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Cognition in Young Children in a Low-Income Rural Setting: Prominent Correlates in Sub-Saharan Ghanaian Preschoolers

thrive

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Foreword

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Abstract

This study uses a bioecological framework to examine multiple correlates of rural Ghanaian preschool children's (N = 1676; Mage = 4.8 years) cognition at the child-, maternal-, and home-level. We use direct assessments of children's literacy, numeracy, and executive functioning skills and surveys of their mothers conducted in 2022-2023. Candidate correlates include child height- and weight-for-age, as well as proximal variables including mothers' cognitive skills, well-being, relationship conflict and closeness to the child, teaching and discipline practices, and mother's time use during a typical day. More distal candidate correlates included indicators of the home learning environment. To isolate childhood cognition as the principal criterion, child age, gender, birth order, the number of children in the household, as well as maternal education and household wealth and were covaried in a multiple hierarchical regression analysis. This study confirms that children's development is multi-dimensional, with height-for-age as a significant correlate with cognitive abilities. Maternal factors also play a crucial role, with specific parenting practices, such as positive teaching approaches and non-violent discipline, being linked to higher cognitive skills, while conflict and violent discipline negatively impact development. These findings emphasize the need for specificity in intervention design, targeting specific maternal behaviours and family dynamics to enhance child development outcomes.

Keywords

Child development; cognition; rural Ghana

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Introduction

The preschool years are a time of rapid expansion in children's knowledge, thinking, reasoning, problem-solving and memory skills, all of which are critical for success in school. Identifying salient correlates of cognition is a compelling aim of contemporary developmental science, the study of human ontogeny. In the current literature, multivariate models have been used to identify specific candidate correlates. The results form the basis for evidence-based intervention design aimed at improving child development outcomes. However, studies have been conducted almost exclusively in high-income country (HIC) populations, and complementary parallel studies in rural, low- and middle-income countries (LMIC) using analogous multivariate analytic approaches have lagged behind.

This is despite the fact that the majority of the 250 million children under the age of 5 who are at risk of not reaching their developmental potential live in LMICs (McCoy et al., 2016), are exposed to poverty, poor health and nutrition, and lack cognitively stimulating environments.

The main aim of this study is to identify which variables—capturing children's characteristics, their mothers, and home environments—correlate with the cognitive ability of young preschool-age children in rural Ghana, an understudied and high-risk context.

The Ghanaian context

Ghana, in sub-Saharan Africa, ranks second to last out of 13 countries ranked medium on the Human Development Index in terms of the amount of cognitive stimulation parents report providing to their children (Bornstein & Putnick, 2012). Only 33.1% of children had been read to in the previous three days, compared to an average of 54.1% across all LMICs (McCoy et al., 2018). In northern Ghana, the setting of this study, where most families live on less than US$2 per day, only 13% of primary caregivers reported that someone in the household had played with their 3-4 year old child in the previous 3 days (Amadu et al., 2018).It is estimated that a third (32.6%) of children in this age group do not meet the thresholds for school readiness indicators, including following directions, working independently, avoiding distractions, getting along with others, and avoiding aggression (McCoy et al., 2016).

Cognition and its significance in early childhood

Cognition in childhood refers to the processes or capacities by which knowledge is acquired and manipulated, and includes what and how children learn, what they know, and how what they learn and know guides their behaviour. Cognition is a reflection of the mind and is not directly observable but must be inferred from what children do or say. As the field of cognition in child development is vast and varied, we have confined this study to testing three basic and prominent domains in Ghanaian children to represent their cognition: literacy, numeracy and executive function.

Literacy is the ability to read, write and communicate linguistic information that is essential for developing one's knowledge and potential, achieving one's goals and functioning in society. Studies in high-income countries clearly show that children from low socio-economic backgrounds have lower literacy skills and that persistent poverty is particularly debilitating (Sulkunen, 2013; Hart & Todd, 1995; Albert & Trommsdorff, 2014). The World Bank and UNESCO developed a measure of the proportion of students who are unable to read and understand a simple story by age 10. In low- and middle-income countries, 53% of children were judged as "learning-poor" as were up to 80% of children in poor countries (World Bank, 2021).

Numeracy reflects a command of mathematical thinking which includes the use of logical reasoning in the domain of quantities, sets, numbers, measures, and space as well as mathematical symbols and signs. Numerical knowledge is a fundamental parameter by which we make sense of the world and is a part of everyday life, whether in telling time or calculating change in a commercial transaction (Dehaene, 2001). Children rapidly acquire a “sense for number,” the ability to perceive, understand, and manipulate numerosity (Cantlon, Platt, and Brannon, 2009; Dehaene, 1997; Feigenson, Dehaene, and Spelke, 2004). Knowledge of math at or before school entry predicts outcomes in mathematics across primary and secondary school (Duncan et al., 2007; Rittle-Johnson, 2017), and early mathematics skills are among the strongest predictors of later academic achievement (Elliot & Bachman, 2018; Herbert & Stipek, 2005). However, children’s skill levels vary substantially (Elliott & Bachman, 2018).

Executive functions (EF) regulate thought and behavior, planning and performing higher-level cognitive tasks such as reasoning and problem solving (Miyake & Friedman, 2012). Many types of executive functions have been identified (Jurado & Rosselli, 2007). This study focused on two related components of executive functions: working memory (a limited capacity cognitive system that holds information temporarily, is important for reasoning and the guidance of decision-making and behavior, and allows for the manipulation of stored information), inhibition, or impulse control (preventing oneself from making some cognitive or behavioral response or keeping unwanted information out of mind). Research supports long-term relations between executive functions in early childhood and later psychological benefits (Ahmed et al., 2021; Duckworth & Steinberg, 2015; Michaelson & Munakata, 2020), such as for memory, IQ, reasoning, and school achievement (Miyake & Friedman, 2012; Richland & Burchinal, 2013; Roebers, 2017; Schnitzspahn et al., 2013; Alloway & Alloway, 2010), a variety of cognitive,

health, and psychological adjustments in adulthood (Ahmed et al., 2021; Michaelson & Munakata, 2020).

Individual variation in childhood cognition and its predictive validity

Like most human characteristics, cognition in childhood is characterized by individual variation; simply put, children differ considerably from one another in their cognitive abilities. Developmental scientists are as interested in the expression of individual differences in literacy, numeracy and executive function as they are in the sources, correlates, development and consequences of these individual differences. Since individual variation in children's cognition is at least partly influenced by experience, this individual variation is likely to be associated with several of the correlates that we examined in this study. In addition, as suggested above, literacy, numeracy and executive functions are of particular importance, first because of their many important functions in childhood - at the very least, young children with more advanced cognitive functions are likely to process information and learn faster, more efficiently or more comprehensively than others - and second because these cognitive processes anticipate virtually all aspects of later development, from knowledge and wisdom to personality and social relationships to health and well-being. It is therefore important to identify correlates of individual differences in the expression and promotion of cognition in childhood.

