs, sample composition, and methodological approaches (e.g., longitudinal vs. cross-sectional) were possible sources of variation in the findings. Moreover, recent studies have hypothesized the potential mediating role of EF in the relations between the HLE and emergent literacy, indicating that EF supports the mechanism by which the effect of HLE is transmitted to emergent literacy skills (Devine et al., 2016; Korucu et al., 2020; Simmons et al., 2023). Due to little research examining the associations of these constructs simultaneously, particularly in the low-income population, and the need for clarity on the role of EF, it is the goal of the current study to address some of these gaps and replicate or extend previous findings to contribute to the growing literature on this topic. Exploring early home experiences and understanding what underlies differences in children's foundational abilities can help address persistent academic disparities among children living in poverty. The

results of the study aim to inform child and family intervention programs of the role of the HLE and child characteristics, such as EF, in the development of children's early literacy skills.

The following sections begin with a review of the literature on emergent literacy and major theoretical perspectives. Next, EF and its components, as well as its developmental trajectory and the structure in preschool-age children, are described. Then, the concept of the HLE is examined, outlining the key theoretical framework guiding the current study. This is followed by a synthesis of research on the direct and indirect associations among the HLE, EF, and emergent literacy. After the literature review, the purpose and research questions of the current study are outlined. Then, a description of the methodology, statistical analysis, results and discussion, and finally the implications and recommendations for future research are discussed.

Emergent Literacy

Emergent literacy is commonly defined as the knowledge, skills, attitudes, and behaviours that develop in the years prior to formal schooling, and this set of skills serves as a foundation for conventional reading and writing (Whitehurst & Lonigan, 1998). The term emergent literacy was first conceptualized by Marie Clay in 1966, who described it as reading and writing behaviours that young children demonstrate before they can read or write conventionally. Historically, literacy in the 1920s was understood from a maturational view, which assumed that children could learn to read only after reaching a certain age or level of developmental or neural maturity. By the late 1950s, the "delay-until-ready" view shifted toward recognizing the role of environmental experiences and early exposure to reading in fostering reading readiness, especially among socioeconomically disadvantaged children. In the United States, programs such as Head Start were established to support early literacy development

lacking within the immediate environment of children from low-income backgrounds. In the 1980s, a new perspective on how children become literate was introduced. Teale and Sulzby argued that the term "emergent" indicates that children are actively involved in the process of becoming literate, and demonstrate literacy behaviours even before they receive formal schooling (Teale & Sulzby, 1986). This means that children may acquire skills in several ways, such as through active exploration of their environment and interactions with people around them, who model literacy behaviors. For instance, young children who were raised in a literate environment often show early interest in books by playing with them, pretending to read, or asking to be read to. These behaviours represent early, legitimate markers of their literacy development (Whitehurst & Lonigan, 1998).

Emergent literacy is viewed as a continuum of development in which children's knowledge of print gradually becomes more organized and complex as they move toward conventional literacy (Whitehurst & Lonigan, 1998). Young children first develop awareness of symbols, such as recognizing that print carries meaning and purpose. Through regular exposure to language and print within their environment, they acquire other foundational literacy skills, such as alphabet knowledge, phonological awareness (i.e., the awareness of sounds at the sentence, syllable, and phoneme level) and vocabulary. Though there is variability in the rate at which these skills are acquired, researchers have argued that several literacy concepts and behaviours typically emerge during the preschool years (Sénéchal et al., 2001; Whitehurst & Lonigan, 1998).

Ehri's (2005) phases of word reading explained how children progress through literacy stages to become fluent readers, and each phase describes a change in how children use visual, phonological, and orthographic information to recognize words. Preschool children, typically

ages 3 to 5, fall within the pre-alphabetic phase. At this stage, preschoolers may not have developed a complete understanding of the alphabetic principle (e.g., associating letters with their sounds to decode words), thus they may rely primarily on visual cues, such as pictures, logos or environmental print, to identify words and their meaning. Although many preschool children may already have some understanding of print, such as being able to recognize letters in their names or that what is being read in the book is the printed text and not the pictures, their ability to associate letters with their sounds is still emerging. In fact, these early literacy skills (e.g., print concepts, alphabet knowledge) are closely related to the amount of literacy exposure they have had in their immediate environment, usually through shared book reading and other parent-child interactions (Ehri, 2005; Reading Rockets, n.d.). These developmental insights suggest how preschoolers' early literacy behaviours may be acquired through their interactions and exposure with their environment long before they enter school. While there is no definitive model that specifies all the skills and behaviors included in emergent literacy, research has identified key components that serve as foundations for the development of conventional literacy.

Emergent Literacy Components

Over the last three decades, a wealth of research has established that reading is a multi-componential process (Gough & Tunmer, 1986; Joshi & Aaron, 2000; Perfetti & Stafura, 2014). One influential framework, the simple view of reading (SVR), conceptualizes reading comprehension as a product of two literacy components - decoding and language comprehension. The framework indicates that both skills – the ability to recognize words and to understand spoken language – are required for successful reading (Gough & Tunmer, 1986; Joshi & Aaron, 2000). The SVR framework aligns with the emergent literacy component perspective,

which identifies foundational knowledge and skills children acquire in the early years. Similar to the SVR framework, emergent literacy comprises two domains – outside-in (oral-language skills) and inside-out (code-related skills) that are strongly interrelated during the preschool years (Storch & Whitehurst, 2002; Whitehurst & Lonigan, 1998). The outside-in domain includes skills that support children's understanding of the meaning of print. These skills also refer to oral language skills, which cover semantic knowledge (e.g., expressive and receptive vocabulary), syntactic knowledge (e.g., word order and grammar), narrative skills (e.g., telling a story) and background knowledge. The inside-out domain involves skills that support children's ability to decode print. These skills are also known as code-related skills that include alphabet knowledge (e.g., recognizing letters), grapheme-phoneme correspondence (e.g., knowledge that letters make sounds), phonological awareness (e.g., identifying beginning sound in a word), print concepts (e.g., understanding books' front and back and title, reading from left to right), and early forms of writing (e.g., scribbling or drawing to represent letters). The oral language skills are believed to be the first to develop through adequate verbal interaction between children and their caregivers. Thus, these skills are highly sensitive to the quality and quantity of language input within the home environment during the first five years, a period when children spend most of their time with their primary caregivers (Storch & Whitehurst, 2002).

The longitudinal study conducted by Storch and Whitehurst (2002) involving 626 four-year-olds from low-income families in New York examined the relationship between the two domains of emergent literacy – code-related (e.g., print concepts and phonological awareness, early writing concepts) and oral language skills (e.g., receptive and expressive vocabulary, narrative skills), and their contribution to later reading skills. They found that oral language skills had a strong influence on code-related skills during the preschool years, but this relationship

deteriorated over time. They also found that preschool emergent literacy skills were strongly linked to later reading skills. Specifically, both preschool language and code-based skills were directly related to kindergarten's language and code-related skills, respectively, and continued to account for variance in oral and code-related skills in Grades 1 and 2. Furthermore, both concurrent and prior reading language and code-related skills predicted reading comprehension and accuracy in Grades 3 and 4. Cabell et al.'s (2011) study resulted in similar findings involving preschool children from low socioeconomic status families. They indicated a strong concurrent relationship between oral language abilities and code-related skills, suggesting that stronger language ability enables the development of code-related abilities, allowing children to engage more actively in literacy activities when they understand the concepts being taught. Lower language skills may also preclude children from participating in literacy activities due to difficulty understanding instructions or expressing themselves.

These findings highlight the relationship between components of emergent literacy skills and their contributions to later reading abilities. Because word recognition relies on preschool code-related skills, and reading comprehension depends on both code-related and oral language skills, young children with early delays in these skills are likely to experience difficulties in comprehending print in the future. These results are particularly important for children from low-income backgrounds, the population included in the current study, who enter school with lower language abilities and print-related skills than their more advantaged peers, making them at risk for later reading difficulties. The component perspective emphasizes the need to support both code-related and oral language development during the early years and to understand how these two components complement each other for successful reading. The home environment, where

children spend most of their time before entering school, needs to be examined to understand how it can support the development of emergent literacy components.

Emergent Literacy Construct

Emergent literacy is generally conceptualized as a multifaceted construct made up of interrelated oral language and code-related skills that work together to support children's early literacy development (Storch & Whitehurst, 2002; Whitehurst & Lonigan, 1998). However, some researchers have questioned whether emergent literacy should be viewed as encompassing both domains (oral language and code-related) or whether oral language skills should be treated as a separate construct. For instance, Sénéchal et al., (2001) argue that emergent literacy and oral language are distinct but related constructs. In their analysis of two emergent literacy frameworks, including Whitehurst and Lonigan's (1998) outside-in and inside-out model, they found that components of emergent literacy mostly include print-related literacy behaviours, raising concern about whether oral language skills should be included as subcomponents of the emergent literacy construct. They proposed that emergent literacy, consisting of conceptual (e.g., purpose of print) and procedural knowledge (e.g., alphabet knowledge) about literacy, is a separate construct from oral language, such as vocabulary, narrative skills (the ability to construct and retell stories in sequence) and metalinguistic skills (phonological awareness). However, their proposed model needed further investigation to support their theory. A more recent comprehensive emergent literacy model (Rohde, 2015) identified four components, such as print awareness (e.g., alphabet knowledge, print concepts), phonological awareness, emergent writing (e.g., initial attempts at writing such as scribbling or drawing letter-like shapes), and oral language. The components of the newer model are quite similar to Whitehurst and Lonigan (1998), except that they refined the construct by specifying particular literacy skills within the

emergent literacy construct rather than categorizing them as code-related and language skills. Unlike Sénéchal et al. (2001), language skills are included in the overall emergent literacy model, as they are in the present study, rather than being treated as a separate construct.

Several studies have distinguished subcomponents of emergent literacy skills, such as measuring code-related skills and oral language skills separately to determine pathways through which predictors influence each early literacy skill, while other studies have operationalized emergent literacy as a composite or latent construct. For instance, Sénéchal and LeFevre (2002) found that different home literacy activities relate differently to each early literacy skill. Specifically, they found that informal literacy activities, such as storybook reading, were related to children's language skills (receptive language), whereas formal literacy interactions, such as teaching how to read, were linked to emergent literacy skills (print concepts, alphabet knowledge, decoding, invented spelling). In contrast, Carroll et al.'s (2019) study on the contribution of the HLE to emergent literacy skills involving preschool children in the UK, computed a composite score for vocabulary, letter knowledge, phonemic awareness and rhyme as an index of emergent literacy. This decision to create a single construct was due to the strong intercorrelations among the four variables. They argued that combining them would minimize measurement errors and capture shared variance. Similarly, Foster et al., (2005) investigated the relationships between home learning and family factors and children's emergent literacy skills in low-income families and modeled emergent literacy as a latent construct incorporating measures of vocabulary, phonemic awareness, and parent-reported skills on alphabet recognition, print concepts and emergent writing to control for measurement error.

Taken together, the differences in how emergent literacy is conceptualized and measured across studies inform the present study. While examining specific skills can explain distinct

associations between predictors and particularly emergent literacy components (Sénéchal & LeFevre, 2002), using a single, integrated emergent literacy construct can provide methodological advantages, such as reducing measurement error and capturing shared variance when skills are highly correlated (Carroll et al., 2019; Foster et al., 2005). This is particularly relevant to preschool samples, where oral language and code-related skills tend to be strongly related. Drawing on previous studies that have operationalized emergent literacy as a composite, the current study extends this approach to capture the interrelatedness of its components in early childhood.

Child and Environmental Influences on Emergent Literacy

The child and environmental perspectives recognize the dynamic interaction between child characteristics and environmental influences in supporting literacy development (Rhyner, 2009). Child-level factors that might influence how children engage and benefit from literacy experiences are the child's health, language skills, literacy interest, or cognitive abilities (e.g., EF, attention). The environmental factors can include the physical environment where the child lives and where literacy interactions occur (e.g., home, day care), the people who model literacy practices (e.g., parent, siblings, teachers), the resources accessible to the child (e.g., books), and the learning opportunities offered within the environment (e.g., shared book reading).

Two early frameworks by McNaughton (1995) and Wasik and Hendrickson (2004) described child and environmental factors that may influence the emergent literacy development. McNaughton's (1995) socialization model views emergent literacy as a social process that develops through children's literacy interaction with their families and communities. The model suggests that children acquire literacy skills through engaging in activities with their caregivers (e.g., parents, siblings, teachers) who model and scaffold literacy behaviours. For instance,

shared book reading with a parent might introduce children to the purpose of a book and the conventions of reading. McNaughton also indicated that literacy learning extends beyond the family context when children apply their acquired skills in other settings, such as in preschools, church and community events (Rhyner et al., 2009).

Similarly, Wasik and Hendrickson (2004) identified four aspects that support literacy development in young children, namely parental characteristics, child characteristics, the HLE, and parent-child relationships. Parental characteristics can include beliefs about literacy (e.g., importance of becoming literate), culture and ethnicity (e.g., language at home, preferred literacy activities) and socioeconomic status (e.g., parental education level, financial and time resources). These parental characteristics can influence the frequency and type of literacy experiences a child is exposed to, the literacy resources available at home, and the quality of literacy information and interaction the child receives within this environment. Child characteristics, including interest and motivation, language proficiency, cognitive skills, and health conditions, can also influence how children engage and benefit from literacy activities. For instance, a child with a high level of interest in literacy might ask their parents to read more often to them. The HLE may involve either direct literacy-related activities, such as shared book reading and teaching letters and sounds, or indirect activities, such as literacy habits that children observe from their caregivers, both of which may contribute to the development of early literacy skills. Finally, parent-child relationships involve the qualitative aspect of the interaction, such as being nurturing and supportive, which can support language and literacy development (Rhyner et al., 2009). These two frameworks stress the importance of considering both child characteristics and environmental factors when explaining mechanisms that shape children's literacy development.

