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RESEARCH ARTICLE

Executive functioning skills and their environmental predictors among pre-school aged children in South Africa and The Gambia

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Abstract

Executive functions (EFs) in early childhood are predictors of later developmental outcomes and school readiness. Much of the research on EFs and their psychosocial correlates has been conducted in high-income, minority world countries, which represent a small and biased portion of children globally. The aim of this study is to examine EFs among children aged 3–5 years in two African countries, South Africa (SA) and The Gambia (GM), and to explore shared and distinct predictors of EFs in these settings. The SA sample (N = 243, 51.9% female) was recruited from low-income communities within the Cape Town Metropolitan area. In GM, participants (N = 171, 49.7% female) were recruited from the rural West Kiang region. EFs, working memory (WM), inhibitory control (IC) and cognitive flexibility (CF), were measured using tablet-based tasks. Associations between EF task performance and indicators of socioeconomic status (household assets, caregiver education) and family enrichment factors (enrichment activities, diversity of caregivers) were assessed. Participants in SA scored higher on

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all EF tasks, but children in both sites predominantly scored within the expected range for their age. There were no associations between EFs and household or familial variables in SA, except for a trend-level association between caregiver education and CF. Patterns were similar in GM, where there was a trend-level association between WM and enrichment activities but no other relationships. We challenge the postulation that children in low-income settings have poorer EFs, simply due to lower socioeconomic status, but highlight the need to identify predictors of EFs in diverse, global settings.

KEYWORDS
executive functions, global child development, socioeconomic status, South Africa, The Gambia

Research Highlights

- Assessed Executive Functioning (EF) skills and their psychosocial predictors among pre-school aged children (aged 3–5 years) in two African settings (The Gambia and South Africa).
- On average, children within each setting performed within the expected range for their age, although children in South Africa had higher scores across tasks.
- There was little evidence of any association between socioeconomic variables and EFs in either site.
- Enrichment activities were marginally associated with better working memory in The Gambia, and caregiver education with cognitive flexibility in South Africa, both associations were trend-level significance.

1 | INTRODUCTION

Executive Functions (EFs) refer to a set of top-down mental processes that support the pursuit of long-term goals, resilience to change and self-regulation (Diamond, 2013; Thompson & Steinbeis, 2020). EFs are comprised of three core components, including Inhibitory Control (IC; regulation of attention, behaviour and/or emotions), Working Memory (WM; the ability to retain information and utilise it) and Cognitive Flexibility (CF; flexible adaptation to change in the environment) (Diamond, 2013). EFs begin to develop during early childhood, with rapid growth in these skills observed during preschool age (Hendry et al., 2016). Individual differences in EFs are posited to be associated with an array of outcomes throughout the lifespan, such as academic achievement, mental health, and subjective wellbeing (Moffitt et al., 2011).

Household socioeconomic status (SES) has consistently been shown to predict EF skills and to also mediate the association between EFs and academic achievement (Hackman & Farah, 2009; Lawson & Farah, 2017). Consequently, it has been postulated that children growing up in poverty are at risk of negative outcomes due to disparities in EF development, with children in low- and middle-income countries (LMICs) bearing the brunt of this disparity (Ahmed et al., 2022; Haft & Hoeft, 2017; Obradović & Willoughby, 2019; Suntheimer et al., 2022) . Indeed, individual differences in EFs have been found to predict literacy, numeracy, socioemotional competence, and self-regulation among children in LMICs (Ahmed et al., 2022; Dutra et al., 2022; Salvador-Cruz & Becerra-Arcos, 2023; Willoughby et al., 2019; Wolf & McCoy, 2019a). However, recent cross-cultural research demonstrates that children from low-income settings, even those in the lowest-SES groups, perform equally well to their counterparts in High-Income Countries (HICs) on measures of EFs (Howard et al., 2020; Legare et al., 2018; Metaferia et al., 2021), which does not align with predictions derived very simply from low SES. In spite of this, much of the work examining EF development in these contexts is centred around a deficit model, focused solely on ameliorating the negative consequences of adversity (Ellis, Abrams, et al., 2022; Ellis, Sheridan, et al., 2022). This risk-centred perspective neglects to incorporate potential adaptive cognitive skills that develop in *response* to hardship (Ellis, Abrams, et al., 2022). A growing literature suggests that some individuals who live in environments with higher adversity develop equivalent, or even enhanced, EF skills, as these can help to navigate uncertainty and unpredictability (Ellis, Sheridan, et al., 2022; Mittal et al., 2015; Nweze et al., 2021; Young et al., 2018). In line with this, recent work from South Africa reported that even the most disadvantaged children in this setting outperformed middle- and high-SES participants in Australia on a tablet-based assessment of EFs (Howard et al., 2020). Taken together, these findings suggest that exposure to poverty does not inherently predispose children to having poorer EFs and that there is a more complex interplay of risks and protections. Analogously, the study of environmental predictors of EFs in LMICs vastly focuses on risk factors, thus overlooking the multitude of protective factors that could be harnessed in individual communities to foster healthy cognitive development.