Candidate correlates of cognition and their theoretical underpinnings

We therefore investigated important concurrent correlates of in cognition in young Ghanaian children. In this regard, our study was designed with two important considerations in mind. One is that we conducted a cross-sectional investigation of several concurrent candidate correlates of child cognition, and the other is that these correlates were selected using a bioecological framework. The first point is statistical and interpretive, the second theoretical.

Theoretical framework. This study was designed to align with key elements of the bioecological framework in developmental science (Bronfenbrenner & Morris, 2006). According to this framework, children are situated within multiple, nested systems of environments and experiences that range from proximal to distal influences. In our modified version of this ecological framework, we selected specific environments and experiences for examination based on their closeness and directness in relation to children. For example, we focused on patterns of interaction between children and their mothers, as well as maternal characteristics that shape children's immediate experiences. Additionally, we considered more distal, material environments, such as the home learning environment and family wealth, which, although farther removed from children, still have an impact on their development. We categorized a range of potential correlates, both proximal and distal, into blocks, and structured the regression analysis to reflect their varying degrees of immediacy and closeness to the child.

Blocks of candidate correlates

The **first block** of candidate correlates was at the child-level and included height- and weight-for-age, indicators of child's health. With widespread poverty and malnutrition in rural Ghana, as well as high levels of stunting, understanding the association between health and cognition is critical in light of strong, multi-country evidence linking these two constructs descriptively (e.g., Alam et al., 2020; Woldehanna et al., 2017) and causally (e.g., Palloni, 2006).

The **second block** consisted of several proximal maternal measures. They were mothers' cognition, well-being (self-esteem/mental health), relationship to the child, approaches to teaching their children, and time use. All prominent theories of child development put experience in the world either as the principal source of individual cognitive growth or as a major contributing component. For example, an extensive literature confirms that aspects of the mother–child relationship correlate with cognitive developmental status in the child, free from genetic confounds (Horn & Loehlin, 2010).

The **third block** represented more distal material measures of the child's home learning environment in line with literature that even before children enter school their cognitive skills are influenced by their home environment (Haft & Hoeft, 2017, Kassai et al., 2019).

Controls and covariates. Our criterion correlates focused on malleable constructs at the child-, mother-, and household-levels. To further isolate childhood cognition as the principal criterion of interest, we included and accounted for several sociodemographic covariates in the regression analysis: children's age, known to robustly predict children's cognition (for example Steinberg et al., 2011); children's sex, generally not predictive of cognition (Bornstein et al., 2023; Lu et al., 2020; Hyde, 2005, 2014), but typically queried in developmental science; children's birth as research indicates that firstborns often exhibit slightly higher cognitive abilities compared to their younger siblings given higher stimulation (Zajonc and Markus, 1975; Rohrer, Egloff, and Schmukle, 2015). Related, we include the number of household members under the age of 18 years, given household crowding is associated with slower child development in part because parents have less time to spend with any given child (Bornstein, Putnick, & Suwalsky, 2016; Juhn et al., 2015; Zajonc, 2001; Zajonc & Markus, 1975; Bradley & Caldwell, 1984; Evans, 2021; Evans et al., 2010; Galpin et al., 1992). We include maternal cognitive skills as they appear to be a powerful correlate of cognition in young children (Koşkulu-Sancar et al., 2023), including in LMICs (e.g., Bornstein & Bradley, 2003; Bradley & Corwyn, 2002; Davis-Kean et al., 2019; Duncan et al., 2015; Hoff & Laursen, 2019). Finally, we control for family wealth, which has consistently been found to differentiate cognitive development across high-, middle-, and low-income country contexts (e.g., Bourdillon & Boyden, 2014; Brooks-Gunn & Duncan, 1997; Conger & Donnellan, 2007).

Age group

Every age in the life span merits investigation in developmental science. In this study, we tested preschoolers ages 3.5 to 6.5 years for several reasons. By the time children reach this age span, they are (or are fast becoming) more sophisticated cognitively as persons in themselves and as social partners, and they possess increasing abilities to formulate and express their thoughts and beliefs verbally. In this age range, children are becoming proficient number word users (Feigenson, Libertus, and Halberda, 2013). Children this age are cooperative and interact more felicitously with adults, display declining tendencies to behave impulsively, increasing playfulness and other executive processes. At the same time, most children in this age range have not yet experienced the homogenizing influences, intellectual demands, and social rigors of institutional schooling. This age also precedes the "5-7 shift" to operational thinking. For younger children, cognition characteristically involves limitations on the number of objects that can be thought about at one time, and systematic or abstract reasoning is still relatively rare. Children have not yet begun to organize tasks maturely and independently. Such young children cannot solve more difficult, abstract intellectual problems, such as are increasingly common in school, and cannot yet master growing and more complex responsibilities at home and in other common settings (Case, 1998; DeLoache, Miller, and Pierroutsakos, 1998; Fischer and Bullock, 1984). Sometime beginning around 5 to 7 years is universally regarded as the advent of "the age of reason" (Piaget, 1983; Sameroff and Haith, 1996). Thus, children's abilities prior to entering school, that is their school readiness, has a major impact on how much they learn during their school careers (Hunt, 2011a, 2011b; Phillips, Crouse, & Ralph, 1998).

This study

Building on the bioecological framework, this study investigates the factors influencing children's cognitive development in a large sample of pre-primary children from rural Ghana. Using a multi-method, multi-informant approach, we gather data from maternal reports, direct observations of mother-child interactions, child assessments, and anthropometric measures. This comprehensive dataset enhances global understanding of early social and emotional development and seeks to inform future intervention research by focusing on modifiable factors at the child, mother, mother-child, and household levels.

Methods

This section outlines the participants, procedures, and measures included in the analysis. A table of summary statistics for all variables can be found in Appendix A.

Participants

Between May 2022 and November 2023, interviews were conducted with 1,676 biological mother-child pairs from 48 districts in rural Northern Ghana. The children were selected from kindergarten (KG) attendance lists of 305 schools, randomly sampled from the Ghana Education Management Information System (EMIS) to ensure a representative sample of government primary schools, excluding single-gender schools. Eight children were randomly chosen per school, and their cognitive skills were evaluated by trained enumerators during visits to the KGs. The enumerators also visited the children's homes to conduct interviews with their mothers and observe mother-child interactions. An overview of the study sample is presented in the Results section, with details of the assessments, interviews, and observations provided in subsequent sections.

Procedures

Trained enumerators assessed children's cognitive skills at school, where they also measured the children's weight and height. Both the children's assessments and the interviews with their mothers were conducted in the participants' preferred languages. To facilitate this, the survey instruments were translated from English into the 14 major languages commonly spoken in the evaluation districts. To ensure accuracy, the translated instruments were back-translated into English as part of the quality control process. Enumerators received training on how to observe and score a predefined list of items. Whenever possible, the mother survey and the mother-child interaction observation were conducted at the respondent's home. If a child was absent from school during testing, the assessment was carried out at home.