Bronfenbrenner's bioecological model is an evolving but widely adopted theoretical framework that offers a holistic approach to understanding multiple factors influencing child development. Its most recent model delineates four interrelated elements - person, process, context, and time, also known as the P-P-C-T model, that simultaneously influence developmental outcomes. Proximal processes are the key drivers of human development. It is described as "*processes of progressively more complex reciprocal interaction between an active evolving biopsychological human organism and the persons, objects, and symbols in its immediate environment* (Bronfenbrenner & Morris, 2006)." In other words, proximal processes are interactions, either with another person or with objects within their environment, that drive human development over time. However, the effectiveness of the proximal processes is dependent on several factors, such as the characteristics of the person, their immediate and distant environment where the interaction takes place (context), and the time conditions at which the interaction occurs. Bronfenbrenner described three types of persons characteristics. First, the forces are behaviors that can either enable and sustain engagement (e.g., curiosity, initiative to engage in activity) or prevent or disrupt the interaction from happening (e.g., distractibility, lack of interest). For instance, a curious child is more likely to initiate activities with another person or with objects and toys at home than a child who lacks interest. Second, resources are biological and psychological capacities that enable a person to either engage effectively (e.g., prior knowledge, language skills) or limit their participation in the process (e.g., developmental conditions). For instance, a child who is healthy and has adequate language skills can participate more actively in the activities than a child with developmental delays. Finally, the demands are the person's attributes (e.g., age, gender, physical appearance, and personality) that elicit responses from other people. For example, a child who appears to be shy may be given more

time to warm up before engaging in an activity, while a very energetic child might receive frequent reminders to sit still. Additionally, Bronfenbrenner noted that a person's characteristics may function as both influences, as one of the four components of PPCT, and as developmental outcomes, which indicates that the person is actively involved in their own development. (Bronfenbrenner & Morris, 2006).

Context, in the PPCT model, refers to layers of environmental systems in which the person develops. These systems range from the most immediate setting (microsystem) and the relationships between different settings (mesosystem), to a broader system encompassing cultural and societal structures that influence a person's growth. The microsystem refers to the characteristics of the person's immediate environment, including its physical features, such as the presence of objects that allow for exploration, as well as the structural qualities, such as organization, stability and predictability of events that may affect the proximal processes. The microsystem, such as the home, is the setting where children spend most of their time in the early years, thus serving as the primary ecological influence on their development. Likewise, the time component has three types – micro-, meso- and macrotime. Bronfenbrenner defined microtime as the continuity or duration of the proximal processes, whereas mesotime refers to the frequency of the interaction, usually measured in terms of days, weeks or months. Both microtime and mesotime are important in the proximal processes to see meaningful change in a person's development.

Bronfenbrenner's framework informs the current study as it recognizes that both child characteristics and environmental inputs can mutually influence emergent literacy development. Emergent literacy is influenced not only by biological attributes but also by the aspects of the home environment. The PPCT model allows the current study to examine specific child-level

predictors, such as EF, and environmental predictors, such as the HLE, to shed light on the mechanisms that shape early literacy skills. In the next section, EF and the HLE are discussed.

Executive Function (EF)

EF refers to a set of cognitive processes that facilitates planning, problem solving, and goal-directed behaviours (Diamond, 2013; Garon et al., 2008; Miyake et al., 2000). These skills support learning and enable young children to regulate attention, follow instructions, and persist in learning tasks. Miyake and colleagues' (2000) model of EF has served as the foundation for the many studies on EF. They stipulated three core EF component processes, namely inhibition (i.e., suppressing impulse or prepotent responses and distractions), working memory (i.e., maintaining and manipulating stored information in mind), and cognitive flexibility (i.e., shifting between mental sets, tasks, or rules), each representing unique but interrelated skills, indicating both unity and diversity of executive function processes. However, because their analysis involved college students, they acknowledge that their results may not be generalized to other samples such as children, adults, or people with neurological conditions, as the degree of relations among these three constructs might be affected by age-related and other biological factors (Miyake et al., 2000).

Several studies have adapted Miyake et al's. (2000) EF theory to other samples, including in early childhood. Basic EF skills emerge during the initial years after birth and continue to develop until early adulthood. It is also believed that early childhood is an important stage marked by rapid improvements in EF performance (Best & Miller, 2010). According to Garon et al. (2008), EF growth during the preschool years involves two stages. First, the foundations for the development of EF abilities, such as the ability to hold things in mind, inhibit responses or sustain attention, emerge before the age of 3. Then, between the ages of 3 and 5, the

development of children's attention system supports the increasing integration of EF components, resulting in more complex and organized EF during the latter half of the preschool period (Garon et al., 2008). However, despite the large literature on EF, the construct remains elusive. There is a lack of agreement on how the executive function processes are structured and organized especially in young children (Best & Miller, 2010), with some studies providing support that EF components are not dissociable in young children, supporting a unitary EF structure (Fuhs & Day, 2011; Wiebe et al., 2008, 2011) while others indicating partially differentiated components or a two-factor structure (Miller et al., 2012).

Wiebe and colleagues (2008) investigated the EF structure by assessing inhibition and working memory in typically developing children ages 2 to 6. Their factor analysis confirmed a single-factor model of executive control, which means that measures of working memory and inhibitory control measured a single cognitive capacity. Additionally, they found gender differences in the level of executive control, with girls outperforming boys, but no differences in socioeconomic status. In a similar study involving only 3-year-olds from diverse socioeconomic backgrounds, Wiebe et al. (2011) replicated their previous findings, suggesting that a unitary structure of EF best explained preschoolers' cognitive abilities. However, contrary to their previous findings (Wiebe et al., 2008), there were no gender differences in the EF but at-risk children showed lower levels of EF than children with better SES conditions. They noted that contextual differences, such as spending most time at home versus attendance at preschool, which is a more structured environment, might explain the difference. Similarly, Fuhs and Day (2011) reported that despite using a different set of EF measures, such as inhibition and attention shifting, instead of working memory, a unidimensional structure of EF remains as the better representation of EF for preschool children (ages 3-5) from low-income backgrounds. These

findings reinforce the view that EF components reflect a single cognitive capacity during the preschool years. Miller et al., (2012) on the other hand, identified a two-factor structure in their analysis of 3 to 5-year-old children. They noted that the contrary findings might be attributed to differences in the sample characteristics, such as the age range included in the sample and the sociodemographic characteristics.

In summary, while older children and adults often exhibit independent, three-factor EF structure, findings for preschool children remain mixed. Most factor analyses support a unitary EF model, with some evidence for a two-factor structure. Using a composite EF measure in the current study is theoretically and conceptually appropriate, given the interrelated structure of EF in early childhood. The EF composite measure is more often used and established in the literature, especially in studies involving preschool-aged children. However, relying on a single EF task is considered a limitation of the current study, as using only one task may not fully capture the EF ability, and it is also prone to measurement errors and task reliability despite its strong psychometrics.

Home Learning Environment

Researchers have been guided by major theoretical frameworks to clarify the role of the home learning environment in children's development, such as the bioecological theory (Bronfenbrenner & Morris, 2006) and sociocultural theory (Vygotsky, 1978). Both frameworks emphasize the importance of proximal processes, which refer to children's interaction with their caregiver and their immediate environment, as the primary mechanism that supports learning. The quality of parent-child interactions and the social and learning experiences offered within the home support the development of many foundational skills essential for learning. A high-quality home environment characterized by consistent, responsive, and supportive relationships

encourages children to explore their environment and engage in meaningful learning experiences that help develop their cognitive and pre-academic skills (Rodriguez & Tamis-LeMonda, 2011).

Home Literacy Environment (HLE)

Among the various domains of the home learning environment (e.g., home digital, home science, home numeracy), the home literacy environment (HLE) remains the most extensively studied (Napoli et al., 2025). The HLE is a well-researched construct, but its conceptualization continues to evolve, particularly in terms of what comprises the HLE and which aspects are strongly related to children's literacy development. The HLE is a broad construct encompassing parent-child literacy interactions (e.g., book reading, teaching reading), resource availability (e.g., number of books), parental characteristics (e.g., reading level, habits and interests), and parental educational beliefs and expectations (Phillips et al., 2025). Studies involving HLE have operationalized and assessed the construct in different ways, which reflects the lack of a universal or standard approach to measuring this variable. Most studies have relied on parental reports to measure multiple dimensions of the HLE. For instance, the frequency of shared book reading and code-related activities has been a common and reliable indicator of the HLE (Hood et al., 2008; Phillips et al., 2025; Sénéchal & LeFevre, 2002). Other studies have employed direct observations to assess the quality of parent-child interactions during literacy activities, not captured by survey questionnaires (Roberts et al., 2005). Some studies have used a global measure of the HLE, in addition to specific home literacy practices (Roberts et al., 2005) or created composite variables as an index of multiple HLE indicators for stronger reliability and validity of the construct (Weigel et al., 2006), while some analyzed each HLE item independently to determine their unique contributions to preschool's emergent literacy skills (Sylva et al., 2010). Thus, these differences in how the HLE is measured and conceptualized in

previous studies inform how the HLE construct is operationalized in the current study. In this study, each type of HLE activity (reading books, telling stories, and learning activities) was examined to determine whether each would result in a unique association with children's overall emergent literacy. Furthermore, the study aims to extend previous research on whether less formal code-related activities (e.g., engaging in learning activities involving letters, numbers) or meaning-related activities (e.g., reading books, telling stories) would result in a different pattern of associations with emergent literacy. Additionally, a composite HLE variable would be tested to determine whether a composite or the individual indicators would better explain the variation in children's emergent literacy skills.

Associations between the HLE and Emergent Literacy

The contribution of the HLE to the language and literacy outcomes is well-recognized. Different aspects of the HLE have been linked to children's language abilities and the development of components of emergent literacy among preschool children (Baroody & Diamond, 2012; Burris et al., 2019; Carroll et al., 2019; Hood et al., 2008; Roberts et al., 2005; Rodriguez & Tamis-LeMonda, 2011; Sénéchal & LeFevre, 2002; Storch & Whitehurst, 2001; Sylva et al., 2010; Weigel et al., 2006).

Sénéchal and LeFevre's (2002) widely used HLE model distinguishes home literacy activities into two categories – formal and informal. Formal activities are those that involve explicit teaching of literacy skills, such as recognizing letters, phonics, and writing, whereas informal activities focus on the exposure and meaning behind the print, such as shared book reading. In their study involving 168 4–5-year-old kindergarten children from middle to upper income families in Ontario, Canada, they found that parents' storybook exposure, measured by the number of titles and authors of children's books parents can recognize, was linked to

children's language skills, whereas the frequency of parent's teaching the child to read and write were associated with early literacy skills. These findings indicate that home literacy activities were differentially associated with children's skills. Specifically, informal activities, such as storybook reading, were more related to children's language abilities, whereas formal experiences, such as parental teaching of reading and writing skills, were linked to emergent literacy. Additionally, the non-significant relation between storybook exposure and emergent literacy skills indicates that informal literacy activities may not be sufficient to support the development of emergent literacy components such as alphabet knowledge. However, it is important to note that the measure for storybook exposure did not involve examining the content and quality of the parent-child interaction during the activity. Some parents who read books to their children might also be teaching early literacy skills, such as naming letters, while others may not. This variation in literacy practices, not captured by using frequency measures, is an important limitation. Additionally, the sample in the study involved middle to upper income families, raising a question whether the same pattern of relationship would be found in the low-income population (Sénéchal & LeFevre, 2002).

Several studies have adopted this home literacy model to examine patterns of associations between different types of home literacy activities and several components of emergent literacy. Hood et al. (2008), for example, examined home literacy experiences of preschool children from low to middle-class families in Australia. Consistent with the findings of Sénéchal and LeFevre (2002), preschoolers' letter-word identification was significantly associated with parental teaching but not with parental reading activities. Their results further reinforce the evidence of the stronger influence of more formal activities, such as parental teaching, on children's emergent literacy skills than storybook reading. One important consideration raised by the

authors is the timing of examining literacy practices. The type and frequency of home literacy activities offered by caregivers may vary across the preschool period, so variations in these experiences and their cumulative effects might be critical to understanding the degree to which HLE influence emergent literacy development.

Another study conducted by Rodriguez and Tamis-LeMonda (2011) explored variation in the home learning environment across the first five years of children's life and their relations to children's language and emergent literacy skills. In their study involving 1852 low-income mother-child dyads in the U.S., they found differences in children's home learning experiences over time and categorized them into several groups based on the home learning trajectories (e.g., low rise, low decline, moderate rise, high decline). They found that prekindergartners' language and emergent literacy skills were strongly associated with the home learning trajectories. Specifically, they noted that children's experiences in the initial years were linked to language skills, while experiences at preschool relate to emergent literacy skills (e.g., letter word identification). This emphasizes the role of timing when examining the influence of HLE on specific literacy skills. Furthermore, their findings support the differential effects of the types of home literacy activities on children's outcomes found by previous studies (Hood et al., 2008; Sénéchal & LeFevre, 2002). Informal literacy experiences, such as shared book reading, promoted language and vocabulary acquisition, whereas formal literacy experiences, such as teaching letters or writing their names, supported early literacy skills, such as alphabet knowledge, emergent writing. These insights support the study's goal of examining whether different types of literacy experiences would show distinct associations with children's early literacy outcomes.

Sylva et al.'s (2010) study involving 2700 children ages 3-5 attending preschool in the UK, examined a range of HLE indicators, including reading, playing with letters/numbers, general learning activities, and library visits. The frequency of children playing with letters and numbers and engaging in learning activities with the alphabet was reported to have a direct impact on code-related skills, such as phonological awareness and letter knowledge. Contrary to other studies, their findings suggest that even less formal activities (without explicit teaching) may also exert some influence on children's code-related skills acquisition. This supports the current study's hypothesis that less formal literacy activities, such as the frequency of engaging in learning activities involving letters, numbers, and shapes, storytelling, and reading books, may influence children's emergent literacy abilities. However, it is important to note that their study was longitudinal and that home experiences were measured when children were around three years old, while domains of emergent literacy were examined at age five, suggesting that HLE effects may not show up immediately but possibly at a later time.