1.1 | Impact of environmental and SES factors in LMICS of EFS

Research into the predictors of EFs in LMICs has largely focused on undernutrition and poor physical growth, which have widely been reported to negatively impact on child cognitive skills (Armstrong-Carter et al., 2020; Black et al., 2019; Obradović et al., 2019; Perumal et al., 2021; Sánchez et al., 2023). There is growing recognition of the impact of psychosocial factors – social enrichment from caregivers (both in terms of stimulative and educational activities) has been shown to have important implications for child EF skills (Haft & Hoeft, 2017). For example, Jasińska et al. (2022) demonstrated that both the home learning environment (e.g., having literate family members, access to books), as well as physical growth, contributed to schoolchildren's EFs in rural Cote d'Ivoire. Similarly, reading activities in the home were found to explain most of the association between SES and EF skills among 6-year-old children in Zambia (McCoy et al., 2015).

These associations, however, have not been found consistently across settings and it is posited that there is an interplay between caregiver characteristics (particularly education) and availability of enriching materials that result in better EFs (Obradović et al., 2016a; Wolf & McCoy, 2019a). For example, among families in rural Pakistan, maternal working memory has been associated with enhanced scaffolding, which, in turn, has a positive impact on child EFs (Obradović et al., 2016b, 2017a). Research with Mayan families in rural Guatemala has helped elucidate how western-style education systems impact on traditional parenting practices; parents with higher educational attainment tended to adopt a more directive approach to problem-solving tasks, similar to teachers in classroom settings (Chavajay, 2008, 2016; Chavajay & Rogoff, 2002). A more directive parenting style has been found to benefit self-regulation among children in LMICs because it increases compliance, which may be beneficial in areas of heightened adversity (Cook, Howard, et al., 2022). Parenting interventions aimed at increasing environmental enrichment and scaffolding have been shown to result in improved EF skills both in childhood (Obradović et al., 2017b) and adulthood (Walker et al., 2022).

Preschool attendance also plays an important role in early EF development as it provides additional opportunities to engage in cognitively stimulating activities and can help support children from low-income families, where caregivers may have less time and fewer resources for such activities (McCoy et al., 2018; Rey-Guerra et al., 2022). For example, in a rural area of Zambia, attendance to preschool was associated with improved school readiness, as well as self-regulation and attention (McCoy et al., 2017). Conversely, factors that may contribute to a less stimulating environment, such as caregiver poor health or depression, have been associated with poorer EFs across a number of settings (Familiar et al., 2020). Similarly, prior work in South Africa (using the sample from the present study population) showed that high exposure to stress was associated with poorer IC (Cook, Draper, et al., 2022).

It is important to note that in much of this foundational work there has been a prevailing emphasis on concepts deemed important in HIC settings, such as one-to-one parent-child interactions, generally focused exclusively on the mother, as well as ownership of books and educational toys (Morelli et al., 2017). However, these factors may not capture the reality of life in LMICs (particularly in rural areas), where people frequently live in kin-based clusters and children interact with a broader range of caregivers and social partners (Bradley & Corwyn, 2005; Morelli et al., 2017). Recent research is expanding the scope of enrichment to include activities commonly carried out in low-resource contexts, in the absence of toys, such as singing songs and telling stories (Rey-Guerra et al., 2022). Furthermore, the benefit of interacting with family members beyond only parents is being recognised. For example, Rathore et al. (2022) found that having a larger number of older siblings was associated with better EFs among children in Pakistan. Therefore, it is imsportant to build on this work to further characterise context-specific protective factors in EF development.