Measures

Outcome: Children's cognitive skills. Children's cognitive skills were assessed directly using the emergent numeracy, emergent literacy, and executive functions items form the International Development and Early Learning Assessment (IDELA; Pisani et al., 2015). The IDELA was developed by Save the Children for use in LMICs to measure holistic child learning and development among preschool-aged children (3.5 to 6 years old). It has been used in 75 countries, including Ghana (Wolf & McCoy, 2019b). See Pisani et al (2015) for a detailed description of how

the IDELA was developed. Following Pisani et al. (2015), multiple tests were conducted to evaluate the quality of the data collected. Extensive piloting ensured the instrument was adapted to the local context; following the piloting, minor changes were made to some items (see Appendix B). As part of their training, enumerators were required to achieve inter-rater reliability (IRR) of at least 0.80.

Emergent numeracy was measured using 39 items grouped into 7 sub-tasks covering number knowledge, basic addition and subtraction, one to one correspondence, shape identification, sorting based on colour and shape, size and length differentiation and completion of a simple puzzle. Emergent literacy was measured using 38 items grouped into six sub-tasks covering print awareness, letter knowledge, phonological awareness oral comprehension, emergent writing and expressive vocabulary. Executive functioning was measured using 10 items grouped into two sub-tasks covering working memory (forward digit span) and impulse control (head-toes task).

Each item was scored as correct or incorrect. The exceptions to this are the puzzle, expressive vocabulary and writing sub-tasks which are scored as the fraction of the maximum possible score a child could attain. Each sub-task was scored as percent of correct answers across the items. The Cronbach's alpha for the 15 sub-tasks is 0.84. Exploratory factor analysis indicated that the 15 sub-tasks formed a unique factor. The final cognitive skills index is the factor obtained by the exploratory factor analysis and is standardized to have zero mean and unit variance.

Child variables

Anthropometrics: Trained enumerators recorded each child's weight and height, and z-scores for height-for-age and weight-for-age were calculated using the WHO Reference 2007 standards (World Health Organization, 2007; World Health Organization, 2017). These z-scores were derived based on the mean and standard deviation of weight and height in a reference population of children of the same age and sex. The final scores reflect the number of standard deviations (SDs) a child's measurements fall above or below the reference population mean. In this sample, the average height z-score is -0.86 (SD = 1.54), and the average weight z-score is -0.94 (SD = 1.19). These values indicate that, on average, the children's height and weight are slightly less than one standard deviation below the reference population mean for their age and sex.

Mother variables

Mothers' cognitive skills. Mothers' cognitive abilities were evaluated using the Digit Span Memory Test (DSMT; Richardson, 2007). This verbal assessment involved enumerators reading sequences of digits aloud and asking mothers to repeat them either in the same order (Forward Digit Span task) or in reverse order (Backward Digit Span task). The Forward Digit Span measures verbal working memory and attention, while the Backward Digit Span assesses cognitive control and executive function (Hester et al., 2004). Each task consisted of eight trials, beginning with two-digit sequences and progressing to seven-digit sequences.

The scores from both tasks were combined, with the final score reflecting the proportion of sequences correctly recalled. The average score in the sample is 0.29 (SD = 0.14).

Mothers' well-being. Maternal well-being was measured in two ways. First, maternal mental health was assessed using the Kessler-10 Psychological Distress (K10) scale, a brief but robust instrument with strong psychometric properties that is widely used in the WHO World Mental Health Surveys (Kessler, 2002). The scale consists of 10 items asking respondents how often they experience various symptoms of psychological distress. Responses are recorded on a 5-point Likert scale ranging from 1 ('none of the time') to 5 ('all of the time'). The scale has high internal consistency, with a Cronbach's alpha of 0.90. The total score is calculated by summing responses across all items, with higher scores indicating greater levels of psychological distress. Possible scores range from 10 to 50, with a sample mean score of 19.61 (SD = 7.01).

The second approach to capture maternal well-being was the Rosenberg Self-Esteem Scale (Rosenberg, 1965). This 10-item scale is one of the most widely used measures of self-esteem worldwide, including in LMICs (Schmitt and Allik, 2005). Responses are on a 4-point Likert scale with 1= 'strongly disagree' and 4= 'strongly agree' and alpha=0.68. The final score is constructed by reversing responses to negatively worded items so that responses to all items are summed, with a higher score indicating higher self-esteem. The highest possible score is 40, the lowest is 10 and the sample mean is 29.2 (SD=3.48).

Mother-Child Relationship. The Short-Form Child-Parent Relationship Scale (CPRS-SF; Driscoll & Pianta, 2011) is a 15-item self-report instrument that assesses the degree of conflict and closeness between a mother and her child. Example items for the conflict subscale include: "I always seem to be struggling with my child," while an example of the closeness subscale is: "I share an affectionate, warm relationship with my child." Responses are given on a 5-point Likert scale, where 1 = 'definitely not true' and 5 = 'definitely true'. In this sample, the internal consistency for the conflict subscale was α = 0.81 and for the closeness subscale α = 0.78. Following the scoring guidelines of the instrument, we calculated the total score for the 8 items of the conflict subscale and the 7 items of the closeness subscale. The mean scores for these subscales in this sample were 30.1 (SD = 4.6) for conflict and 21.03 (SD = 7.32) for closeness.

Mothers' Parenting Practices. Parenting practices were assessed in two ways: first, the enumerators observed the mother's teaching style during two games with the child, and second, they observed mother-child interactions during the interview.

The measurement approach involved the enumerator explaining two simple guessing and sorting games to the mother, who then played the games with her child, allowing the enumerator to observe her teaching style. Enumerators were trained to note whether the mother exhibited specific behaviours from a list of 15 items, which were coded as 0 (not observed) or 1 (observed). These behaviours were related to the mother's teaching practices during the games, such as "Tried new strategies if one wasn't working," "Provided instructions based on the child's previous actions," "Acted intrusively, not allowing the child to solve the task

independently," or "Appeared shy, timid, or underconfident when performing the task. "Using these items, we developed measures of the degree to which mothers exhibited positive and negative teaching styles, with internal consistency alphas of 0.83 for positive style and 0.64 for negative style. The final positive teaching style score was calculated as the proportion of positive behaviours observed during the games (mean = 0.75, SD = 0.26), and the negative teaching style score was based on the proportion of negative behaviours observed (mean = 0.24, SD = 0.29).