Another study employed a broader set of HLE measures that included parental characteristics such as parental literacy habits and beliefs, and parent-child activities involving both literacy (e.g., reading aloud, telling stories, number of picture books at home, library visit) and non-literacy activities (e.g., drawing pictures, playing games, watching educational TV programs). Weigel et al.'s (2006) analysis of 85 middle-income families with children around the age of four attending childcare centers found that parental literacy habits, reading beliefs and parent-child activities were related to print knowledge and reading interest. Their findings suggest that children demonstrated better print knowledge and stronger interest in reading when their parents read more to them, make books accessible at home and through visiting the library, as well as when engaging in other activities such as drawing and playing games with their

children, and these positive effects persist after a year. However, children's language skills were related to parents' demographics but not to parent-child activities. These patterns are more common in middle to high-income families whose parents have higher educational levels than in low-income families with lower educational attainment. Similar to Sénéchal and LeFevre (2002), these findings suggests that socioeconomic status is an important influence on the associations between the HLE and literacy outcomes and that these relationships might look different for families with lower SES.

Further studies were conducted in low-income populations (Burris et al., 2019; Storch & Whitehurst, 2002). For instance, Burris et al., (2019) examined several aspects of the HLE and language and early literacy skills of children from 267 low-income families in the US. Measures of the HLE included the number of books at home, the frequency of caregiver and other adults reading to the child, library visits, and parents' familiarity with children's book titles, while outcomes included language skills (expressive and receptive) and emergent literacy skills (print concepts, letter knowledge). Their findings suggest that aspects of the HLE relate differently to components of emergent literacy. Reading frequency did not predict children's letter knowledge but did for children's print concept, despite being both code-related skills. These findings contrast with (Hood et al., 2008; Sénéchal & LeFevre, 2002), which found that informal activities, like shared reading, are not associated with code-related abilities like print concept. They suggest that parents may not just engage in reading alone but also incorporate some formal experiences, like locating a book title, during their reading interactions, which could explain the association. The lack of significant association between reading frequency and letter knowledge may reflect the very low letter-knowledge scores, common in low-income young children. The limited variability in the data can reduce the power to detect true associations. This is particularly

relevant as the current study involves children from low-income families who often exhibit lower literacy levels but large variations in their home literacy experiences.

Earlier studies supported a strong and positive association between the HLE and emergent literacy skills, but some studies have reported a weak or non-significant direct association between HLE indicators and early literacy skills (Baroody & Diamond, 2012; Roberts et al., 2005). The study by Roberts et al., (2005) conducted with 72 African American children ages 3 to 5 attending child care centers and their parents from low-income backgrounds reported that not all specific home literacy activities are associated with language and literacy outcomes, after controlling for maternal (e.g., education and reading skills) and child characteristics (e.g., age). Similar to Storch and Whitehurst (2001), they utilized a wider range of HLE measures that include both quality and quantity of interactions, such as the frequency of book reading, child's interest in reading, an observation of the number of times the mother use book reading strategies (e.g., explaining the plot, making predictions, book concepts, letter-word identification, etc.) and mother's sensitivity during the shared book reading interaction (e.g., showing warmth, encouragement, responsiveness), as well as a global measure of the home environment (i.e. overall quality and responsiveness). Contrary to the findings of Sénéchal and LeFevre (2002) and Storch and Whitehurst (2001), their results indicate that the frequency of book reading and the child's interest in reading were not significantly associated with either language or literacy outcomes. Instead, maternal sensitivity and book-reading strategies were related to children's vocabulary. Additionally, a global measure of the home environment (not specific to literacy practices only) was significantly related to both language and early literacy skills after accounting for the four home literacy practices and covariates. They indicated that a

measure that captures both educational and social aspects of the home environment may have a stronger influence on a child's language and literacy development.

Likewise, Baroody and Diamond (2012) examined the relations in children's literacy interest, the HLE, and code-related emergent literacy skills among preschoolers ages 4- to 5-year-old who were at risk for reading difficulties. In their study, they assessed the HLE using a questionnaire and computed two composite variables – the Active and Passive HLE. Active HLE involves the frequency of reading books to the child, the number of books at home, library visits and the age when shared reading began, whereas the passive HLE includes parent reading habits and interest. Children's outcomes included code-related skills (letter-word knowledge and alphabet knowledge) and the child's literacy interest. They found that literacy interest, but not the HLE, was associated with code-related skills, after controlling for gender, parent education and language skills. Their study suggests that children who show higher interest in literacy activities tend to perform better in code-related skills, however this relation differs in terms of children's level of receptive language, where a weaker association were found in children with lower receptive scores. These findings suggest that child characteristics, such as language and interest, are key factors that may influence emergent literacy acquisition. They posit that weaker language skills limit children's ability and interest to engage in literacy activities due to difficulty understanding instructions or expressing themselves. However, they acknowledge that findings might be influenced by the small sample and the reliability of the HLE measures used.

Recent meta-analyses reviewed the associations between the HLE and aspects of emergent literacy skills using different samples. Castillo-Rabanal and Heitmayer (2025) explored the relations between code-related activities and components of early literacy skills in samples with diverse backgrounds. Their analysis found a significant but small correlation between code-

related HLE activities and overall emergent literacy skills. Correlations with components of early literacy skills, such as letter knowledge, emergent writing, and early reading, likewise showed small correlations. They indicated potential bias attributed to differences in the measures used. Similarly, a meta-analysis conducted by (Nag et al., 2024) involving samples from low to middle-income countries found a significantly positive but near-zero association between home attributes and language and literacy skills (r = .08). Comparing associations of home attributes, books at home and adult literacy practices showed a stronger association with children's language and literacy skills than parental teaching. However, all correlations were weak (below 0.1) and did not differ across different literacy outcomes (e.g., language, emergent literacy). These findings suggest that in samples involving lower socioeconomic status, the influence of the HLE might still exist but is minimal. Thus, even if theories support an association between the HLE and emergent literacy, it is reasonable to expect a small effect size in studies involving a low-income sample.

In summary, there have been inconsistent findings regarding the relationship between the HLE and emergent literacy skills. Despite accumulative evidence revealing that the HLE, either formal and informal activities, are positively related to children's overall early literacy skills (Carroll et al., 2019) and its subcomponents (Burris et al., 2019; Hood et al., 2008; Rodriguez & Tamis-LeMonda, 2011; Sénéchal & LeFevre, 2002; Storch & Whitehurst, 2001; Sylva et al., 2010; Weigel et al., 2006), some studies and meta-analyses reported weak to null associations (Baroody & Diamond, 2012; Castillo-Rabanal & Heitmayer, 2025; Nag et al., 2024; Roberts et al., 2005). These mixed findings justify the need to examine further the effects of the HLE on the emergent literacy construct, particularly in the low-income population, where literacy experiences and skill levels are often disadvantaged. Additionally, the literature highlights that

different HLE activities vary in their strength of influence on emergent literacy, thus examining specific literacy practices can help identify which are more strongly associated with emergent literacy during this period of rapid development. This information can be useful when designing effective early interventions, especially for low-income families facing limited resources.

Associations between the HLE and EF

Executive function develops rapidly during the preschool years, and it is believed that its growth is not only influenced by neurobiological maturation but also by environmental factors (Best & Miller, 2010; Carlson, 2005). Recent evidences support the role of the HLE in the development of EF. Horowitz-Kraus et al.'s (2024) study of 51 children aged 4 to 6 found support that a composite measure of literacy exposure, which includes frequency and quality of shared reading and the number of books at home, was positively correlated with children's EF. They proposed that children's frequent exposure to reading may lead to stronger EF skills. However, their study relied on a parent-reported questionnaire rather than a direct assessment of children's EF. Similarly, Korucu et al.'s (2020) study involving 102 preschool children in the US reported that parent-child literacy interactions were positively related to EF. They argued that structured literacy activities, such as storybook reading, provide opportunities for caregivers to practice children's EF skills (e.g., focus and remember details of the story), which can support children's EF development.

Earlier studies have also found evidence that other aspects of the HLE, such as maternal scaffolding and socioeconomic conditions, influence EF development. In a study of 125 children from disadvantaged families in the UK, Hughes and Ensor (2009) found that several aspects of home environment (family chaos, maternal planning, maternal scaffolding) predicted individual differences in children's EF. Their study argued that family chaos, characterized by disorganized

and unpredictable family routines, negatively affects EF, while maternal scaffolding, where mothers show support during structured and goal-directed activities, was positively associated with EF. These findings suggest that children's EF development is influenced by several environmental factors, including home literacy experiences and broader aspects of the home environment such as parent and family characteristics. However, research examining the contribution of several aspects of the home environment to the development of EF remains limited, underscoring the need for further investigation to explain their relations.

Associations between EF and Emergent Literacy

EF has increasingly gained the interest of many researchers by examining its contributions and predictive relations with emergent academic skills (Blair & Razza, 2007; Ernst et al., 2022; McClelland et al., 2007; Welsh et al., 2010). In the study involving 217 3-4 year old preschoolers from diverse socioeconomic backgrounds in two US states, McClelland et al., (2007) examined whether behavior regulation (involving inhibitory control, attention and working memory) was related to children's pre-academic skills, including emergent literacy skills (measured by Letter-Word identification). Their study found a weak but significant correlation between behavior regulation and emergent literacy, supporting the view that a child's ability to regulate their behavior support acquisition of early literacy skills. However, they noted that the weaker association between behavior regulation and emergent literacy might be attributed to the individual differences in early literacy skills upon preschool entry, suggesting possible influence of home environment in this relation.

Further studies investigated the relations between EF skills and school readiness skills, including emergent literacy in low-income populations (Blair & Razza, 2007; Welsh et al., 2010). For instance, in the study conducted with 164 children attending the Head Start program,

Welsh et al., (2010) path analysis revealed that the EF composite measure (involving working memory and attentional control) was highly correlated with emergent literacy skills during the preschool years and predicted children's reading achievement at kindergarten, indicating the EF provides a foundation for both early and academic skills. However, they noted that due to the limited developmentally appropriate measures for young children, the creation of an EF composite measure prevented them from identifying specific EF skills that might be more related to children's outcomes.

Blair and Razza (2007) examined the role of EF measured in preschool on the kindergarten math and literacy skills among 170 children from low-income homes. They found that teacher-reported effortful control in preschool and inhibitory control in kindergarten was linked to letter knowledge. Their findings noted that inhibitory control, or the ability to inhibit responses and ignore distractions, is an important aspect of EF that uniquely contributes to the emerging abilities of preschool children. However, one limitation they pointed out is that the use of parent and teacher report effortful control measures in preschool rather than direct assessment might have influenced its relations with other constructs. For instance, a teacher's rating of a child's effortful control may have been influenced by the child's academic performance. Furthermore, they reported poor internal consistency on their parent-report EF measure, suggesting that parents may have misinterpreted some items. These measurement issues are limitations that may affect the validity of the findings.

In contrast, a recent study of 92 preschool children aged 4-6 in the US (Ernst et al., 2022) found that an EF composite was associated with children's math skills but not with their literacy performance (letter-word identification) after controlling for age, language skills, IQ, and SES. They suggest that the absence of association for literacy may be attributed to differences in child

characteristics when covariates that are correlated with EF, such as IQ and language, were included in the model. They also pointed out that the literacy assessment used ceiling rules. Children with lower scores may not have reached items involving other literacy skills, such as word knowledge. This limitation may have prevented the measure from detecting specific literacy skills (print vs word knowledge) that may show different associations with EF.

In summary, these inconsistent findings suggest that associations between EF and emergent literacy may be influenced by methodological (e.g., measures) and differences in children's developmental and sociodemographic characteristics (e.g., SES, language, IQ), thus needing further studies to clarify the influences of these factors.

Executive Function as a Mediator

Due to the growing evidence that the EF contributes to emergent literacy development and that EF may be shaped by environmental influences such as the HLE, it is hypothesized that EF might play an important role in the associations between the HLE and emergent literacy outcomes. Several studies have examined the associations among the HLE, EF and emergent literacy. Segers et al. (2016) study examined the individual and combined influences of the HLE and EF on children's literacy and language skills. In their study involving Dutch kindergarteners, they found that both the HLE (measured as parental reading frequency) and EF (measured as attentional and action control and verbal short-term memory) had direct effects on children's phonological awareness and vocabulary skills, but the effect of HLE was reduced when EF was controlled for. Their findings are aligned with (Davidse et al., 2011) where they found that cognitive control (short-term memory, inhibitory control and attention) directly influences literacy outcomes but does not moderate its relationship with the HLE. They indicated that

children benefit from HLE activities, such as book sharing, regardless of the child's level of cognitive control.

Other studies have explored indirect effects of EF on the relations between the HLE and emergent academic skills. A recent study conducted by Korucu et al., (2020) involving 102 preschool children in the US proposed that EF might be an important mechanism linking aspects of the HLE to children's early academic abilities. Their findings indicated that even though the HLE was not directly associated with school readiness skills (e.g., early language, math, general academic skills), it was significantly related to the EF, which then predicted early language, numeracy and general academic skills. Their results showed that the HLE had significant indirect effects on math and general academic skills (e.g., letters, numbers recognition) through EF, but the effects were small. Their findings suggest that parents providing enriching and structured literacy activities such as storybook reading, printing letters, and identifying letters and sounds can support the development of their children's EF, which subsequently can support their school readiness skills. However, they acknowledged that their analysis includes a small sample, which limits generalizability and power to detect direct and indirect effects. Furthermore, they suggested differentiating informal and formal literacy activities as they may have different patterns of association with children's outcomes. Finally, they did not include specific measures of emergent literacy skill, but rather used language and general academic skills (e.g., letter, number, color, shapes recognition). Thus, it remains unclear whether the HLE would exert direct or indirect effects via EF on emergent literacy, a goal the current study aims to address.

However, Devine et al., (2016) found no mediating effects of EF on the relation between the aspects of the HLE (e.g., scaffolding, parent-child interaction, informal learning experiences) and early academic abilities (literacy and numeracy outcomes) in 117 parent-child dyads. Their

findings indicated that HLE demonstrated direct effects, rather than indirect effects through EF, on children's academic skills, which means that parents who engage more in general learning activities (not limited to literacy) tend to have children with better academic skills. Unlike (Korucu et al., 2020), the study did not find a significant relationship between the HLE and EF. However, EF mediated the relations between specific parent behaviors - parental scaffolding and negative parent-child interactions, and academic skills. One important limitation is that they examined overall academic ability using a composite of literacy and numeracy rather than examining each academic domain separately. This approach may have prevented their study from identifying differential effects for literacy versus numeracy. The current study addresses this gap by focusing only on the literacy domain to determine whether a unique association would emerge when emergent literacy is examined independently.