1.2 | Study context

In the present study, we used tablet-based assessments to examine EFs (WM, IC and CS) among children aged 3–5 years from communities in two settings – South Africa (SA) and The Gambia (GM).

Participants from SA were recruited from four low-income communities within the Cape Town Metropolitan area. The population in this area, as in the rest of SA, is highly diverse in terms of ethnicity, religion, and SES (Draper et al., 2023; Makiwane et al., 2017; McFarlane et al., 2016). Family structure is similarly multifaceted, with the presence of nuclear, single-parent, multigenerational, skipped-generational, and child-headed families (Makiwane et al., 2017; Sooryamoorthy & Makhoba, 2016). Extended family and the broader community have an important role in supporting families (Nkosi & Daniels, 2013), and there are many community organisations that provide nutritional, social, and educational support (Hall et al., 2019). Furthermore, SA has free, universal, education and approximately 97% of eligible children are enrolled in primary school (World Bank, 2020), although the legacy of apartheid continues to compromise the quality of the education provided for the most vulnerable children (Mlachila & Moeletsi, 2019). On the other hand, preschool education is not subsidised, and attendance rates are much lower, at 36% (Wills & Kika-Mistry, 2021). In spite of this, recent qualitative work suggests that caregivers place a strong emphasis on early childhood development and make great efforts to provide quality learning resources (Draper et al., 2023). These communities are exposed to several challenges, which have important impacts on children and families. Two of the communities consist of mostly informal housing or dwellings, while the other two contain both formal and informal housing. Informal dwellings are defined as makeshift structures, not approved by the local authority, and not meant for permanent residence. Therefore, overcrowding is an issue (population density 16,957.67 per km^2 and 10,120.31 per km^2), as are high rates of unemployment, food insecurity, alcohol abuse, crime and HIV (Statistics SA, 2011).

In GM, participants were recruited from the rural West Kiang region of the country. The community largely consists of subsistence farmers, who live in extended, multi-generational households (Brotherton et al., 2021; Kea, 2013; Sear & Mace, 2009). Childcare is viewed as a shared responsibility among family members, with grandmothers and older sisters having the biggest role in supporting parents (Brotherton et al., 2021; Sear & Mace, 2009). Islam is the predominant religion and raising children in accordance with religious and community values is of high importance (Sosseh et al., 2023). Since the introduction of free universal schooling in the last decade, enrolment in primary education has risen to 97% (CEICdata.com, 2018) and preschool education is also becoming increasingly available (Blimpo et al., 2015, 2022). This community also faces several challenges. In particular, the fluctuation in productivity of farming during the annual rainy and dry seasons means that there is variation in the availability of nutritious food throughout the year (Hennig et al., 2015; van der Merwe et al., 2013). The majority of the population live below the poverty line, with earnings of less than $2/day (The Gambia Bureau of Statistics, 2011) and rates of literacy are low, particularly among women (Hennig et al., 2015). Infectious disease is also highly prevalent and follows seasonal patterns (Hennig et al., 2015). These environmental factors have been shown to impact on child development, with many infants showing growth faltering from 3-months of age (van der Merwe et al., 2013).

1.3 | Present study

The aims of the present study are twofold; we seek to characterise early childhood EFs in these two settings and to examine the contribution of context-specific risk (low-SES) and protective (expanded network of caregivers, enrichment activities, caregiver education) factors to EF development, within each setting. These two contexts are dissimilar in many ways – the SA sample is urban, while the GM sample is rural, and they are separated by over 6000 miles. Therefore, it is not our goal to assume that they are equivalent in EFs. Instead, using the same EF measure in two distinct settings gives us an opportunity to identify predictors of EFs that are shared across LMICs and those that are uniquely relevant in specific populations. The distinction between common and shared predictors is an important one that adds richness and goes beyond direct cross-cultural comparisons.