The second method involved enumerator observations of mother-child interactions throughout the survey. Enumerators recorded whether mothers used any of three discipline strategies with their child: nonviolent discipline (e.g., taking away privileges, explaining why the behaviour was wrong, or giving the child alternative activities), psychological aggression (e.g., shouting, yelling, or calling the child derogatory names such as "dumb" or "lazy"), or physical violence (e.g., shaking, spanking, hitting, or slapping the child with either a bare hand or an object). These items are a subset of the behaviours captured in the UNICEF Multiple Indicator Cluster Surveys (MICS) for constructing discipline strategy measures (Bornstein et al., 2023). Enumerators were trained to observe mother-child interactions during the survey and code whether a specific behaviour was observed (0 = no, 1 = yes). These observations were used to construct measures of the degree to which mothers used nonviolent (alpha = 0.62) and violent (alpha = 0.69) discipline strategies. The final scores were calculated as the proportion of nonviolent and violent behaviours observed, with means of 0.24 (SD = 0.32) for nonviolent discipline and 0.11 (SD = 0.21) for violent discipline.

Mothers' time-use: Time-use data were collected using a task in which mothers were asked to allocate 24 pebbles across 8 categories of activities, reflecting a "typical" day for them. This approach is similar to that used in other large-scale studies on child development in low- and middle-income countries (LMICs) (Espinoza-Revollo & Porter, 2018). For analysis, the 8 categories were combined into 4 broader categories, representing the following activities: (1) sleep/leisure (mean = 10.45 hours, SD = 1.88); (2) school activities/playing with children (mean = 2.30 hours, SD = 1.62); (3) family farm/domestic tasks (mean = 9.98 hours, SD = 2.47); and (4) paid work outside the household (mean = 1.26 hours, SD = 1.26).

Home environment

Home stimulation environment. We used the Family Care Indicators (FCI) instrument, adapted from the Home Observations for Measurement of the Environment (Hamadani et al., 2010), for large-scale population surveys. The scale assesses the availability of play and learning materials in the household, as well as educational and play activities conducted with the child in the past three days by any household member over the age of 15. Enumerators recorded whether each of the 13 categories of play and learning materials was available and how many were observed. Maternal reports were used to determine the frequency of learning and play activities that occurred over the previous three days. Exploratory factor analysis revealed a two-factor structure: the first factor represents the availability of play and learning materials (alpha = 0.69), and the second factor reflects play activities (alpha = 0.76). These two factors were

standardized to have a mean of zero and a variance of one and were used in the analysis.

Control variables

Several variables were collected to account for observable characteristics of the child and mother that may be correlated with the outcomes or main independent variables. These variables include the child's age (in months), sex (0 = boy, 1 = girl), and birth order, as well as the number of children (individuals under the age of 18) living in the household, and the level of mothers' education. Additionally, we gathered information on household wealth through a combination of enumerator observations and mother reports regarding the quality of housing and family amenities. These data were combined into a single wealth index (alpha = 0.60), derived from exploratory factor analysis.

The Housing Quality items assess the structural conditions of the home that support health and safety, in line with WHO guidelines (2018). These items cover eight dimensions of the home's structure: the main source of drinking water, toilet facilities, the number of rooms in the house, the materials used for flooring, roofing, and walls, the type of cooking fuel used, and access to handwashing facilities. The Family Amenities items capture whether the household has access to electricity and which of 12 listed assets it owns, including items such as a box iron, electric iron, television, video player, satellite dish, bicycle, motorcycle, car, mobile phone(s), and radio. For each item, 0 indicates absence, and 1 indicates presence. Exploratory factor analysis revealed that the Housing Quality and Family Amenities items load onto a single factor. The final measure is this factor, standardized to have a mean of zero and a variance of one.

Analytical plan

To address the research questions of this study, we employ the following analytical strategies: First, we analyse descriptive statistics to characterize the study sample and summarize the average levels of the outcomes of interest. Second, we use nested linear regression models, adding blocks of variables sequentially to examine the relationships between the study variables. Specifically, we regress the outcome variable Y for child i on the explanatory variables, clustering standard errors, ϵ, at the school level. We proceed by including three blocks of explanatory variables: in the first regression, we incorporate B^1, a vector of variables related to the children's characteristics; in the second regression, we add B^2, a vector of variables pertaining to the children's mothers; and in the final regression, we include B^3, which contains variables related to the children's home environments. Additionally, we control for a vector of variables X. All variables in block regressed on cognitive factor aligned with the proximal-to-distal underpinnings of bioecological theory entering covariates first, then the children's independent variables (IVs), then the mothers' IVs, and then the home learning environments' IVs.

$$Y_i=\alpha+\beta^1 \ 〖B^1〗_i+\beta^2 \ 〖B^2〗_i++\beta^3 \ 〖B^3〗_i+\delta X_i \ + \epsilon_i \ (2)$$

In presenting the results, we focus on the beta coefficients (β) for clarity, omitting subscripts and superscripts. The β coefficient reflects the unique relationship between an explanatory variable and the outcome, while controlling for all other variables included in the regression. Additionally, we report comparison tests between nested models using F-statistics.

We note that the cross-sectional design of the present study makes the relationships between candidate correlates and child cognition reciprocal and dynamic. For example, parenting practices may influence children's literacy, numeracy, and executive function, or these components of child cognition may evoke parenting practices. In short, children and experiences exist in reciprocal relationships, and in the transactional perspective of human development, experience can influence the child, just as a child can influence experience. Consequently, in this report we avoid the language of 'causality' in favour of the language of 'association' and 'correlation'. This imposes limits on interpretation. At the same time, however, the revelation of strong associations between specific candidate correlates of childhood cognition and childhood cognition itself is descriptively powerful, valuable for hypothesis generation, and potentially key to tailoring effective interventions.

Results

Descriptive statistics

Table 1 presents information on the study sample. The table is structured to reflect the analytical approach, showing means, standard deviations and observed minimums and maximums of the variables in relation to the three blocks and covariates. Most of the variables presented in Table 1 feed directly into the subsequent multivariate regression analysis, for others (mainly indices such as wealth) we provide statistics on some of the underlying variables. Appendix A provides descriptive statistics for all variables entered into the analysis, as well as their zero-order correlation matrix.