A recent longitudinal study by (Simmons et al., 2023) investigated direct and indirect associations between aspects of the HLE (code-related and meaning-related activities), inhibition, and early reading skills in 274 children followed from preschool (average age = 3) to primary school (average age = 5). Their analysis revealed that code-related home literacy activities (e.g., letter-sound interaction), measured when children were 3, were significantly related to children's early reading skills at age 5. However, code-related HLE with less emphasis on letter-sound association (e.g., letter activities) was not significantly related to later word reading. Additionally, their path analysis revealed that although a significant direct path was found between inhibition (measured at age 4) and early reading skills at age 5, no significant indirect path emerged between the HLE code-related experiences and early reading skills through EF, when language and other cognitive skills were accounted for. They indicated that including other EF components not accounted for, such as shifting and working memory, might

result in a different pattern of associations. The current study extends this research by using a developmentally appropriate EF measure that captures the three core EF processes in preschool children, which allows for a more comprehensive assessment of EF and its relations with HLE and emergent literacy.

In summary, despite limited evidence, research provides partial support for indirect pathways linking the HLE to emergent literacy through EF. These mixed findings emphasize the need for further research to clarify their associations, including the specific role of EF in these relationships.

The Present Study

Although the HLE and emergent literacy skills constructs have been extensively studied, findings regarding their association remain inconsistent. Earlier studies reported positive associations between HLE indicators and children's language and literacy-related outcomes (Burris et al., 2019; Carroll et al., 2019; Hood et al., 2008; Sénéchal & LeFevre, 2002; Storch & Whitehurst, 2001; Sylva et al., 2010; Weigel et al., 2006), whereas other research has documented weak or non-significant associations (Baroody & Diamond, 2012; Roberts et al., 2005). These inconsistencies suggest that the association between these two constructs, HLE and literacy, may be influenced by various factors, such as the characteristics of the sample and how the HLE and emergent literacy constructs are conceptualized and measured. Additionally, only a few studies have explored the potential influence of child characteristics, such as EF, on the relation between HLE and early academic skills (Devine et al., 2016; Korucu et al., 2020; Simmons et al., 2023), as well as their combined and unique contributions (Davidse et al., 2011; Segers et al., 2016) in preschool children from low-income backgrounds. Despite this evidence,

it remains unclear whether HLE is directly associated with literacy outcomes or whether its effects are mediated by children's EF skills.

Guided by Bronfenbrenner's bioecological framework, the current study aims to examine both biological (EF) and environmental factors (HLE) and how they simultaneously influence early literacy development of four-year-old children from low-income families. The present study extends previous studies and contributes to the growing literature by examining the associations among the HLE, EF, and emergent literacy skills simultaneously. Given the mixed findings on the association between the HLE and emergent literacy skills, the study aims to replicate previous studies with a larger sample from the low-income population. Children from low-income families typically are behind their more advantaged peers in pre-academic skills upon school entry, which puts them at a greater risk for later academic difficulties (Brooks-Gunn & Duncan, 1997; Wolf et al., 2017). Exploring their early home experiences at age four may offer insights into how best to prepare them for formal schooling within the home context. Previous studies indicated that a small sample size may have reduced the power to detect associations among constructs (Baroody & Diamond, 2012; Burris et al., 2019; Korucu et al., 2020), thus using a larger sample may increase the chances of detecting meaningful associations between variables. Additionally, the study explores aspects of the HLE to determine differential associations with emergent literacy and EF (Korucu et al., 2020) using developmentally-appropriate measures. Finally, the study adds to the growing evidence on clarifying the role of EF, as an important child characteristic, in the development of emergent literacy within the home literacy context (Devine et al., 2016; Korucu et al., 2020; Simmons et al., 2023).

The specific research questions guiding the present study are as follows:

1. Do HLE activities directly influence emergent literacy?

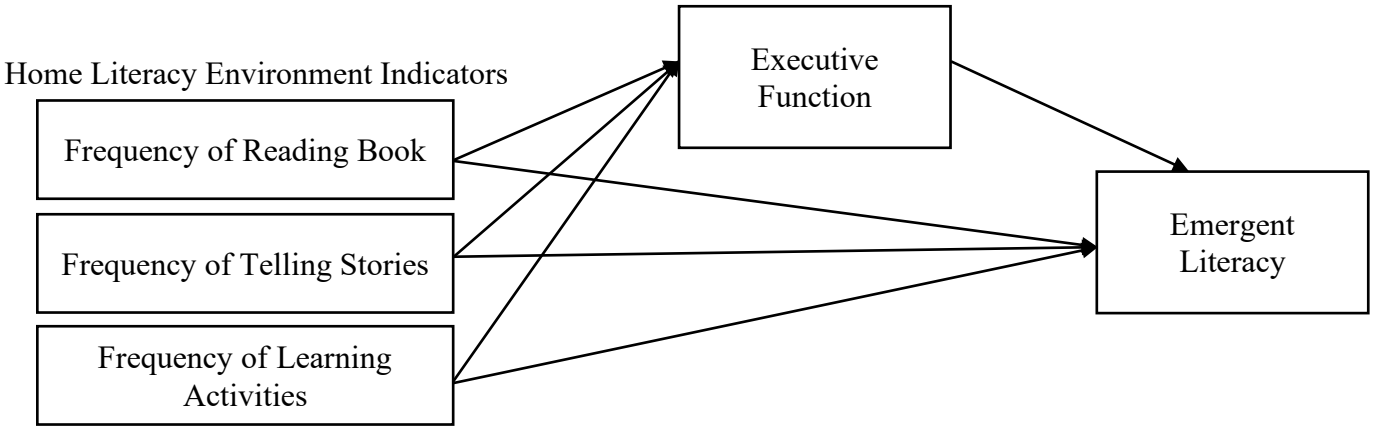
a. Are reading, storytelling, and learning activities differentially associated with emergent literacy?

2. Do HLE activities directly influence EF?
3. Does EF directly influence emergent literacy?
4. Do HLE activities influence emergent literacy indirectly through their effects on EF?

Based on previous studies, it is hypothesized that HLE would be directly related to EF and emergent literacy and that EF would directly influence emergent literacy. Additionally, it is hypothesized that EF may mediate the relation between HLE and emergent literacy.

Figure 1 illustrates the proposed path model. Direct paths were estimated from each HLE indicator to emergent literacy, from each HLE indicator to EF, and from EF to emergent literacy. Then, indirect effects from each HLE indicator to emergent literacy through EF.

Figure 1 Proposed Path Model



Methods

The current study utilized a quantitative, cross-sectional design to examine how the HLE and EF influence emergent literacy skills of four-year-old children from low-income families. Path analysis was used to investigate these associations to provide a more nuanced understanding of their relationships. Path analysis allows for the examination of the unique contribution of each HLE activity (e.g., reading books, telling stories, and learning activities) on the EF and emergent literacy, addressing the first two research questions. At the same time, it will allow for determining whether EF exerts indirect effects on the associations between each HLE activity and emergent literacy.

Data Source

The cross-sectional study used data from the Age-4 follow-up sample of the Baby's First Years (BFY; Noble et al., 2021) project, a large-scale study designed to assess the causal impact of poverty reduction interventions on children's early cognitive, socio-emotional, and brain development among low-income families in the United States. The BFY dataset is publicly available through Interuniversity Consortium for Political and Social Research (ICPSR; see https://clinicaltrials.gov, identifier: NCT03593356, for BFY preregistration). Their study began in 2018 when 1000 low-income mothers and their newborns were recruited from 12 hospitals between May 2018 and June 2019 from four racially and ethnically diverse metropolitan cities in the United States (New York City (NY), New Orleans (LA), Omaha (NE), and the Twin Cities of Minneapolis-Saint Paul (MN)). Participants were found eligible to participate if their reported household income fell below the U.S federal poverty level in the prior year. The BFY study was approved by the Institutional Review Boards (IRBs) of Teachers College at Columbia University, the University of California, Irvine, and the New York State Psychiatric Institute. For

full inclusion criteria, refer to the study's user guide and design (Magnuson et al., 2024; Noble et al., 2021).

Procedure

Data for the age-4 sample were collected between July 2022 and August 2023, coinciding with each child's fourth birthday. At the beginning of the visit, informed consent for participating in the study was obtained. Following consent, mothers and children were separated to complete their assessments and interviews. Measures were administered by trained university site teams. Maternal and child assessments were conducted in person at university lab sites, while maternal interviews were completed either in person or over the phone. Children were accompanied by a trained researcher who administered a series of assessments, including the Minnesota Executive Function Scale (MEFS) to assess executive function, the Receptive One-Word Picture Vocabulary Test (ROWPVT) to measure receptive language, and the Reading House to evaluate pre-literacy skills. Mothers participated in structured interviews and surveys, responding to questions about parent-child activities (e.g., home literacy practices) and other relevant demographic information.

The researcher of the present study sought approval from the University of Victoria's Human Research Ethics Board. The study was found exempt from human research ethics review under the national ethics policy (TCPS2) and the university's ethics policy and guidelines because the dataset is de-identified and accessible in the public domain.

Participants

The Age-4 BFY dataset includes 892 mother-child dyads. The Age 4 sample was selected because the dataset includes measures of several children's developmental outcomes important for school readiness, such as emergent literacy skills and executive function. Moreover, age 4 is

typically the final year before children begin formal schooling as kindergarteners (entrance age to school is 5 in the U.S.; National Center for Education Statistics, n.d.), making it an important period for exploring their home experiences and skills. The Age 4 BFY dataset included children with developmental diagnoses and chronic health (n = 180), which were excluded from the current analysis. Observations without response to either item were also excluded (n=10). In total, 702 children met these criteria, which comprised the analytic sample for the current study.

Figure 2 illustrates the participant retention from the original study participants to the final study sample, including exclusion criteria. Of the original 1000 mother-child dyads, 984 remained eligible at the Age-4 wave. The 16 mother-child dyads were ineligible due to five maternal deaths, five child deaths, two mother-child separations and four maternal incarcerations. During the Age 4 data collection period, 37 mothers refused to be interviewed, four withdrew from the study, and 51 mothers were either unreachable or unavailable for interview, resulting in an Age 4 follow-up sample of 892 mother-child dyads. After adjusting for ineligibility, the response rate for the Age 4 data collection was 91% (Magnuson et al., 2024). For the current study, 180 children whose parents reported either a developmental condition diagnosis or a chronic health diagnosis, and 10 with no response to either question, were also excluded, reducing the study sample to 702 participants.

Figure 2 Participant flow and eligibility determination for the study analysis

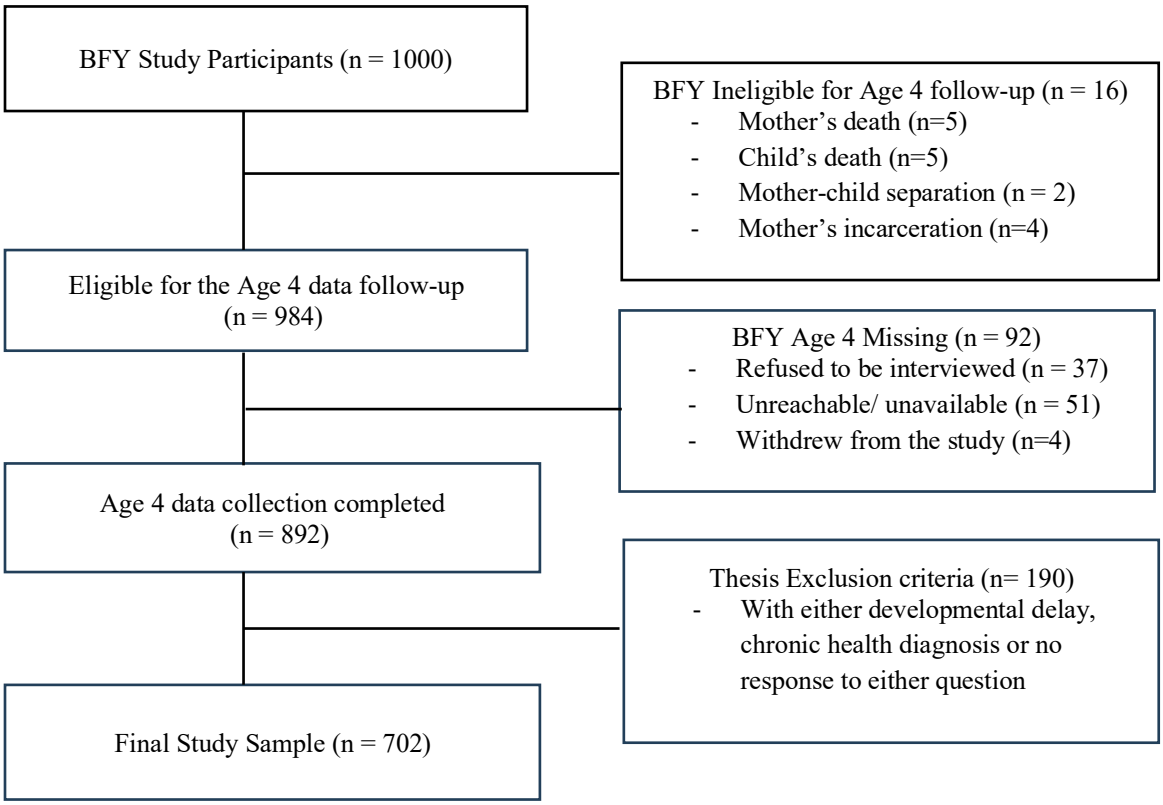


Table 1 summarizes the baseline demographic characteristics of the Age-4 sample (n = 890; Noble et al., 2025). About half of the children are female (49%). On average, mothers were 27 years old at childbirth and completed 11.90 years of schooling, roughly a high school education level. Most of the mothers are not married (45.2%), followed by those who are single but living with a partner (23.6%) and are married (22.1%). The sample is predominantly Black (42.2%) and Hispanic (41.2%), with relatively few White (9.3%) or multiracial (3.7%). In terms of household characteristics, families have an average of 2 children and 2 adults, with 37.6% reporting that children live with their biological father. The average combined household income is $ 21, 847.73, suggesting an economic disadvantage of the sample. The majority of the families (58%) were assigned to the low cash gift group.