Given prior work demonstrating normative or above average EF performance among children in low-income settings (Howard et al., 2020; Legare et al., 2018; Metaferia et al., 2021), we hypothesise that children in both SA and GM will score within the expected age-range on measures of EF, compared to normed data on the tasks. Comparisons of scores between SA and GM are exploratory and specific hypotheses regarding the differences and/or similarities between the data from these two contexts have not been stated. It is anticipated that the findings of this study will inform hypotheses of future studies comparing different cultural contexts. Furthermore, we predict that, within each setting, engaging in more enrichment activities, having a wider network of caregivers, and higher caregiver education will be associated with better EF skills, while lower SES will be associated with reduced skills.

2 | METHODS

2.1 | Participants

Two cohorts of participants were assessed, one in GM and one in SA. In GM, participants included 171 children aged 3- to 5-years (M_{age} = 4 years, 6 months, 49.7% female) and their caregivers. Participants were recruited as part of the Brain Imaging for Global Health (BRIGHT; www.globalfnirs.org/the-bright-project) project – a prospective longitudinal study examining child development from the antenatal period to preschool age in the rural West Kiang region. Families were initially recruited during an antenatal clinic visit to the Medical Research Council Unit The Gambia at the London School of Hygiene and Tropical Medicine (MRCG at LSHTM; www.mrc.gm;). Only members of the Mandinka ethnic group, the largest group in West Kiang (Hennig et al., 2015), were recruited to avoid confounds associated with translating measures into multiple languages. Infants were included if they were born between 37–42 weeks' gestation and had no diagnosis of a neurological condition, assessed during their postnatal checks. Mothers were initially seen at a 34–36 weeks' antenatal visit and the children were assessed at study visits during infancy (at 1–3 and 7–14 days, and 1-, 5-, 8-, 12-, 18- and 24-months) and at a pre-school age follow-up at 3–5 years (hereafter 'BRIGHT Kids'). Data used in the present study were collected at the BRIGHT Kids follow up. At the onset of the study, the sample consisted of 204 infants and 181 of the cohort consented for participation in the BRIGHT Kids follow up. Of these, three subsequently withdrew, six missed the study visit and one was excluded due to evidence of developmental delay, resulting in a final sample of N = 171 (for more information, please see Lloyd-Fox et al., under review). Ethical approval was given by the joint Gambia Government–MRC Unit The Gambia Ethics Committee (project title 'Developing brain function for age curves from birth using novel biomarkers of neurocognitive function', SCC number 1451v2 for BRIGHT and Understanding neurocognitive development at 3–5 years of age: The BRIGHT-Kids Study, SCC number 22737).

In SA, participants included 243 children aged 3- to 5-years (M_{age} = 4 years, 8 months; 51.9% female) and their caregiver from low-income settings in Cape Town, South Africa. Participants were recruited through community-based organisations in Cape Town, serving communities with limited access to Early Childhood Care and Education (ECCE) centres. Specifically, children who were not attending ECCE centres were recruited, as they represent a particularly vulnerable group that remains understudied. The procedures for this study were approved in advance by the Human Research Ethics Committee (Medical) at the University of Witwatersrand (reference: M200104). Written informed consent was provided by all participants (parent/caregiver consent for children).

2.2 | Measures

2.2.1 | Executive Functions

Executive Functions were assessed using tablet-based assessments from the Early Years Toolbox (EYT; Howard & Melhuish, 2017). Three tasks were used to assess the core components of EF –Mr Ant (WM), Card Sorting (CF) and the Go/No-Go (IC) tasks. While these tasks have not been developed for use in GM or SA specifically, they have previously been successfully implemented in SA (Cook, Draper, et al., 2022; Cook, Howard, et al., 2022; Cook et al., 2019; Howard et al., 2020). Furthermore, EYT measures have been translated, used, and validated in a variety of settings around the world, including Brazil (Murray et al., 2019) and South Korea (Chung et al., 2018).