Table 1: Descriptive statistics

		M/%	SD	Min	Max
Block 1: Child					
	Age (months)	58.21	9.00	42	77
	Sex (female %)	39.86	48.97	0	100
	Birth order	2.77	1.56	1	9
	Height (cm)	104.49	7.76	79	135
	Weight (kg)	16.08	2.71	8.7	33
	Stunting (%)	21.30	40.96	0	100
	Wasting (%)	15.57	36.27	0	100
Block 2: Mother					
	Mother has attended school (%)	45.76	49.84	0	100
aa1_d	Satisfied with herself overall	91.05	28.55	0	100
pr22_d	Felt depressed in the last 30 days	7.28	25.99	0	100
al4	Shouted, yelled at, or screamed at the child	20.64	40.49	0	100
al8	Called the child dumb, lazy, etc.	6.92	25.39	0	100
	Shares an affectionate warm relationship with the child	92.24	26.76	0	100
al3	Child is uncomfortable with physical affection or touch	32.76	46.95	0	100
Block 3: Home environment					
	Books	26.91	44.36	0	100
	Homemade toys	28.04	44.93	0	100
	Store-bought toys	20.82	40.62	0	100
ae5b_c	Tell stories to child	25.12	43.38	0	100
ae5e_c	Play with the child with toys	14.26	34.98	0	100
Other covariates					
	Number of under-18s in the household	3.63	1.74	1	15
	Household wealth:				
	Walls material: natural/rudimentary	48.75	50.00	0	100
	The house has some form of electricity	61.16	48.75	0	100
	Main source of toilet: open defecation	61.22	48.74	0	100

	Main source of water: unimproved source	23.09	42.15	0	100
	Dedicated handwashing space	6.92	25.39	0	100

Source: Own primary data.

Notes: Mean, SD, minimum and maximum values. The dependent variable is the children's cognitive ability based on the IDELA. Stunting and wasting correspond to height-per-age and weight-per-age, respectively, with z-scores of over three SDs under the mean, calculated using the WHO standardised age- and sex-specific growth reference (2006, 2007). For children where either the height-for-age z-score (HAZ) or weight-for-age z-score (WAZ) was out of range, but not both (19 for height and six for weight), the values for height and weight were replaced by the sample mean and were not included in the stunting and wasting variables. In the home environment panel, all the variables, excluding the number of under-18s, correspond to the percentage of the household with a certain object/characteristics.

The children in the analysis sample have an average age of 58 months, ranging from 42 months (3.5 years) to 77 months (almost 6.5 years). On average, these children are the third child of the mother (average birth order 2.77) and live in households with four members under the age of 18. Their average height is 105 cm and they weigh about 16 kg. Of the children, 21% are stunted (short for their age) and 16% are underweight (low weight for their age). Boys make up 61% of the sample, reflecting a notable gender imbalance. While this imbalance is not consistent with patterns of gender parity in school enrolment in Ghana or the study areas, it is consistent with evidence that attendance can be inconsistent and vary by gender. Research by Wolf et al. (2016) suggests that girls in primary schools in these contexts are more likely to drop out or skip school to perform domestic tasks or care for family members. As some of the assessments were conducted in schools, this gendered difference in attendance posed a challenge in identifying and including girls in the sample.

The living conditions for most of these children are very basic. Nearly half (49%) reside in homes with rudimentary walls, and close to 40% lack access to electricity. Sanitation facilities are minimal, with 61% of households practicing open defecation and 23% relying on unimproved water sources for their primary supply. Furthermore, only 6% of households have a designated space for handwashing.

The mothers in the study were, on average, 32.87 years old (SD = 6.84) at the time of data collection. Education levels were generally low: 54% had never attended school, 14% started but did not complete school, and 32% completed primary education. In line, 88% of mothers reported that they could not read at all (69%) and 19% stating they could read "with difficulty".

Most mothers expressed positive feelings about themselves, with 91% reporting they were generally happy, although 7% experienced feelings of depression within the last 30 days. Observed approaches to teaching children revealed that 21% of mothers shouted at their child, and 7% called their child "stupid" or "lazy." Despite this, 92% of mothers described their relationship with their children as loving and warm. However, one-third reported that their child feels uneasy with physical affection or touch from them.

Multivariate results

The main results of the correlations of children's cognition with child, maternal and household level variables are presented in Table 2.

Column (1) shows the relation between children's cognitive development and their physical growth, accounting for covariates. Results suggest that higher height-for-age z-scores are associated with higher levels of cognitive development, β=0.170, SE=0.028, p<0.01. The coefficient on the weight-for-age z-score is also positive, but smaller in magnitude (β=0.023) and not associated with children's cognitive development. This block of child-level variables is jointly significant; adding it doubles the proportion of the variance in the dependent variable that is explained, increasing the unadjusted R2 from 0.089 (not shown) to 0.170.

Column (2) adds the second block of variables relating to the children's mother. This block of variables increases the R2 of the model to 0.215 and variables are also jointly significant. The results suggest a positive relation between children's cognitive development and their mothers' cognitive ability, self-esteem, a positive approach to teaching and a non-violent approach to discipline, and their time allocation to leisure and play activities. Specifically, the better the mothers' attention and short-term working memory, the better the children's cognitive development, β=0.875, SE=0.198, p<0.01. Similarly, higher maternal self-esteem is associated with higher children's cognitive development, β=0.022, SE=0.008, p<0.01. Higher scores on positive approaches to teaching are associated with higher child cognition, β=0.233, SE=0.102, p<0.05, and non-violent discipline observed by enumerators during the interview has an estimated coefficient of β=0.254, SE=0.111, p<0.05. Finally, mothers spending an additional hour on leisure and/or sleep, rather than paid work, is also positively associated with children's cognition, β=0.050, SE=0.017, p<0.01. Spending an additional hour more directly with the children (doing school activities and/or playing with the child) has a weak positive correlation with the outcome variable of interest, β=0.040, SE=0.020, p<0.10.

Table 2: Multiple regression analysis; the dependent variable is child cognitive development

Block 1: Child				
	Z-score weight	0.023	0.017	0.017
		(0.032)	(0.032)	(0.032)
	Z-score height	0.170***	0.175***	0.173***
		(0.028)	(0.028)	(0.027)
Block 2: Mother				
	Cognitive skills		0.872***	0.908***
			(0.198)	(0.196)
	Self-esteem		0.022***	0.023***
			(0.008)	(0.008)
	Mental health problems		0.001	0.001
			(0.005)	(0.005)
	Relationship with child: close		-0.002	-0.001
			(0.006)	(0.006)
	Relationship with child: conflict		0.014***	0.014***
			(0.004)	(0.004)

Positive approach to teaching the child		0.233**	0.214**
		(0.102)	(0.101)
Negative approach to teaching the child		-0.036	-0.020
		(0.104)	(0.101)
Non-violent discipline		0.254**	0.235**
		(0.111)	(0.108)
Violent discipline		-0.295**	-0.280*
		(0.145)	(0.142)
Unpaid work (hours in typical day)		-0.008	-0.007
		(0.014)	(0.014)
Leisure and sleep (hours in typical day)		0.050***	0.047***
		(0.017)	(0.017)
School activities and playing with children (hours in typical day)		0.040*	0.038*
		(0.020)	(0.020)
Block 3: Home environment			
Stimulating activities			-0.036
			(0.029)
Learning materials			0.087**
			(0.034)
Number of observations	1,676	1,676	1,676
Unadjusted R2	0.170	0.226	0.231
Adjusted R2	0.165	0.215	0.220

Source: Own primary data.