Table 1 Baseline Demographic Characteristics of the BFY Age-4 follow-up sample

Characteristics	N/mean	SD
Child is female	0.490	
Maternal Characteristics		
Mother's age at childbirth	27.181	5.880
Mother's education (in years)	11.90	2.843
Marital status		
Never married	0.452	
Single, living with partner	0.236	
Married	0.221	
Divorced/separated	0.039	
Other/unknown	0.052	
Race/ethnicity		
Hispanic	0.412	
White, non-Hispanic	0.093	
Black, non-Hispanic	0.422	
Multiple, non-Hispanic	0.037	
Other or unknown	0.035	
Household Characteristics		
Number of children	2.463	1.405
Number of adults	2.056	0.972
Lives with biological father	0.376	
Household combined income	21847.73	19628.38
Cash gift group		
High cash	.419	
Low cash	.581	

Measures

Several children's developmental outcome measures and maternal survey responses were used from the available Age-4 dataset in the BFY study. Measures used for children's developmental outcomes were validated and standardized (Noble et al., 2025).

Emergent Literacy Skills. Emergent literacy, the outcome variable for the study, was measured using The Reading House Assessment (Hutton et al., 2019). This is a children's book designed to screen and measure the emergent literacy skills of 3–4-year-olds. It assessed print knowledge/concepts, alphabet and letter-sound knowledge, phonological awareness (alliteration,

rhyming, syllable blending), expressive vocabulary, and emergent writing. In this assessment, children were shown The Reading House board book and were asked questions to assess each component of early literacy skills using a 9-item, scripted scoring form. Scores for each item were added to create the raw score, ranging from 0 to 14. Based on the Reading House scoring form for 4-year-olds, a total score of 4 or lower indicates below average, suggesting at-risk emergent literacy skills, while a score between 5-10 indicates average, and 11 or higher indicates an above-average emergent literacy level. The raw score was used for the descriptive reporting, but the standardized scores, with a mean of 0 and standard deviation of 1, available in the dataset were used for the main analysis. Internal consistency for the measure is $\alpha = .68$, which the developer described as good for a newly developed measure. While this value falls below standard benchmarks for an acceptable reliability (0.70), coefficients in this range can be acceptable for early-stage measures (Hutton et al., 2019). There were 84 missing cases for this variable.

Executive Function. EF was measured using the Minnesota Executive Function Scale (MEFS; Carlson, 2017). MEFS is a standardized direct child assessment of EF skills, intended for children ages 2 and older. It is designed to be adaptive, child-friendly and efficient to administer using an iPad or tablet, which takes only between 2 to 7 minutes to finish. It assesses core EF skills, such as working memory, inhibitory control and cognitive flexibility in one brief, composite measure. The MEFS generated age-standardized, norm-referenced standard scores with a population average of 100 and a standard deviation of 15. Standardized scores, with a mean of 0 and a standard deviation of 1, are included in the dataset and used for the main analysis. MEFS has been proven to be a valid measure of EF in preschool and kindergarten

children. It has a validity of .92 and a test-retest reliability of .93, indicating high reliability and validity (Carlson, 2017; Magnuson et al., 2024). There were 69 missing cases for this variable.

Home Literacy Environment. Mothers answered multiple questions regarding the number of days in a week they engage in activities with their children. For the current study, the HLE was measured by the frequency of literacy-related activities between the mother and focal child. Variables related to literacy activities include reading books, telling stories, and learning activities (e.g., learning numbers, letters, colors, shapes; Rodriguez & Tamis-LeMonda, 2011). The frequency of parent-child literacy activities was measured by asking how many days in the past week the mother and child engaged in each activity on a four-point scale: (1) No days, (2) 1-2 days, (3) 3-5 days, (4) 6-7 days. Each response was then converted in the following manner: "No days" is 0, "1-2 days" is 1.5 days, "3-5 days" is 4, and "6-7 days" is 6.5 (Magnuson et al., 2024). The descriptive statistics report the frequency in its raw scores (average number of days per week), but for the main analysis, each score was standardized, with a mean of 0 and a standard deviation of 1. See Appendix A for parent-child literacy activities survey questions. There were 2 missing scores for the frequency of reading books and telling stories, and 3 missing scores for the frequency of learning activities.

A Cronbach analysis was conducted for the three HLE activities, resulting in an alpha coefficient of .63, which is below the acceptable threshold of .70. This indicates a low reliability for the HLE composite measure. Dropping any of the items would also result in a slightly lower coefficient. Despite the low reliability of the HLE composite, a supplementary analysis was conducted to examine whether it would yield stronger associations with emergent literacy than the individual literacy activities examined separately.

Covariates. Four covariates were included in the analytic model to account for their potential confounding influences on the main study variables. Covariates were included in both the mediator (EF) and outcome (emergent literacy) models to statistically control for their influences and isolate the unique effects of the HLE (Hayes, 2013).

Treatment group. In the original BFY study, participants were randomly assigned to two groups – high cash gift and a low cash gift. Since the original study's design is experimental, it is important to account for the possible effects of the differences in the monetary intervention received by the sample. Therefore, the treatment group variable was added as a covariate.

Gender. Gender was included as a covariate because of its association with both emergent literacy outcome and EF. Prior research determined that there were gender differences in early literacy skills among children from high-poverty households, with girls outperforming boys (Lee & Al Otaiba, 2015). Additionally, gender differences were found in children's engagement with literacy activities (e.g., boys engage less in letter-related behavior than girls; Deasley et al., 2018). Gender differences in early self-regulation skills were also found, with girls exhibiting stronger performance than boys (Matthews et al., 2009). Therefore, controlling for gender would allow for a more precise estimation of the effects of the predictor variables when gender differences are accounted for.

Language. Language ability was included as an important covariate because of its strong association with both EF (Fuhs & Day, 2011) and emergent literacy skills (Sénéchal et al., 2001; Storch & Whitehurst, 2002). Receptive vocabulary was measured using the Receptive One Word Picture Vocabulary (ROWPVT, Martin & Brownell, 2011). Controlling for language ability can isolate the effects of HLE and EF on the emergent literacy outcome. It also allows for the examination of EF as a mediator above and beyond the language ability. Without controlling for

language, associations among key variables may reflect differences in language skills rather than the unique contribution of home literacy exposure or EF. Standardized scores were used for the analysis, with a mean of 0 and a standard deviation of 1. There were 131 missing cases for this variable.

Data Preparation

The Age-4 dataset from the BFY study was de-identified by the BFY research team. Since the dataset is publicly accessible, researchers can access and use the data without obtaining special permissions. Due to proprietary restrictions on several child assessments, such as The Reading House (TRH), Minnesota Executive Function Scale (MEFS), and ROWPVT, raw item-level data were not available in the dataset, which limits the researcher's ability to examine the specific components of emergent literacy skills and EF in greater depth. The present study relied only on the composite scores for each assessment.

Additionally, certain key demographic variables were not available in the Age-4 data file. For instance, children's age in months was not available as a potential identifier. Instead, it was recoded as a binary variable based on whether the child was assessed under four years old. However, the binary age variable was not used in the current study because age is typically treated as a continuous variable in studies involving child development. Other baseline demographic information, such as race/ethnicity, marital status, and maternal education, reported in the descriptive table 1 was drawn from the baseline data, as these variables were not available in the Age 4 dataset. These variables were not included in the main analyses and are presented for descriptive purposes only.

Power Analysis

A priori power analysis was conducted using the semPower package (Moshagen & Bader, 2024) in R to determine the required sample size for detecting indirect effects in a simple

mediation model. Hypothesized path coefficients specified in the model were: predictor to mediator (a) = 0.20, mediator to outcome (b) = 0.20, and predictor to outcome (c') = 0.10, to detect a small indirect effect (a*b). These hypothesized coefficients are based on previous literature. Korucu et al., (2020) found a small but significant effect (β = .20) between the HLE and EF. Ernst et al., (2022) found a small but significant correlation (r = .24) between MEFS, an EF measure, and emergent literacy (measured by Letter-Word Identification), but they did not find significant effects when using the EF composite, when covariates were controlled for. For the direct effects between the HLE and emergent literacy, a recent meta-analysis by (Nag et al., 2024) reported a positive, significant, but near-zero (r = .08) association between the two constructs. Finally, for the indirect effects, Korucu et al., (2020) found a small but significant indirect effect between the HLE and general academic skills (β = .09). However, in the longitudinal study by (Simmons et al., 2023), no significant indirect path (β = .01) emerged between code-related HLE and early word reading skills. The null hypothesis was no indirect effect at the significance level of 0.05 and desired power of 0.80. The results indicated that at least 192 observations are required to detect a small mediation effect. Adjusting the desired power to .99, the results indicated that at least 452 samples are required. Since the current study has 702 participants, the study is adequately powered to detect a small indirect effect.

Missing Data Analysis

Patterns of missingness were examined prior to conducting the main analysis. Missing data were minimal for the three HLE predictors, ranging from 0.28% to 0.42%. In contrast, higher rates of missing data were observed for EF (9.83%) and for the emergent literacy outcome measure (11.97%). To determine whether the data were missing completely at random (MCAR), Little's MCAR test was conducted using the naniar package in R (Tierney & Cook, 2023). The test included the three HLE indicators, EF, emergent literacy, and control variables, such as

gender, treatment group, maternal work status, and child language. Little's MCAR test was statistically significant (p-value < 0.05), indicating that the missingness pattern was not consistent with MCAR and missingness may depend on observed variables (MAR) or unobserved variables (MNAR).

To assess the likelihood of the MAR assumption, logistic regression was conducted in R to examine whether missingness was related to the study variables (Acock, 2012). Indicator variables were created for each variable with missing values (1 = missing, 0 = not missing). All measured variables (the 3 HLE indicators, emergent literacy, EF, and 4 covariates) were included in the analysis to help explain the missingness of the indicator variable. Results show that EF predicted the missingness of emergent literacy (b = -0.42, p = .047), suggesting that children with higher EF scores are less likely to have missing data on emergent literacy. However, none of the study variables explained the missingness of EF, even after adding auxiliary variables (e.g., site, child health index, binary age variable) from the original dataset. These results suggest that the missingness is likely MAR, although it is possible that other variables not measured may account for the missing values. Despite the uncertainty of meeting the MAR assumption, using modern methods such as the Full Information Maximum Likelihood (FIML) may help reduce bias when there is some missing data.

Table 2 MCAR test results

statistic	Df	p-value	Missing patterns
146.2925	104	0.003981166	17

Data Analysis

The primary aim of the study was to examine the direct and indirect associations among the home literacy environment (HLE), executive function (EF), and emergent literacy skills. Path analysis was selected to test these associations because it allows for the simultaneous estimation of the direct and indirect effects among observed variables and provides a framework for testing mediation (Kline, 2011). This approach aligns with the study's goal of identifying patterns of association and specific literacy experiences linked to emergent literacy and EF and to clarifying EF's role in these relations.

EF and emergent literacy were modelled as observed variables because each was measured using a single composite score (the MEFS composite score for EF and the Reading House composite score for emergent literacy). Although a single-indicator latent variable can be created by fixing measurement error variances based on reliability estimates, this approach requires a strong assumption of the stability of the reliability estimates (Kline, 2011). The MEFS reported a strong test-retest reliability ($r = 0.93$; Carlson, 2017), but The Reading House is a relatively new measure that has a moderate internal consistency ($r = 0.68$; Hutton et al., 2019), making it less suitable for modelling as a single-indicator latent construct. Although the HLE could be estimated as a latent variable, the present study treated its three indicators - frequency of reading, telling stories, and learning activities - as separate observed predictors. This decision aligns with the conceptualization of HLE as a multidimensional construct, and it allows the model to estimate the unique and combined contributions of each literacy activity to EF and emergent literacy. An additional analysis was conducted using the HLE composite created by averaging the three HLE activities for comparison with individual literacy practices.

Mediation analysis is a statistical technique that allows for estimating the effect of a predictor on an outcome that is transmitted through a mediator (Hayes, 2013). This approach was used in the study to test whether the effect of each HLE activity on emergent literacy operated indirectly through EF. There are two paths: a direct pathway from the predictor (HLE) to the outcome (emergent literacy) and an indirect pathway from the predictor (HLE) to the mediator (EF), which in turn influences the outcome (emergent literacy). The indirect effects were calculated as the product (a*b) of the path from predictor to mediator (path a) and the path from mediator to outcome (path b). The total effect is the sum of the direct effect and the indirect effect. Modern mediation analysis no longer requires a significant direct effect between the predictor and outcome to test for mediation (Hayes, 2013).

Direct and indirect effects were estimated using the lavaan package in R version 4.5.2 (2025) using maximum likelihood estimation with bias-corrected bootstrapping (5000 bootstrap samples and 95% confidence intervals). Maximum likelihood (ML) is a statistical technique that estimates values of the parameters, such as path coefficients, variances and covariances, that make the observed data most probable given a specified model (Kline, 2011). Because several variables in the study have non-normal distribution, standard errors and confidence intervals were calculated using nonparametric bootstrapping, which generates sampling distributions through repeated sampling with replacement. Bootstrapping is widely used and recommended for mediation analysis because indirect effects are typically non-normal, and it does not assume normality of the sampling distribution (Hayes, 2013; Preacher & Hayes, 2004).

Missing data were handled using full information maximum likelihood (FIML), which uses all available information for estimation without deleting cases or imputing values. FIML produces unbiased parameter estimates under MAR assumptions, calculated from all available

data. It is widely used for structural equation modelling, including path analysis (Acock, 2012; Kline, 2011). Additionally, FIML is built in the lavaan package (Rosseel, 2012), making it an efficient and appropriate choice for the present study.

The specified path models in the study were just-identified (0 degrees of freedom) models, resulting in a saturated model that fits the data perfectly by definition. However, because just-identified models do not provide informative global model fit indices or allow for model-level hypothesis testing, the results focused on interpreting parameter estimates and their statistical significance. All coefficients were reported as standardized estimates, which provide information on the strength of influence for each path. Each path coefficient represents the independent influence of the predictor on the outcome, taking into account all other variables in the model. Two models were estimated, one with individual HLE activities and one using the HLE composite, for comparison. Covariates, such as child gender, language, treatment group, and maternal work hours, were in both EF and emergent literacy equations. The three HLE predictors were allowed to covary to account for shared variance.