Task instructions, presented as audio playing from the tablet, were translated into Mandinka for GM and Afrikaans and isiXhosa for SA, by staff who were native speakers of each language at their respective sites. Scores from each task can be situated into age-based quantiles (in 6-month age bands), based on norms from an Australian pre-school aged sample. Scores in the middle three bands (characterising the middle 60% of children) are considered to be within the expected range for a given age group. The top and bottom 20% are considered to be above and below expectation, respectively (http://www.eytoolbox.com.au/toolbox-norms).

Mr. Ant (working memory; WM) requires participants to recall the spatial locations of stickers placed on a cartoon ant. In each trial, stickers appear on Mr Ant for 5s, which is then replaced by a blank screen for 4s ('retention interval'). Mr Ant then re-appears, and the participant must tap on the location where they think they stickers were previously placed (presented until response is complete). The task consists of 8 levels of difficulty (progressing from 1 to 8 stickers), with three trials at each level. The task starts with three practice trials, followed by the test phase. The task continues until the participant fails three trials at the same level of difficulty or completes Level 8. Working memory is indexed by a point score, calculated as follows: starting at the first level, 1 point is awarded for each consecutive level in which at least 2 of 3 trials were performed accurately, plus 1/3 of a point for all subsequent correct trials.

The *Card Sort task* (cognitive flexibility; CF) requires participants to sort stimuli (red rabbits and blue boats) to one of two locations (signalled by a blue rabbit or red boat) by a sorting rule (colour or shape). Participants are instructed to begin sorting based on the first rule for six trials (pre-switch stimuli). Subsequently, the rule 'switches' and they must sort the stimuli on the alternate sorting rule (post-switch stimuli). If participants successfully sort at least 5 of 6 pre- and post-switch stimuli, they move on to the 'border phase'. In this phase, consisting of 6 trials, participants are asked to sort by colour if the stimulus has a black border or by shape if it has no border. Each phase starts with two practice trials and rules are reiterated prior to presenting the 6 stimuli. Cognitive flexibility is indexed as the number of correct sorts after the pre-switch phase. If a participant does not progress to the border phase, no credit is given for these trials.

The *Go/No-Go task* (inhibitory control; IC) is comprised of 'go' trials, where participants are instructed to tap the screen when a fish is presented, and 'no-go' trials, where they must resist touching the screen when a shark is presented. A majority of the stimuli (80%) are 'go' stimuli, creating a prepotent tendency to respond and requiring inhibition of this response on 'no-go' trials. Each trial presents an animated fish or shark for 1500 ms, with a 1000 ms interval between trials. The task starts with 20 practice trials and contains 75 test trials, divided equally across three blocks. Stimuli are presented in pseudo-random order across blocks, such that a block never begins with a no-go trial and there are never more than two successive no-go trials presented. Trials are excluded if the response patterns show evidence of automatic responding (i.e., response is faster than 300 sms), non-responsiveness (go accuracy is below 20% and no-go accuracy exceeds 80%) or indiscriminate responding (go accuracy exceeds 80%, while no-go accuracy is below 20%). Inhibition is indexed by an impulse control score, computed by multiplying the percent go accuracy by percent no-go accuracy. This reflects the ability to withhold a response in relation to the strength of the predisposition to respond.

2.2.2 | Enrichment activities and diversity of caregivers

Enrichment activities and diversity of caregivers were assessed using caregiver report questionnaires. In GM we used the *Family Care Indicators* (FCI; Kariger et al., 2012), which was developed by UNICEF to assess the home environment of children in LMICs. It is comprised of a series of yes/no questions, covering three categories: (1) the variety of play materials available in the home; (2) engagement in six types of enriching play activities (e.g., singing songs, counting or drawing) over the past 3 days and (3) the caregiver (aged 15 or older) that the child did the activities with (options included mother, father and "other", with a free text option provided to indicate who if other).