Notes: OLS multivariate regression with covariates (age, sex, birth order, number of persons in the household aged 17 or younger, a dummy for whether the mother has some primary education, and an index of household wealth). The **dependent variable** is the children's cognitive ability based on the IDELA. **Block 1** includes variables on child physical growth, measured by child HAZ and WAZ, calculated using the WHO standardised age- and sex-specific growth reference (2006, 2007). When a child's HAZ or WAZ was out of range, we replaced the impossible value by the sample mean (19 cases for HAZ and six for WAZ). We include in the regressions dummy variables for children where HAZ or WAZ was replaced in this manner. **Block 2** includes variables related to the mother, and **block 3** includes variables related to the home environment, all constructed as described in the methods section. Standard errors clustered at the school level are shown in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Variables negatively correlated with children's cognitive development are mother-child conflict and violent discipline. The estimated coefficient for relationship conflict is β=-0.014, SE=0.004, $p<0.01$ and violent discipline has a negative coefficient of β=-0.295, SE=0.145, $p<0.05$.

Results suggest no significant correlation between children's cognitive skills and mothers' mental health problems, a close mother-children relationship, negative parenting behaviour and an additional time spent on unpaid, rather than paid, activities.

Adding this second block of variables increases the proportion of variation explained from 0.170 to 0.226 and does not change the relevance of child HAZ the estimated coefficient changes only slightly from β=0.170 to β=0.175, and the significance remains at $p<0.01$.

Column (3) adds the third and final block of variables to the regression, which helps to understand the importance of the home stimulation environment for children's cognitive development, over and above all the other explanatory variables already included in the model. Although the availability of learning

materials is positively correlated with children's cognition, β=0.087, SE=0.034, p<0.05, and the set of variables included in the regression is jointly significant, these variables only help to explain a small additional proportion of the variance in the dependent variable: the R2 increases from 0.215 to 0.220. The inclusion of this block of variables does not change any of the previously discussed results.

Discussion

The aim of this study was to gain a deeper understanding of how three sets of different correlates relating to the children, their mothers and their home environment relate to the level of cognitive skills of preschool children in rural Ghana, an under-researched, high-risk context. Overall, we draw three important conclusions.

First, our findings confirm that children's development is multi-dimensional in that one dimension (such as health) correlates with another dimension (such as cognition). The result that height-for-age is a significant positive correlate with child cognition aligns with existing literature, which shows that early-life deficits in height-for-age can have enduring impacts on health, cognitive development, and productivity (Hoddinott et al., 2008, 2013; Maluccio et al., 2009; Currie & Almond, 2011). Additionally, the observation that height-for-age, but not weight-for-age, is statistically significant supports the distinction between stunting (low HAZ) and wasting (low WAZ): stunting reflects long-term responses to chronic nutritional deficits, while wasting is typically a short-term (acute) reaction to inadequate food intake or infectious disease episodes.

Second, maternal factors emerge as important correlates with children's cognitive abilities. One of our main points of reference in making sense of this literature is the specificity principle, namely that specific experiences at specific times in early life affect specific aspects of children's development in specific ways (Bornstein, 2019, 2022). Whereas the overall level of parental stimulation was once thought to affect children's overall level of development, there is increasing evidence that specific parental activities are related to specific aspects of child development (Bornstein et al., 2013). For example, although we find that children's cognitive skills correlates positively with mothers taking a positive approach to teaching, we do not find that a negative approach correlates with lower skills. Similarly, although a mother-child relationship characterised by conflict is negatively associated with cognitive development, a close relationship characterised by warmth is not significantly associated. On the other hand, the way mothers discipline their children matters both ways: a violent approach is negatively related to cognition, and a non-violent approach is positively related. Overall, the results are remarkably consistent, with positive independent variables correlating with higher cognitive skills and negative independent variables correlating with lower cognitive skills.

Third, these specificities are important for informing policy makers and intervention researchers. Heckman noted that interventions need to take a multifaceted approach, recognising 'the importance of the family, the mechanisms through which families create children's skills, and the stresses under which many families operate' (Heckman, 2011, p. 6). However, the exact factors that mediate the effectiveness of interventions and lead to positive long-

term outcomes are not fully understood. Our findings may help to identify the most effective priorities for future intervention efforts, though establishing causality remains an important step for future research.

Limitations

This study has several limitations that should be taken into account when interpreting the findings. First, the analysis cannot establish causal relationships due to the cross-sectional and non-experimental nature of the data. While we accounted for several potential confounders, other observable and unobservable factors may influence the results, making it difficult to ascertain the direction and magnitude of the observed associations. Second, some measures, such as maternal wellbeing, are based on self-reports rather than clinical assessments. Third, while the study sample is representative of children attending public kindergarten in northern Ghana, the generalizability of the findings to other contexts remains uncertain, and further research is needed in other low-income countries.

Article information

Conflict of interest disclosures

Each author signed a form for the disclosure of potential conflicts of interest. No authors reported any financial or other conflicts of interest in relation to the work described.

Ethical principles

The author/s affirm/s having followed professional ethical guidelines in preparing this work. These guidelines include obtaining informed consent from human participants, maintaining ethical treatment and respect for the rights of human or animal participants, and ensuring the privacy of participants and their data, such as ensuring that individual participants cannot be identified in reported results or from publicly available original or archival data.

The study protocols for data collection have been approved by ethics boards at University College London (21361/001), Yale University (2000031549) and the Ghanaian Health Service Ethics Review Committee (028/09/21).

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None of the funders or sponsors of this research had any role in the design and conduct of the study; the collection, management, analysis, and interpretation of the data; the preparation, review, or approval of the manuscript; or the decision to submit the manuscript for publication.

Data availability statement

No data are currently available. The data used in this study were collected as part of a trial, registered under AEARCTR-0008500, ISRCTN15360698. The data will be made publicly available following the publication of the primary results from that trial.

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Appendix A

Table A1: Descriptive statistics of variables entering the regressions

		M	SD	Min	Max
Independent variable					
	Child cognitive skills	0.00	1.00	-1.99	3.55
Block 1: Child					
	Z-score weight	-0.94	1.19	-5.44	4.84
	Z-score height	-0.86	1.54	-5.99	5.83
Block 2: Mother					
	Cognitive skills	0.29	0.14	0	1
	Self-esteem	29.37	3.41	18	40
	Mental health problems	19.61	7.01	10	45
	Relationship with child: close	30.10	4.63	7	35
	Relationship with child: conflict	21.03	7.32	8	40
	Positive parenting behaviours	0.75	0.26	0	1
	Negative parenting behaviours	0.24	0.29	0	1
	Non-violent discipline	0.24	0.32	0	1
	Violent discipline	0.11	0.21	0	1
	Unpaid work (hours in typical day)	9.99	2.47	2	18
	Leisure and sleep (hours in typical day)	10.46	1.88	2	20
	School activities and playing with children (hours in typical day)	2.30	1.62	0	9
Block 3: Home environment					
	Stimulating activities	0.00	1.00	-0.71	3.15
	Learning materials	0.00	1.00	-0.72	6.89
Covariates					
	Child age (months)	58.21	9.00	42	77
	Child sex (female %)	39.86	48.97	0	100
	Birth order	2.77	1.56	1	9
	No. of children in the household	3.63	1.74	1	15
	Mother has attended school (%)	45.76	49.84	0	100
	Wealth index	0.00	1.00	-1.52	3.54