The current study utilized cross-sectional data, which analyzed concurrent associations rather than establishing causal relations. Causal relations require longitudinal or experimental designs, which are beyond the scope of this study (Streiner, 2005).

Results

Preliminary Analysis

Descriptive statistics (means or frequencies, standard deviation, minimum, maximum, skew, and kurtosis) and bivariate correlations were computed for all analysis variables and are reported in Tables 3 and 4, respectively.

Table 3 Descriptive Statistics (n = 702)

Variables	M/%	SD	Min	Max	Skew	Kurtosis	missing
Gender (% female)	54.3%	.499	0	1	-.171	-1.973	0
Treatment Group (% High Cash Gift)	40.9%	.492	0	1	.370	-1.866	0
Maternal Work (hours per week)	23.35	22.31	0	144	.747	1.184	80
Language (ROWPVT)	.087	.908	-2.48	3.50	-0.24	0.768	131
Executive function	.069	.937	-3.16	1.90	-1.56	3.807	69
Emergent literacy	3.00	2.24	0	12	1.096	1.257	84
HLE Composite (days per week)	3.32	1.55	0	6.5	0.103	-0.545	3
Frequency of reading books (days per week)	2.93	1.83	0	6.5	0.428	-0.720	2
Frequency of telling stories (days per week)	2.79	2.23	0	6.5	0.473	-1.067	2
Frequency of learning activities (days per week)	4.24	2.07	0	6.5	-0.415	-0.958	3

Note: Language and Executive Function are reported as standardized scores with a mean of 0 and an SD of 1, while the emergent literacy, HLE activities, and work hours are reported as raw units for descriptive reporting. For the main analyses, all variables were standardized to put them on the same metric.

The majority of the study sample are female and in the low cash gift group. On average, mothers work 23 hours per week. In general, mothers engage in HLE activities about three days

per week, with learning activities happening more frequently (four days) than reading books and telling stories, with approximately three days per week. Children, on average, scored three out of 12 on the emergent literacy assessment, suggesting that most of them scored below average based on the Reading House assessment scoring interpretation. Children's language and executive function scores were close to the average of the sample. Visual inspections of the histogram and distribution indices, such as kurtosis and skew, indicated that the emergent literacy variable is positively skewed, suggesting that most children scored below the mean, and EF is slightly negatively skewed, suggesting that most children scored at or above the mean. These indicate that some variables slightly deviated from normality. Because non-normality can bias Pearson correlations, bivariate associations were examined using Spearman's rho, a non-parametric test appropriate for skewed or kurtotic variables.

Table 4 Bivariate Correlations between variables

Variables	1	2	3	4	5	6	7	8	9
1. Gender	1								
2. Treatment Group	.02	1							
3. Work Hours	-.04	-.04	1						
4. Language	.08	-.05	.15***	1					
5. Emergent literacy	.07	-.03	.07	.53***	1				
6. Executive function	.03	.04	.08*	.32***	.31***	1			
7. Frequency of reading books	.05	0.08*	-.05	.08	.06	.06	1		

8. Frequency of telling stories	.05	0.02	.02	.02	-.01	.002	.44***	1	
9. Frequency of learning activities	-.03	0.04	.04	.05	-.004	.02	.31***	.31***	1
10. HLE Composite	.03	.06	-.003	.07	.03	.03	.79***	.74***	0.70***

Note: Bivariate correlations are reported as Spearman's rho correlation coefficients
* < .05; ** p < .01; *** p <.001

Bivariate correlations show a moderately significant positive relationship between emergent literacy and EF (r = .31), indicating that children with higher EF were associated with better emergent literacy scores. Correlations among the three HLE activities ranged from .31 to .44, indicating that the three literacy activities are significantly related to each other. Frequency of reading books and telling stories showed a stronger relationship with each other (r = .44) than with learning activities (r = .31). The three home literacy activities, reading books (r = .06), telling stories (r = -.01), and learning activities (r = -.004), showed near-zero and non-significant correlation with emergent literacy. Likewise, EF indicated a near-zero, non-significant relationship with the three home literacy activities - reading books (r = .06), telling stories (r = .002), and learning activities (r = .02). Similarly, the HLE composite showed a very small, non-significant relationship with both the emergent literacy (r = .03) and EF skills (r = .03). The very small and non-significant correlations suggests that the HLE is not associated with emergent literacy and EF at a bivariate level. Although theories and empirical evidence suggest that the HLE, through shared reading or learning activities, may influence emergent literacy directly or indirectly via EF, the resulting near-zero correlations suggest that direct and indirect effects are likely to be small. Even though HLE appeared to be weakly related to both children's outcomes

(EF and emergent literacy), the study analyzed HLE activities as predictors in the path model to test whether its effects might emerge through an indirect pathway via EF.

In terms of the covariates, as expected, children's language is strongly related to emergent literacy skills (r = .53) and moderately to EF (r = .32) but not to any HLE measures. The relationship between emergent literacy and language is theoretically and empirically supported, as children with stronger language skills also show better early literacy skills (Sénéchal et al., 2001; Storch & Whitehurst, 2002). Moreover, evidence links EF and language skills (Fuhs & Day, 2011). Therefore, the study controlled for language to isolate the effects of HLE and EF on emergent literacy.

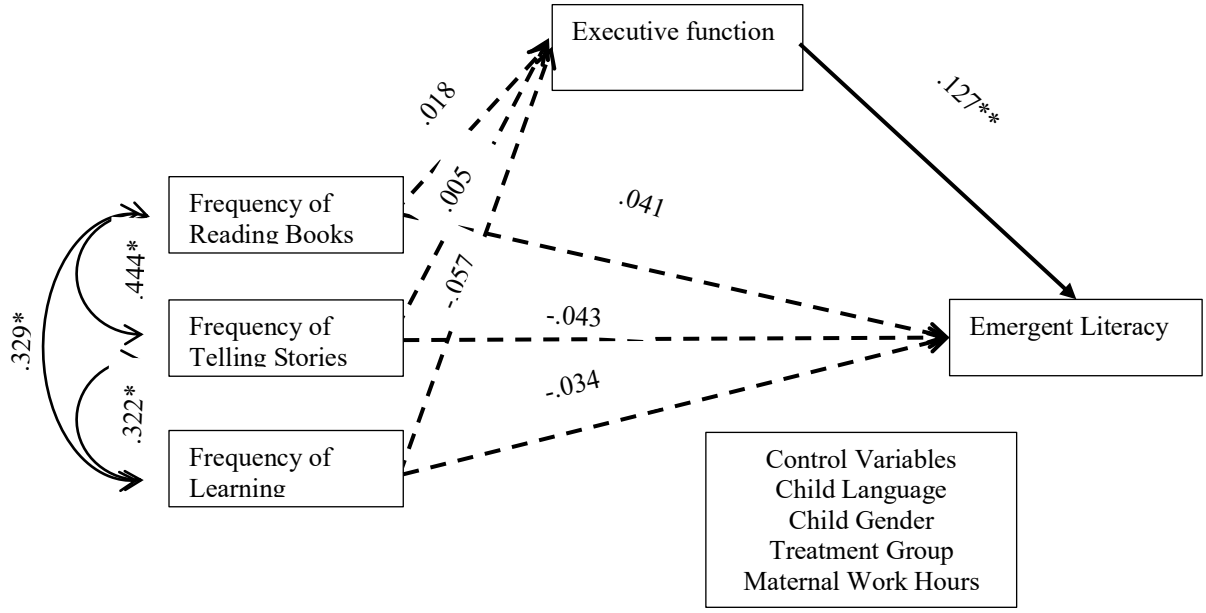
Gender showed no significant relations with any of the variables, suggesting it is unlikely to act as a confounder when estimating path models. However, because prior studies documented gender differences in early literacy skills (Lee & Al Otaiba, 2015) and EF (Matthews et al., 2009), the study included gender as a control. Mother's total work hours were significantly associated with EF and language, and the treatment group was associated with the frequency of reading books. The treatment group was included as a control mainly due to the experimental design of the original study (Noble et al., 2021), to account for differences in children's home environment and children's outcome as a result of the monetary intervention.

Path Analysis

Path analysis was conducted to assess the direct and indirect associations among the three home literacy activities – frequency of reading books, telling stories, and learning activities, executive function, and emergent literacy skills among four-year-old children from low-income families. Associations were also explored for the HLE composite. Figure 3 presents the path

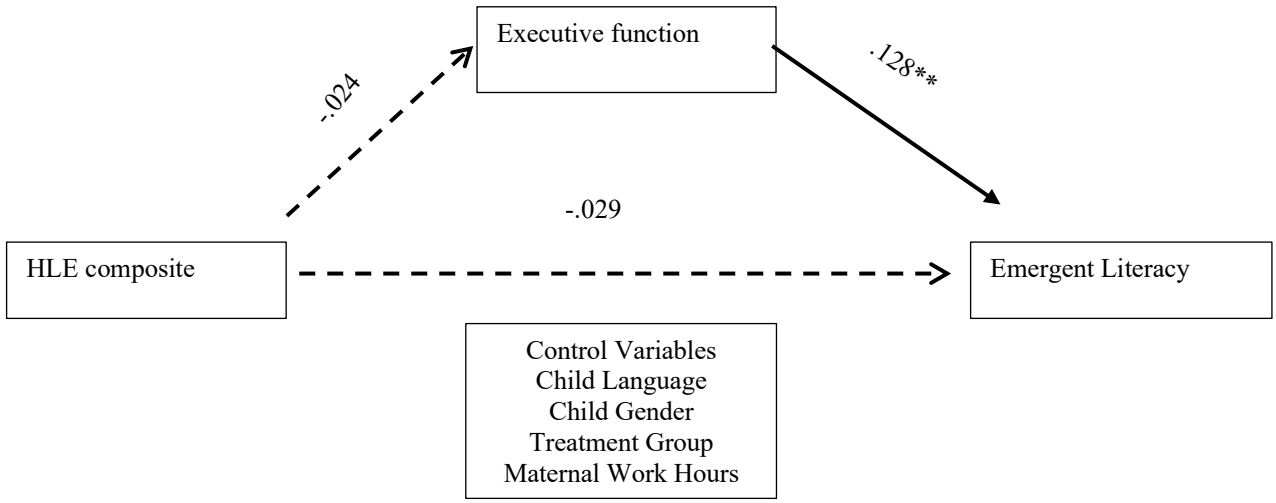
model that includes the disaggregated HLE activities, while Figure 4 illustrates the path model for the HLE composite. All paths include the standardized coefficients.

Figure 3 Path Model for the three HLE activities



Note. Path model for direct and indirect associations between HLE activities and emergent literacy. Solid lines represent significant paths while dotted lines represent nonsignificant paths. All paths include standardized coefficients.

Figure 4 Path Model for HLE composite



Direct Associations between HLE and Emergent Literacy

Regression results in Table 5 show that none of the HLE activities were significantly related to children's emergent literacy skills, after controlling for child gender, language, maternal work status, and treatment group. The standardized coefficients for frequency of reading books (β = 0.041, SE = 0.042, p = 0.321, 95% CI [-0.040, 0.122]), telling stories (β = -0.043, SE = 0.042, p = 0.302, 95% CI [-0.126, 0.042]), and engaging in learning activities (β = -0.034, SE = 0.040, p = 0.389, 95% CI [-0.113, 0.042])) were all very small and nonsignificant. These results indicate that HLE activities have a very small, negligible direct effect on children's emergent literacy skills in this sample. The model explained 26.1% of the variance in emergent literacy (R^2 = .261), with most of the variance explained by language and EF.

Likewise, as shown in Table 8, a separate analysis conducted using the HLE composite resulted in a very small non-significant effect on emergent literacy (β = -0.029, SE = 0.035, p = 0.407, 95% CI [-0.099, 0.039]) and the model explaining 25.8% of the variance, slightly lower compared to the model with separate HLE activities. Although there were no significant associations found between HLE and emergent literacy skills, indirect effects could still be tested when the effect size is small.

Table 5 Standardized direct effect coefficients

	Executive Function				Emergent Literacy			
Predictors	ß	SE	p	CI	ß	SE	p	CI
Reading books	.018	.041	.673	-0.067, 0.098	0.041	0.042	0.321	-0.040, 0.122
Telling Stories	.005	.040	.900	-0.072, 0.083	-0.043	0.042	0.302	-0.126, 0.042
Learning Activities	-.057	.038	.133	-0.132, 0.018	-0.034	0.040	0.389	-0.113, 0.042
EF	-	-	-	-	0.127	0.047	0.007	0.032, 0.215
Language	.371	.048	.000	0.277, 0.467	0.494	0.052	0.000	0.395, 0.600
Child Gender	.131	.071	.065	-0.007, 0.274	0.054	0.070	0.445	-0.082, 0.193
Work Hours	.044	.034	.195	-0.022, 0.108	-0.034	0.038	0.505	-0.175, 0.107
Treatment Group	.123	.072	.090	-0.020, 0.263	-0.025	0.072	0.641	-0.098, 0.050
			R^2 = .149				R^2 = .261	

Direct Associations between HLE and EF

Similarly, none of the HLE indicators were significantly related to EF, after controlling for child gender, language, maternal work hours, and treatment group, as shown in Table 5. The standardized coefficients for frequency of reading books (β = 0.018, SE = 0.041, p = 0.673, 95% CI [0.067, 0.098]), frequency of telling stories (β = 0.005, SE = 0.040, p = 0.900, 95% CI [-0.072, 0.083]), and frequency of learning activities (β =-0.057, SE = 0.038, p = 0.133, 95% CI [-0.132, 0.018]) were very small and not significant. The model accounts for 14.9% of the variance in EF (R^2 = .149), largely explained by language. Similarly, the HLE composite resulted in a very small, nonsignificant effect on EF (β = -0.024, SE = 0.036, p = 0.495, 95% CI [-0.095,

0.044]) with 14.6% of the variance explained by the HLE composite, slightly lower than the other model. The results suggest that HLE activities have very small, negligible direct effects on children's EF.