In SA, the *Home Learning Environment (HLE) Tool* (Dawes et al., 2020) was used to assess factors in the home that influence learning. This questionnaire was specifically developed for use in SA, by combining questions from the UNICEF Multiple Indicator Cluster Survey (https://mics.unicef.org) and the Home Learning Environment questionnaire (Melhuish et al., 2008), and was adapted to include items relevant to the local context. The HLE evaluates the home environment by asking about (1) the play materials available in the home; (2) how frequently (never, sometimes or many times) the child engaged in a set of eight enrichment activities over the last 7 days; and (3) the caregivers that they did the activity with (mother, father, aunt or uncle, grandparent, sibling or 'other', with a free text option also available if 'other').

Two variables were derived from these questionnaires – the **number of enrichment activities** (i.e., a sum of the different activities that the child did) and the **diversity of caregivers** (the number of unique caregivers that the child did activities with). For number of enrichment activities, the frequency data from the HLE in SA was converted into a sum (by counting the number of activities), rather than a frequency score, to make it more comparable with the FCI in GM. Because of the different number of possible activities listed (6 in GM, 8 in SA), the ranges of possible scores varied between SA (0-8) and GM (0-6). To derive the total number of caregivers, we counted the number of unique caregivers that the child did activities with, both from the available options and among those listed in the free text if 'other' was selected. In many instances, this included 'siblings', 'cousins' or 'friends's, but the number was not listed, therefore these groups were treated as representing a single caregiver.

2.2.3 | Household Assets

Household Assets were assessed at each site using questionnaire measures. Household assets are considered a more appropriate measure SES, or the relative status of a household within its community, than household income, in societies where income fluctuates by season (Howe et al., 2012).

In the GM, household assets were assessed via a combination of direct observation and participant report. Items assessed included housing materials and facilities, durable assets, and livestock ownership. An asset score was developed using polychoric principal component analysis (PCA). Details of the PCA and factor loadings are presented in Tables S1 and S2. The first component, which explained 21% of the variation was used as the asset score.

In SA, household assets were assessed using items from the National Income Dynamics Survey (http://www.nids.uct.ac.za), which is used across South Africa. More specifically, the household assets survey has 26 items (e.g., television, lounge set, cell phone, fridge, etc.), and the caregivers are asked to report whether their household has these items. The household assets score is a sum.

2.2.4 | Caregiver education

In both sites, the primary caregiver was asked how many years of school they completed and their highest qualification. The number of years of school completed was used in analyses. In SA, there was variation in who the primary caregiver was (e.g., parent, grandparent; see results), so we included caregiver education regardless of their relationship with the child. In GM, primary caregiver was almost always the mother, with two exceptions (see Results). However, we did not obtain information about caregiver education beyond the parents, so in both these cases we used maternal education in our analyses.

2.3 | Analysis strategy

2.3.1 | Demographic characteristics, identification of confounding variables and data preparation

Analyses were conducted in Jamovi V.2.3.0 (The Jamovi Project, 2001). Participant demographic characteristics, including age and sex distribution, were compared between groups using Kruskal-Wallis and chi-square tests, respectively in each site. In order to identify potential confounds, we checked whether performance on the EF tasks was associated with participant age and sex. In GM, age had a binomial, rather than normal distribution (see Lloyd-Fox et al., under review, for full details). To account for this, a dichotomous age variable was created by computing the median age of the entire sample (SA and GM combined) and dividing participants into *older* (median age and above) and *younger* (below median age) participants. Kruskal-Wallis tests were used to compare the two age groups' performance on the EF measures in each site. There was a significant age effect in both sites (see Results), thus age was controlled for in subsequent analyses. Similarly, Kruskal-Wallis tests were used to assess potential sex differences in task performance in each site. One trend-level sex difference emerged in WM performance in the SA sample (see Results) and, thus, sex was also controlled for in analyses (this was applied in both sites for consistency).

Distributions of EF task scores were examined for extreme outliers (a score $\pm$ 3SD from group mean). One outlier was identified on the WM task in GM and was removed for subsequent analyses (results with this outlier included are presented in the Supplementary Materials 3, Tables S4, and S5). In GM, there was missing data on each of the three tasks due to participant refusal – $N = 7$ for CF and WM, $N = 6$ for IC. Additionally, $N = 5$ participants did not have valid data on the IC task. In SA, missing data was also due to participant refusal – $N = 3$ for CF, $N = 7$ for WM and $N = 4$ for IC.