Table A2a: Zero-order correlation matrix independent variables

	Weight	Height	Cog. abilities	Self-esteem	Mental health	Rel. child: close	Rel. child: conflict	Positive teaching	Negative teaching	Non-violent disc.	Violent disc.	Unpaid work	Leisure & sleep	School & playing	Stim. activities	Learning materials
Weight	1.000															
Height	0.674***	1.000														
Cognitive abilities	-0.021	-0.076***	1.000													
Self-esteem	0.025	0.004	0.052**	1.000												
Mental health	-0.045*	-0.022	0.058**	-0.270***	1.000											
Rel. child: close	-0.027	0.002	-0.015	0.225***	-0.160***	1.000										
Rel. child: conflict	-0.019	-0.033	0.039	0.225***	0.364***	0.018	1.000									
Positive teaching	-0.042*	-0.013	-0.023	0.165***	-0.086***	0.063***	-0.046*	1.000								
Negative teaching	-0.016	-0.010	-0.014	-0.102***	0.157***	-0.255***	0.160***	0.203***	1.000							
Non-violent disc.	-0.054**	-0.045*	0.049**	-0.060**	0.055**	-0.108***	0.011	0.215***	0.263***	1.000						
Violent disc.	-0.008	0.013	0.023	-0.057**	0.094***	-0.090***	0.061**	0.103***	0.330***	0.498***	1.000					
Unpaid work	-0.075***	-0.051**	-0.081***	0.044*	-0.060**	0.125***	-0.091***	-0.043*	-0.076***	-0.036	0.012	1.000				
Leisure and sleep	0.028	0.046*	-0.080***	-0.022	-0.027	0.006	0.029	0.063***	0.005	-0.067***	-0.048**	-0.339***	1.000			
School and playing	0.046*	0.013	0.136***	-0.090***	0.090***	-0.248***	0.036	-0.041*	0.085***	0.102***	0.011	-0.481***	-0.261***	1.000		
Stimulating activities	0.082***	0.052**	0.090***	0.105***	-0.031	-0.052**	-0.036	0.007	0.009	0.050**	0.029	-0.081***	-0.110***	0.167***	1.000	
Learning materials	0.074***	0.071***	-0.002	0.047*	-0.064***	-0.033	-0.028	0.073***	-0.021	0.072***	-0.005	-0.135***	0.050**	0.104***	0.436***	1.000

Source: own data. Note: *** p<0.01, ** p<0.05, * p<0.1

Table A2b: Zero-order correlation matrix cofounders

	Age	Sex	Birth order	No. of children	Education	Wealth
Age	1					
Sex	-0.062**	1				
Birth order	0.034	-0.009	1			
No. of children	0.112***	-0.030	0.570***	1		
Education	-0.126***	0.042*	-0.257***	-0.214***	1	
Wealth	-0.042*	-0.030	-0.077***	-0.025	0.180***	1

Source: own data. Note: *** p<0.01, ** p<0.05, * p<0.1

Table A2c: Zero-order correlations of dependent variables with cofounders and independent variables

	Cognition
Cofounders	
Age	.061**
Sex	-.045*
Birth order	.061**
No. of children	.101***
Education	-.033
Wealth	.030
Independent variables	
Weight	.161***
Height	.238***
Cognitive abilities	.123***
Self-esteem	.064***
Mental health	-.033
Rel. child: close	-.027
Rel. child: conflict	-.107***
Positive teaching	.044*
Negative teaching	-.018
Non-violent disc.	.052**
Violent disc.	-.035
Unpaid work	-.100***
Leisure and sleep	.058**
School and playing	.079***
Stimulating activities	.022
Learning materials	.095***

Source: own data. Note: *** p<0.01, ** p<0.05, * p<0.1

Table A2d: Zero-order correlations of cofounders and independent variables

	Age	Sex	Birth order	No. children	Education	Wealth
Z-score weight	-.156***	.073***	.060**	.012	-.038	.019
Z-score height	-.142***	-.028	.045*	.028	-.067***	-.018
Cognitive abilities	.026	.002	-.096***	-.091***	.142***	.153***
Self-esteem	-.162***	.088***	-.038	-.049**	.082***	.153***
Mental health	.067***	-.039	.091***	.096***	-0.055**	-.062**
Rel. child: close	-.027	.014	.005	-.013	.091***	-.019
Rel. child: conflict	.035	-.059**	.013	.015	.014	.015
Positive teaching	-.084***	.054**	-.035	-.091***	.102	.026
Negative teaching	-.012	-.005	-.006	-.027	.011	.017
Non-violent disc.	-.005	-.031	-.061**	-.075***	.021	.019
Violent disc.	-.023	-.029	-.021	-.003	.028	-.041*
Unpaid work	.042*	.006	.089***	.144***	-.117***	-.170***
Leisure and sleep	-.048**	.041*	-.081***	-.101***	.051**	-.028
School and playing	-.017	-.052**	-.010	-.044*	.001	.131***
Stimulating activities	-.106***	.028	-.010	-.089***	.149***	.179***
Learning materials	-.120***	-.012	-.038	-.075***	.167***	.215***

Source: own data. Note: *** p<0.01, ** p<0.05, * p<0.

Table A3: Descriptive statistics of all variables underlying variables used in the analysis