Direct Associations between EF and Emergent Literacy

On the other hand, EF was significantly associated with emergent literacy after controlling for child gender, language, maternal work hours, and treatment group. The standardized coefficient for executive function (β = 0.127, SE = 0.047, p = 0.007, 95% CI [0.032, 0.215]) was statistically significant. Likewise, the unique relations between EF and emergent literacy are significant in the HLE composite model. This result suggests that EF has a small and significant direct effect on children's emergent literacy skills.

Associations with Covariates

Among the four covariates, language was strongly uniquely related to emergent literacy (β = 0.494, SE = 0.052, p = 0.000, 95% [0.395, 0.600]) and EF (β = 0.371, SE = 0.048, p = 0.000, 95% [0.277, 0.467]). These findings suggest that language has moderate direct effects on both outcomes, but its influence is higher on emergent literacy than on EF.

Indirect Association: EF as a Mediator

A simple mediation analysis was conducted using the lavaan package in R to examine the indirect influence of HLE on emergent literacy through its effects on children's EF. Standardized coefficients for indirect effects are presented in Table 6, and coefficients for the total effect are displayed in Table 7. Additionally, standardized coefficients for indirect and total effects using the HLE composite are presented in Table 8. Results show that HLE activities, such as reading books, telling stories, and learning activities, did not yield a significant indirect effect on emergent literacy through EF. A bias-corrected bootstrap confidence interval for the indirect

effect based on 5000 bootstrap samples included zero for each HLE activity, reading books (β = 0.002, SE = 0.006, p = 0.698, 95% [-0.009, 0.015]), telling stories (β = 0.001, SE = 0.005, p = 0.906, 95% [-0.010, 0.012]), and learning activities (β = -0.007, SE = 0.006, p = 0.202, 95% [-0.020, 0.002]). All coefficients show very small positive effects, except for learning activities, but all are nonsignificant. As a result, there is no evidence that HLE activities influenced emergent literacy through EF. Moreover, there was no evidence that HLE activities influence emergent literacy independent of its effect on EF, reading books (β = .044, SE = 0.043, p = 0.305, 95% [-0.039, 0.126]), telling stories (β = -.043, SE = 0.043, p = 0.319, [-0.126, 0.043]), and learning activities (β = -.041, SE = 0.040, p = 0.300, [-0.120, 0.036]).

The results for the HLE composite are similar to the individual HLE activities model, showing very small negative and nonsignificant indirect (β = -.003, SE = 0.005, p = 0.523, 95% [-0.014, 0.006]), and total effects (β = -.032, SE = 0.036, p = 0.365, 95% [-0.104, 0.037]), on emergent literacy.

Table 6 Standardized indirect effect coefficients

Predictor – Mediator - Outcome	ß	SE	p-value	CI
Reading Books – EF – Emergent Literacy	.002	.006	.698	-0.009, 0.015
Telling Stories – EF – Emergent Literacy	.001	.005	.906	-0.010, 0.012
Learning Activities – EF – Emergent Lit	-.007	.006	.202	-0.020, 0.002

Table 7 Standardized total effect coefficients

Predictor – Mediator - Outcome	ß	SE	p-value	CI
Reading Books – EF – Emergent Literacy	.044	.043	.305	-0.039, 0.126
Telling Stories – EF – Emergent Literacy	-.043	.043	.319	-0.126, 0.043
Learning Activities – EF – Emergent Lit	-.041	.040	.300	-0.120, 0.036

Table 8 Direct, indirect, and total standardized effect coefficients (HLE composite)

	Executive Function				Emergent Literacy			
	ß	SE	p	CI	ß	SE	p	CI
Direct Effect								
HLE Composite	-.024	.036	.495	-0.095, 0.044	-.029	.035	.407	-0.099, 0.039
EF	-	-	-	-	.128	.047	.006	0.034, 0.218
Language	.370	.047	.000	0.276, 0.464	.497	.052	.000	0.398, 0.603
Gender	.137	.071	.054	0.001, 0.281	.056	.071	.427	-0.080, 0.197
Treatment group	.125	.071	.080	-0.016, 0.262	-.027	.072	.708	-0.168, 0.112
Work Hours	.042	.034	.221	-0.025, 0.107	-.028	.038	.451	-0.102, 0.047
			R^2 = .146				R^2 = .258	
Indirect Effect					-.003	.005	.523	-0.014, 0.006
Total Effect					-.032	.036	.365	-0.104, 0.037

Discussion

The present study examined the HLE activities and their associations with emergent literacy skills in children aged four years old from low-income families. The study extends prior studies and contributes to the literature by 1) examining the simultaneous influence of contextual factors (HLE) and child characteristics (EF) on children's emergent literacy skills using a larger sample from low-income population, 2) by clarifying the hypothesized mediating role of EF in the relations between the HLE and emergent literacy skills (Devine et al., 2016; Korucu et al., 2020; Simmons et al., 2023), and 3) disentangling aspects of the HLE, that is to consider code-related (e.g., learning activities involving letters, numbers) and meaning-related activities (e.g., reading books, storytelling) separately and determine their unique associations with EF and emergent literacy skills (Korucu et al., 2020; Simmons et al., 2023). The next section discusses findings in relation to each research question and the implications and limitations of the study.

Direct Effects: HLE and Emergent Literacy

First, the study examined whether HLE activities have direct effects on emergent literacy. The current results revealed a very small, nonsignificant effect of the HLE activities on the overall emergent literacy scores. Likewise, the HLE composite resulted in a near-zero, nonsignificant influence on both EF and emergent literacy composites. The results are consistent with (Baroody & Diamond, 2012; Korucu et al., 2020; Roberts et al., 2005) but contrary to (Burris et al., 2019; Hood et al., 2008; Rodriguez & Tamis-LeMonda, 2011; Sénéchal & LeFevre, 2002; Sylva et al., 2010; Weigel et al., 2006). Possible explanations for the inconsistency of findings are the differences in the conceptualizations and measurements of the HLE and emergent literacy constructs, as well as the characteristics of the sample in the study.

Previous studies that found significant associations either distinguished individual emergent literacy skills (Burris et al., 2019; Hood et al., 2008; Weigel et al., 2006) or categorized (Rodriguez & Tamis-LeMonda, 2011; Sénéchal & LeFevre, 2002; Sylva et al., 2010) into code-related skills (e.g., concepts, letter names) and oral language skills (e.g., expressive, receptive vocabulary), rather than using an overall emergent literacy score. These differences in the way emergent literacy is operationalized resulted in different associations with the home literacy environment. For instance, Burris et al. (2019) found that only print concepts, not letter names, were associated with the frequency of reading, even though both skills are considered code-related skills. Although studies suggest that reading books is more related to language skills than code skills, they noted that parents may be embedding some code-related instruction during reading activities (e.g., location of book title), thus resulting in a unique relation between reading frequency and print knowledge. Mothers in the current sample reported engaging in informal activities, such as shared reading or general letter activities, but possibly did not target letter-sounds knowledge and phonological awareness skills (e.g., rhyming, syllable blending) that were assessed by The Reading House measure. This suggests a possible mismatch between the home literacy experiences and the emergent literacy competencies assessed by the emergent literacy measure, providing a possible explanation for the absence of a significant association in the study. Due to the limitation of using secondary data, the current study could not isolate emergent literacy subskills to check for associations with each literacy activity and possibly detect unique patterns that may not be possible when using a composite score.

Differences in how the HLE is conceptualized and measured may also result in different patterns of associations with emergent literacy. Simmons et al. (2023) study found that more formal code-related activities (e.g., letter-sound interaction) which highlight grapheme-phoneme

correspondence (GPC), significantly predicted phonological awareness among 4-year-olds, but less formal code-related activities (e.g., letter activities) that did not emphasize GPC were unrelated to phonological awareness. Prior studies (Sénéchal & LeFevre, 2002; Storch & Whitehurst, 2002) argued that code-related activities can support components of emergent literacy, such as phonological awareness, print concepts, or letter-sound knowledge, but explicit and intentional instruction is often necessary to see improvement on these skills. In contrast, meaning-related activities tend to be more strongly linked to oral language skills (e.g., vocabulary) than with code-related skills. For instance, storytelling is an example of an informal, meaning-related activity that is often linked to oral language skills, while reading books is also considered a form of meaning-related activity but may involve both print (e.g., having books with letters and words) and language (e.g., a parent reading aloud), possibly targeting more emergent literacy skills than simple storytelling. However, because the current measure captures only frequency with generic questions about the activity and no observation was conducted, the qualitative aspect (content and quality of interactions), could not be determined to explain associations in depth. These findings suggest that the variation in the home literacy experiences may result in differential relations with emergent literacy skills. However, since current results were non-significant, these effects may not be that meaningful to explain variations in the emergent literacy skills.

A study (Carroll et al., 2019) that found a significant association using a composite emergent literacy also differed from the current study in terms of the literacy components measured, the use of a broader range of home learning activities, and the involvement of children from middle to upper-income families. Additionally, their sample included children between 4 and 5 years old who were older than the current sample. Older children may have been more

exposed to literacy experiences through the years or attendance at preschool and thus may have higher literacy skills than children who have just turned four. Also, their sample mostly came from more advantaged families with parents who have higher education and income. Studies show that children from higher socioeconomic status tend to perform better on several cognitive abilities and school achievement outcomes (e.g., literacy skills) than their less advantaged peers (Brooks-Gunn & Duncan, 1997; Wolf et al., 2017). Thus, the extent of association between the HLE and emergent literacy may vary not only in terms of the measurement of the constructs but also according to child and family characteristics.

Association between HLE activities and emergent literacy

Both bivariate and regression analyses revealed very small coefficients for each HLE activity, as well as for the HLE composite, suggesting nonsignificant correlations and no unique direct effects on emergent literacy. At the bivariate level, frequency of reading books appears to have the strongest correlation with emergent literacy. However, when all other variables were factored into the model, telling stories emerged as having the highest, but negative, unique association with emergent literacy, while reading books continued to have a very small positive independent effect. It is possible that activities that are less structured, such as telling stories, do not make that many connections with components of emergent literacy, resulting in a negative association. The negative coefficients for telling stories and learning activities do not suggest that these activities negatively affect emergent literacy, but rather may be interpreted because of having correlated predictors, suggesting a possible suppression effect. For example, parents may spend more time reading books, resulting in less time for telling stories or learning activities. Likewise, the observed negative coefficient for HLE composite when all other variables, including covariates, were included in the model may be interpreted as a possible suppression

effect. The HLE composite demonstrated positive but small correlation at a bivariate level, but when covariates were included in the path analysis, the coefficient showed only the unique variance not shared with other predictors, resulting in a negative coefficient. This suggests that HLE composite shared variance with the other variables in the model, so when they were accounted for in the model, the unique contribution of the HLE to EF and emergent literacy resulted in a minimal and negative coefficient. However, these associations should be interpreted with caution since none of them reached a statistically significant level.

In sum, these findings suggest that the lack of significant association between the HLE and emergent literacy may be attributed to several methodological and conceptual factors, including how the constructs are measured and operationalized. For example, the frequency of literacy activities may not be a strong indicator of the HLE, as it does not capture the quality and complexity of the interaction. Drawing from Bronfenbrenner's framework, meaningful change is more likely to occur when learning interactions are increasingly complex, reciprocal and sustained over time, which are aspects not captured when using frequency measures only. Furthermore, the use of a composite measure of emergent literacy may obscure the distinct influence of HLE on the literacy components. Since there are variations in the development and acquisition of children's emergent literacy skills, combining them into a single score would make it difficult to identify whether a particular HLE activity is more influential on certain subskills than others. Moreover, parents may engage more frequently in certain types of literacy activities and possibly did not match the skills assessed by the emergent literacy measure. For example, if parents focus more on identifying letter names, but the emergent literacy measure also assessed other components such as letter sounds or writing one's name, children's scores may be lower

despite engaging in home literacy experiences. This lack of alignment may partly explain the weak associations observed in the current sample.

Direct Effects: HLE and EF

The study also explored whether the HLE was directly associated with children's EF. The result indicated that there was no significant association between the two constructs, suggesting that a higher frequency of parent-child literacy activities, such as reading books, telling stories, and learning activities (e.g., letters, numbers), did not result in stronger EF skills. The result aligns with the study of Simmons et al. (2023), which found that meaning-related (e.g., book exposure) and less formal code-related activities (e.g., letter activities) were not significantly related to inhibition, a component of EF. Likewise, Devine et al. (2016) indicated that informal home learning activities (e.g., book reading, learning numbers) were not significantly related to EF, indicating that general learning activities did not have an influence on children's EF. In the current study, the two meaning-related HLE indicators (reading books and telling stories) had very small, negligible effects on EF. Despite previous research suggesting that parent-child literacy activities, like storybook reading, can provide opportunities to train EF skills, such as when parents encourage their children to pay attention and remember story details (Korucu et al., 2020), the frequency of these experiences may not be sufficient to support EF development. The quality, content, and structure of these interactions might be more important than what was captured by the current HLE frequency measure. For instance, dialogic reading that involves asking children questions about the story, making predictions, or recalling information is more structured and puts higher demands on children's working memory and inhibitory control, which helps enhance EF skills (Blair & Raver, 2015). It is possible that mothers in the current sample may have engaged more in passive unstructured reading and storytelling activities, and the

benefits of those activities might be minimal. Simmons et al., (2023) also noted that the significant relation between letter-sound interaction (a more formal code-related activity), which emphasizes grapheme-phoneme correspondence (GPC) are more cognitively stimulating than general learning activities, thus they found significance in children's inhibition skills. The third HLE indicator in the study measured general learning activities (e.g., letters, numbers, etc.). It is possible that the parent and child engaged in these activities in a more play-based and less structured manner rather than formally teaching the concept. These findings indicate that types of HLE activities and the qualitative aspects of them might relate to components of EF differently, as found in the previous studies (Korucu et al., 2020; Simmons et al., 2023). Another important points to consider are maternal and family characteristics. The mother's cognitive resources and capacities (e.g., maternal EF and education level) to engage in structured activities, ask meaningful questions, or provide encouragement may also influence EF development. For instance, Hughes and Ensor (2009) suggested that maternal scaffolding predicted individual differences in children's EF at age 4 even after controlling for verbal ability and family background. Furthermore, family chaos was associated with weaker EF development in children between the ages of two and four. This means that even when parents engage in literacy activities, the broader family context may limit the extent to which these literacy experiences could support EF.