2.3.2 | Comparison of EF performance against task norms and across sites

To evaluate participant EF performance against task norms, scores on each of the three tasks were assigned to their age-matched quintile and the proportion of children that fell into each quintile group was compared. Quintiles were further categorised into *high* (top 20%), *average* (middle 60%) and *low* (bottom 20%) scores. Chi-square goodness of fit tests were used to compare the proportion of children in each site that fell into the high, average, and low categories. If a significant difference emerged between the three groups, follow-up chi-square tests were run, comparing each group against each other (with Bonferroni correction applied) to identify which groups significantly differed from each other. The number of children that fell into specific quintiles is summarised in the Table S3.

To compare task performance between the two sites, Analysis of Covariance (ANCOVA) was used. WM (Mr Ant) and CF (Card Sorting) and IC (Go/No-Go) tasks were entered as dependent variables, while site (SA/GM) was entered as the predictor, and age (older/younger) and sex were added as the covariates.

2.3.3 | Association between SES characteristics, home environment and EF performance

Linear regressions were used to assess the contribution of SES, enrichment activities, caregiver diversity, caregiver education and EF performance. EF tasks (WM, CF and IC) were entered as dependant variables. The number of enrichment activities, diversity of caregivers, household assets score, and caregiver education were entered as predictors. Sex and age (older/younger) were entered as covariates. It is important to note that the predictor variables were assessed using different measures, with different scales and range of scores in GM and SA. It was, therefore, deemed more appropriate to run a separate set of regressions within each site.

Prior to running the regressions, correlations between predictor variables were conducted to check for potential multicollinearity (see Tables S6 and S7). There was a strong correlation between enrichment activities and diversity of caregivers in GM. Because of this, we also report multicollinearity diagnostics (VIF and tolerance) for each regression. These values were within the acceptable range (VIF < 4, tolerance > 0.2; Miles, 2014; O'Brien, 2007) so we proceeded with the regressions. However, to ensure that the correlation between enrichment activities and number of caregivers in GM did not impact on the pattern of results, separate regressions were run for these two predictors and are presented in Tables S8 and S9.

3 | RESULTS

3.1 | Demographic characteristics and data preparation

Demographic, caregiver and household characteristics of the GM and SA cohorts are presented in Table 1. Participants in SA were significantly older than in GM $t(386) = 6.54$, $p < 0.001$. The median age of the two samples combined was 55-months, which was used to divide participants into older (GM $N = 79$, SA $N = 128$) and younger (GM $N = 92$, SA $N = 89$) age groups. Older participants had higher scores on each of the EF tasks in both GM (WM – $X^2(1) = 27.33$, $p < 0.001$, $\varepsilon^2 = 0.13$; CF – $X^2(1) = 9.43$, $p = 0.002$, $\varepsilon^2 = 0.04$; and IC – $X^2(1) = 22.67$, $p < 0.001$, $\varepsilon^2 = 0.11$) and SA (WM – $X^2(1) = 9.18$, $p = 0.002$, $\varepsilon^2 = 0.06$; CF – $X^2(1) = 6.65$, $p = 0.01$, $\varepsilon^2 = 0.04$; and IC – $X^2(1) = 34.12$, $p < 0.001$, $\varepsilon^2 = 0.21$).

Sex ratio did not differ in either GM ($X^2(1) = 0.01$, $p = 0.94$) nor SA ($X^2(1) = 0.33$, $p = 0.56$) or between the two sites ($X^2(1) = 0.16$, $p = 0.65$). In SA, girls ($M = 1.64$, SD $= 0.81$) scored marginally higher than boys ($M = 1.33$ SD $= 0.80$) on the WM task ($X^2(1) = 2.89$, $p = 0.09$, $\varepsilon^2 = 0.01$). There were no sex differences in CF ($X^2(1) = 0.25$, $p = 0.62$, $\varepsilon^2 = 0.001$) or IC ($X^2(1) = 1.43$, $p = 0.23$, $\varepsilon^2 = 0.01$). In GM, there were no sex differences in WM ($X^2(1) = 0.06$, $p = 0.80$, $\varepsilon^2 = 0.00$), CF ($X^2(1) = 2.51$, $p = 0.11$, $\varepsilon^2 = 0.02$) or IC ($X^2(1) = 0.91$, $p = 0.34$, $\varepsilon^2 = 0.01$).