		M/%	SD
PANEL A: Mother's characteristics			
Self-esteem			
	Is satisfied with herself on the whole	91.05	28.55
	Feels she has a number of good qualities	95.17	21.45
	Feels she is able to do things as well as most other people	93.68	24.35
	Feels that she is a person of worth	88.01	32.50
	Takes a positive attitude towards herself	94.27	23.24
	At times thinks she is not good at all	33.47	47.20
	Feels she does not have much to be proud of	59.31	49.14
	Certainly, feels useless at times	22.26	41.61
	Wishes she could have more respect for herself	87.71	32.84
	Is inclined to feel that she is a failure	18.97	39.22
Mental health problems			
	Felt tired for no reason	10.08	30.12
	Felt nervous	5.85	23.47
	Felt so nervous that nothing could calm her down	5.85	23.47
	Felt hopeless	7.70	26.66
	Felt restless	5.97	23.69
	Felt so restless that she could not sit still	5.25	22.31
	Felt depressed	7.28	25.99
	Felt that everything was an effort	26.49	44.14
	Felt so sad that nothing could cheer her up	6.80	25.19
	Felt worthless	5.73	23.24
PANEL B: Relationship with the child and discipline			
Relationship with child: close			
	I share an affectionate, warm relationship with my child	92.24	26.76
	My child will seek comfort from me	92.84	25.79
	My child values his/her relationship with me	92.18	26.85
	When I praise my child, he/she beams with pride	75.36	43.11
	My child spontaneously shares information about himself/herself	84.07	36.61
	It is easy to be in tune with what my child is feeling	75.89	42.78
	My child openly shares his/her feelings and experiences with me	83.17	37.42
Relationship with child: conflict			
	My child is uncomfortable with physical affection or touch from me	32.76	46.95
	My child and I always seem to be struggling with each other	34.19	47.45
	My child easily becomes angry at me	34.90	47.68
	My child remains angry or is resistant after being disciplined	42.42	49.44
	Dealing with my child drains my energy	29.89	45.79
	When my child wakes up in a bad mood, I know we're in for a long and difficult day	36.40	48.13
	My child's feelings towards me can be unpredictable or can change suddenly	34.96	47.70
	My child is sneaky or manipulative with me	30.67	46.13
Positive parenting behaviours			
	Informed the child that they are there to provide help if needed	77.39	41.85
	Responded positively when the child completed part of the task	89.80	30.28
	Focused the child when they lost interest	80.85	39.36

	Provided instructions contingent on the child's previous action	68.32	46.54
	Set rules or told the child how they expected him/her to behave	68.97	46.27
	Broke the task into small steps	65.87	47.43
	Turned the task into a game for the child	80.85	39.36
	Tried new strategies for teaching if one was not working	68.20	46.58
	Provided feedback	82.22	38.25
	Persisted despite difficulties	83.65	36.99
	Used descriptive words for objects or actions	55.07	49.76
Positive negative behaviours			
	Seemed largely disinterested in the task	21.96	41.41
	Appeared shy, timid, or underconfident in performing the task	23.93	42.68
	Displayed anger or hostility towards the child	15.39	36.10
	Acted intrusively, not allowing opportunities for the child to solve the problem on their own	32.88	46.99
Non-violent discipline			
	Took away privileges, forbade something	19.09	39.32
	Explained why the behaviour was wrong	29.47	45.61
	Gave the child something else to do	22.49	41.77
Violent discipline			
	Shouted, yelled at, or screamed at the child	20.64	40.49
	Called the child dumb, lazy, etc.	6.92	25.39
	Shook the child	11.69	32.15
	Spanked or hit the child on the bottom with bare hand	8.11	27.31
	Spanked or hit the child on the bottom with bare something	7.46	26.28
PANEL C: Household environment			
Learning materials			
	Books	26.91	44.36
	Magazines	4.30	20.28
	Homemade toys	28.04	44.93
	Store-bought toys	20.82	40.62
	Household objects	37.23	48.36
	Toys to play music	5.43	22.67
	Building blocks	3.52	18.43
	Things for drawing, painting, and writing	13.84	34.54
	Toys that encourage physical activity	13.96	34.67
	Toys that aid role play and fantasy games	7.94	27.04
	Children’s picture books	9.84	29.80
	Toys to learn shapes and colours	3.16	17.50
	Toys to learn vocabulary	2.92	16.85
Stimulating activities			
	Read books or look at picture books with child	17.78	38.25
	Tell stories to child	25.12	43.38
	Sing songs with child	25.54	43.62
	Take child outside the home	20.41	40.31
	Play with the child with toys	14.26	34.98
	Spend time with child in drawing, painting, or writing	6.03	23.80
Household wealth			
	Main source of water: unimproved source	23.09	42.15
	Main source of toilet: open defecation	61.22	48.74
	No. of rooms in the household	2.90	1.82
	Floor material: natural/rudimentary	31.50	46.47
	Walls material: natural/rudimentary	48.75	50.00
	Roof material: natural/rudimentary	29.65	45.69
	Unhealthy cooking fuel	98.99	10.02
	Dedicated handwashing space	6.92	25.39
	Box iron	22.08	41.49

	Electric iron	14.56	35.28
	Television	38.25	48.61
	Video player	7.10	25.69
	DVD Player	7.82	26.85
	MP3 player	17.66	38.15
	Satellite dish	29.95	45.82
	Bicycle	53.94	49.86
	Motorcycle	44.57	49.72
	Car	3.04	17.18
	Radio	35.14	47.76
	Electricity	61.16	48.75
	Mobile phone	96.78	17.66

Source: own data. Notes: All the variables, with the exclusion of number of rooms in the household, are dummies. The items in the **self-esteem** scale were originally on a four-point scale and were recoded to equal one if the mother answered agree or strongly agree. The items in the **mental health** scale were originally on a five-point scale and were recoded to equal one if the mother said she felt in a certain way most of the time or all of the time in the last 30 days. The items in the **relationship with the child** scales were originally on a five-point scale and were recoded to equal one if the mother answered somewhat applies or definitely applies.

Table A4: Dependent variable factor loadings

Variable	Loadings	Uniqueness
Size	.3821	.8533
Sorting	.5657	.6799
Shape	.4376	.8171
Number identification	.5851	.6577
One-to-one correspondence	.5825	.6607
Additions and subtractions	.6759	.5431
Puzzle	.5380	.7106
Vocal expression	.6024	.6371
Print awareness	.4768	.7727
Letters identification	.5022	.7478
Words pair	.4374	.8087
Writing level	.4901	.7598
Oral comprehension	.6031	.6362
Memory	.4176	.8256
Head to toes	.5664	.6792

Appendix B: Record of changes made to the IDELA

During the efficacy trial for the GES-LM programme, extensive piloting was run to ensure that the IDELA measure was adapted to the local context. As a result, a few minor changes were made to the original IDELA assessment (Amadu et al. 2018):

- Item 1(f). Dropped because almost all children got this question wrong during the two pilots.
- Item 7. Apples were replaced with mangoes as children in the study area were not familiar with apples.
- Item 8. We added a four-piece puzzle to serve as an example for the six-piece puzzle.
- Item 11. The picture of a cartoon child crying was changed to one of an African boy crying.
- Item 21. The triangle shape was replaced with a square shape as most children in this setting were more familiar with a square shape than with a triangle.
- Item 4. The hopping question was replaced with a pencil tap game.

Thrive

Thrive is a multi-country research programme that aims to support countries to turn what we know about positive early childhood development into practical, scalable, low-cost programmes, able to transform societies over multiple generations. Working closely with policymakers and other stakeholders, Thrive aims to build understanding of early childhood development service delivery models and how they can be provided cost effectively and at scale, and how these systems can innovate, improve, and better serve children and communities in low- and middle-income countries.

Our five focus countries are Bangladesh, Ghana, Kiribati, Sierra Leone and Tanzania.

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