In summary, findings suggest that the frequent exposure to but less structured literacy experiences may not be as influential on EF, highlighting the need to explore the qualitative aspects of parent-child activities, as well as maternal characteristics and other family factors and how they relate to EF. Furthermore, investigating different types of literacy activities and how

they relate to components of EF, rather than a composite EF, might provide a more nuanced understanding of the associations between HLE and EF.

Direct Effects: EF and Emergent Literacy

The third research question examined whether EF exerts a direct effect on emergent literacy. The current findings replicate prior findings (Blair & Razza, 2007; Segers et al., 2016; Welsh et al., 2010), indicating that children's early EF predicted the development of emergent literacy and its components. For example, Welsh et al.'s (2010) study found that the preschool's EF composite score (working memory and attention control) was strongly related to emergent literacy even after controlling for language skills, indicating that EF supports mechanisms of early learning by supporting children's ability to focus on goal-directed tasks. Similarly, Blair and Razza (2007) study of preschool children from low-income families indicated that as children acquire early literacy skills, such as letter knowledge and phonemic awareness, EF processes, such as inhibitory control, become actively involved. Taken together, these findings emphasize the important role of EF in supporting the acquisition and development of early literacy skills during the preschool years.

Indirect Effects: HLE on Emergent Literacy via EF

Finally, the last research question explored whether EF mediated the associations between HLE activities and emergent literacy. The results indicated very small, non-significant indirect effects, suggesting that HLE did not transmit its effects to emergent literacy indirectly through EF. The same finding is observed for the HLE composite, showing near-zero nonsignificant indirect effects. This finding is consistent with the work of Simmons et al. (2023) and Devine et al (2016) but contrary to that of (Korucu et al., 2020). Several possible reasons to explain differences in the findings are the influence of contextual factors, such as SES status,

characteristics of the sample, as well as differences in the methodological approach. First, Korucu et al., (2020) found a significantly small indirect effect between the HLE composite and indicators of school readiness. However, their outcome measure involves general academic skills (e.g., letters, numbers recognition) which are not specific to emergent literacy skills alone. However, Simmons et al. (2023) documented that inhibition, one of the core EF components, did not mediate the relation between code-related home literacy experiences (e.g., letter-sound interaction) and early word reading skills. Likewise, Devine et al., (2016) found no mediating effects between the HLE and early academic abilities, however their main outcome variable is a composite of both numeracy and literacy and not purely literacy. Due to differences in the methodologies and conceptualization of the constructs, it is difficult to make a direct comparison with the previous studies.

From a bioecological lens, it is important to consider that the current study was conducted within a low-income population, where several socioeconomic factors might interfere with access to high-quality home literacy experiences. Important contextual variables that were not accounted for in this study, such as access to childcare, number of books and other literacy resources available at home, maternal level of education, as well as the quality of parent-child literacy interaction, are potential influences on these relations. These aspects of the environment may vary despite the homogenous income profile of the sample. Caregivers may vary in the way they read books, tell stories or engage in learning activities with their children, depending on maternal cognitive capacities. For example, maternal level of education is a strong predictor of children's cognitive and literacy skills (Brooks-Gunn & Duncan, 1997; Sénéchal & LeFevre, 2002). However, maternal level of education was not collected during the age-4 follow-up, so this variable could not be included in the current analysis. Though the maternal education

variable was available in the previous years, those data may not reflect the most recent educational attainment of mothers, which could potentially bias the result. Thus, it was decided not to include this variable, and it is considered a limitation of the current study. Including information on whether a child attends a childcare or preschool program like Head Start may also be important when studying the influences on children's literacy other than at home. Children who attend childcare may learn some of the basic literacy skills from a more structured environment like preschool. Additionally, other child characteristics, such as language skills, EF, or motivation, could either support or hinder children's ability to benefit from these literacy experiences. For example, a child with limited language skills or who lacks interest in participating may not fully benefit from literacy activities even when those opportunities are offered at home. This means that children's EF skills may be able to support children during literacy interactions only when the child has the capacity and willingness to do so. Lastly, the study is cross-sectional, and all constructs were measured concurrently, so it may not capture developmental change. While it is possible that the HLE construct is not strongly related to emergent literacy to yield a significant change or that the HLE measure itself may be inadequate, by not capturing broader aspects of the HLE, it is also possible that effects might emerge later, as some longitudinal studies have found (Weigel et al., 2006).

In summary, even though EF and emergent literacy skills are significantly associated, children from low-income backgrounds often experience environmental constraints that could weaken the link between HLE and EF, which reduces the likelihood of detecting mediation. For instance, inconsistent literacy routines, limited access to high-quality structured literacy interaction, maternal cognitive resources (e.g., language and EF skills), and limited learning resources may reduce opportunities for meaningful responsive interaction that supports EF

development. These ecological challenges may attenuate the association between the HLE and child outcomes, hence weakening the ability to find significant effects. Furthermore, the use of a composite EF may mask the differential effects of HLE on EF and of EF components on emergent literacy. While many studies have used EF composite for early childhood, as EF appears to be undifferentiated at this stage (Garon et al., 2008), and it reduces measurement error (Ernst et al., 2022), investigating their components might reveal a different pattern. Finally, the emergent literacy measure used in this study taps a broad range of skills expected to emerge at the age of four. It is possible that different aspects of the HLE relate uniquely to specific literacy components, which may be masked when using a composite emergent literacy measure.

Limitations and Recommendations for Future Research

The findings do not mean that parent-child literacy activities have no influence on the emergent literacy skills and EF of four-year-old children, as previous studies have provided evidence on their significant associations. However, the results point to the idea that there are several important limitations of this study that could be addressed in future research. First, the limitation concerns the use of secondary data. While the Age-4 follow-up dataset has a large sample and multiple variables, several important variables that would have been useful to elaborate on the complex associations between constructs were not available. For example, children's performance on each emergent literacy component (e.g., phonological awareness, print concepts, letter-sound knowledge, etc.) would be useful in determining unique patterns of association between types of HLE activities and early literacy subskills. Another limitation is the presence of missing data on both mediator and outcome variables. Although using the full information maximum likelihood method and bootstrapping is a best practice technique for path analysis on a dataset with missing cases and non-normality, future studies would benefit from a

dataset with less or no missing data to minimize bias in the estimates. Also, despite having a large sample, the findings cannot be generalized to a broader low-income population, as participants were sampled from urban cities in the U.S. Moreover, the exclusion of children with developmental and health conditions and the inclusion of only children four years of age limit the generalizability to the preschool population.

The HLE indicators, as parent-reported measures, present their own limitations due to being prone to social desirability bias and recall. Parents may not accurately recall how many times they engage in each activity or may overreport the frequency of interactions, resulting in these variables being overestimated or underestimated, thus affecting their associations with EF and emergent literacy outcomes. Future research can address this by including observational measures that capture the qualitative aspect of the HLE interactions (e.g., scaffolding, structure of the activity) and adding more specific literacy activities indicators that clearly distinguish code-related from meaning-related experiences (Korucu et al., 2020). Also, including other HLE indicators such as book exposure, the number of books available at home might be able to assess children's print exposure better, which is less vulnerable to social desirability. Future research might also consider exploring other family-related variables, such as maternal cognitive resources (e.g., EF and language), maternal level of education, or maternal stress, as they may have affected the degree to which these literacy experiences support EF and emergent literacy. Data on the level of education of mothers were not available in the Age-4 data file, and using data collected from the previous year may not provide the most recent information on the mother's educational attainment, so it was decided not to include this variable in the analysis. Future studies should consider adding this important factor to the analysis.

It is important to note that most of the previous studies recruited children from Head Start or preschool, implying a possible contextual influence other than home. Further research might consider other factors, such as childcare attendance and community literacy resources, to understand multiple systems that may also influence child outcomes. These unmeasured variables may account for effects on emergent literacy. Moreover, language is an important mechanism that drives children's development at this early stage. This construct was included in the model as a covariate to control for its effect and estimate the unique effect of the HLE and EF, however, it might be important to explore this variable as a predictor or mediator as well, to clarify its role in the relations among the HLE, EF and emergent literacy (Simmons et al., 2023).

Furthermore, the study relied only on a single measure for the EF variable, which may not fully capture the true EF ability of the child. While it has good psychometrics, EF studies often use multiple EF tasks to reduce measurement errors attributed to developmental or situational factors, such as child fatigue or lack of motivation during the assessment. Because the EF construct is not well-established in the very young population, the variations in how the construct is measured and operationalized, which components are included, as well as whether the tools are age- and developmentally appropriate, may result in biases. Thus, future studies can utilize a wider range of developmentally sensitive EF measures that tap into different components of EF to obtain a more reliable assessment of children's EF (Best & Miller, 2010; Simmons et al., 2023). Additionally, the measure for the main outcome variable, emergent literacy, is a newly developed tool with borderline psychometric acceptability. The use of a single measure could bias the results, as score reliability is important in SEM techniques like path analysis, where variables are assumed to be measured without error. According to (Kline,

2011) when variables are measured with error, the associations among constructs are underestimated, including indirect effects.

Finally, the study is a cross-sectional design that explored concurrent relations among constructs. Previous studies and theories suggest that the effects of proximal processes such as HLE may be observed over time. Investigating the cumulative effects of home literacy activities from when the parent began engaging in literacy might result in a stronger association than when constructs are measured at the same point in time. Future studies may explore the relations among these constructs longitudinally to capture causal developmental pathways.

Implications

The findings present important implications for examining children's early literacy development within the bioecological perspective. The HLE, measured in terms of the frequency of parent-child literacy interaction, represent the proximal processes that are expected to influence emergent literacy outcomes in the study. The non-significant finding on this association suggests that exposure to literacy interactions may not be sufficient to drive the growth of emergent literacy and EF outcomes. Aligning these findings to Bronfenbrenner's bioecological framework, he emphasized that children require a consistent and increasingly complex reciprocal interaction over a period of time with their caregivers, who are actively involved and supportive of the process. This also suggests that it is important to consider not only the characteristics of the child but also the cognitive resources the caregiver brings to the experience. Thus, to observe a significant gain in the child's outcomes, the quality and depth of the activities and the relationships between the mother and child matter more than the quantity. The results imply that home literacy activities may support EF and emergent literacy only when the activities are progressive and is sustained over time, which might not have been captured by

the HLE indicator used in the study. The findings of the study may inform future related studies to further investigate specific contextual and cognitive mechanisms underlying child development, especially among children from socioeconomically disadvantaged backgrounds. These findings also have important implications for early childhood education and intervention programs, as well as parent and teacher programs. The study highlights the importance of providing accessible support for children from low-income backgrounds and guidance and resources to caregivers in promoting early literacy to help prepare children for school entry. Parents or caregivers can be trained to incorporate simple activities that may not require formal teaching but are more cognitively stimulating, consistent, and structured to better support EF and literacy. For instance, dialogic reading is an interactive approach that involves asking questions, recalling details, and making predictions about the story (Whitehurst & Lonigan, 1998), which may support EF skills. A study conducted with Hebrew-speaking preschool children (between 4 and 6 years old) from middle-class families compared the effects of dialogic reading and screen-based storytelling intervention on executive function skills. Parents of children in the dialogic reading group asked their children to recall parts of the story or asked open-ended questions about the story, while children in the screen-based storytelling viewed videos of the same book used by the intervention group, but no questions nor interactions occurred between the experimenter and the children. They found an increase in EF abilities, particularly attention, switching, and speed of processing in children involved in the dialogic reading intervention compared to the screen-only intervention. Their findings underscore the positive effects of interactive reading that involve human interaction on children's EF skills development (Twait et al., 2019). Moreover, Dicataldo et al. (2022) investigated the effects of a parent intervention using dialogic reading strategies on improving the quality of parent-child interaction and

subsequently improving early language and literacy skills of preschool children from middle-class families in Italy. Their study found that the children in the treatment group (whose parents received dialogic reading training) performed better in language and early literacy measures compared to other groups. Moreover, improvement in parents' reading strategies and practices was observed for those who participated in the intervention. These findings suggest that teaching parents effective literacy strategies may be an effective way for promoting children's early literacy and language skills within the home environment. Additionally, since the sample involves families from the low-income population, programs should consider contextual factors, such as access to literacy resources, family routines, and household dynamics, that may either disrupt the interactions or provide support to maximize the benefits of literacy activities. Finally, in the bioecological model, the child's characteristics influence development and play an important role in the success of the proximal process. The strong associations found between EF, language, and emergent literacy suggest that child characteristics are central to the development. Individual characteristics may exert a stronger effect on early literacy skills than distal factors such as home literacy experiences.

Conclusion

The study examined the relations between the HLE and children's emergent literacy skills and the potential mediating role of EF. Findings indicated that HLE did not significantly predict children's EF or the emergent literacy outcome. Moreover, EF did not mediate the relationship between the HLE and emergent literacy. Rather, EF emerged as a significant predictor of emergent literacy even after accounting for children's language ability. These results contribute to the growing evidence on the important role of early EF in supporting the development of foundational literacy skills of young children. The positive, unique association

between EF and emergent literacy can inform parents and teachers on the importance of offering quality early experiences that promote EF in young children. This significant finding also suggests that supporting EF development during the preschool years can help ensure that children, especially from low-income backgrounds who are at-risk for academic difficulties, have the cognitive tools to be successful in a school setting.

Appendix A

Parent-Child Activities Survey Questions (Magnuson et al., 2024)

1. In the past week, how many days did you... Read books or look at pictures in a book with [childnamef]? Would you say no days, 1-2 days, 3-5 days, or 6-7 days?
2. In the past week, how many days did you... Tell stories to [childnamef]? Would you say no days, 1-2 days, 3-5 days, or 6-7 days?
3. In the past week, how many days did you... engage in learning activities with [childnamef], such as learning numbers, colors, letters, shapes? (Would you say no days, 1-2 days, 3-5 days, or 6-7 days?)

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