3.2 | Performance on EF tasks

Summary scores for the WM, CF and IC tasks are presented in Table 2 and Figures 1–3. Overall, Participants in SA scored higher on the WM ($F(1, 370) = 56.2$, $p < 0.001$, $\eta^2 = 0.12$), CF ($F(1, 373) = 49.6$, $p < 0.001$, $\eta^2 = 0.11$) and IC ($F(1, 369) = 22.6$, $p < 0.001$, $\eta^2 = 0.05$) tasks.

The number of participants falling into the high, average, and low groups was assessed at each site. In GM, there were significant differences in the proportion of participants that scored within each group for the WM ($X^2(2) = 90.8$, $p < 0.001$), CF ($X^2(1) = 66.0$, $p < 0.001$) and IC ($X^2(2) = 43.7$, $p < 0.001$) tasks. For WM, more participants fell into the average group than the low ($X^2(1) = 25.9$, $p < 0.001$) or high ($X^2(1) = 81.4$, $p < 0.001$) groups and, when comparing low and high scoring groups, more children fell into the low than the high group ($X^2(1) = 22.3$, $p < 0.001$). Similarly, on the IC task more participants fell into the average group than either the low ($X^2(1) = 10.9$, $p < 0.001$) or high ($X^2(1) = 42.0$, $p < 0.001$) groups and, when comparing low and high scoring groups, more children scored in the low than the high group ($X^2(1) = 11.8$, $p < 0.001$). There were no participants that fell into the low group on the CF task.

Similar patterns were observed in SA, where there were significant differences in the proportion of participants who fell into each group for the WM ($X^2(2) = 128$, $p < 0.001$), CF ($X^2(1) = 12.6$, $p < 0.001$) and IC ($X^2(2) = 42.1$, $p < 0.001$) tasks. On the WM task, significantly more children fell into the average, than the low ($X^2(1) = 86.5$, $p < 0.001$) or high ($X^2(1) = 64.2$, $p < 0.001$) groups. There were no differences between the high and low groups ($X^2(1) = 2.68$, $p = 0.10$). Similarly, on the IC task, more children fell into the average, than the low ($X^2(1) = 30.6$, $p < 0.001$) or high ($X^2(1) = 23.8$, $p < 0.001$) groups. There were no differences between the high and low groups ($X^2(1) = 0.50$, $p = 0.48$). Finally, no participants fell into the low scoring group on the CF task.

3.3 | Associations between enrichment activities, caregiver diversity and education, household characteristics and EFs in each site

Table 3 summarises the regressions in the GM sample, showing the impact of enrichment activities, caregiver diversity, caregiver education and household assets on WM, CF, and IC, controlling for participant age and sex. The overall model predicting WM reached trend-level significance ($F(6, 125) = 1.93$, $p = 0.08$, $R^2 = 0.08$). While age was the only significant predictor of WM ($\beta = 0.38$, $p = 0.01$), there was a trend level association between enrichment activities and WM ($\beta = 0.10$, $p = 0.06$). The model predicting CF was not significant ($F(6, 126) = 1.62$, $p = 0.15$, $R^2 = 0.07$), but there were trend level associations between age ($\beta = 0.64$, $p = 0.07$) and sex ($\beta = 0.68$, $p = 0.06$) and CF. Finally, the model predicting IC was non-significant ($F(6, 126) = 1.62$, $p = 0.15$, $R^2 = 0.07$) and age was the only significant predictor of IC ($\beta = 0.19$, $p < 0.001$).

A summary of the regression results for SA is presented in Table 4. The overall model significantly predicted WM scores ($F(6, 203) = 5.93$, $p < 0.001$, $R^2 = 0.15$). Among the individual predictors, only age was significantly associated with WM ($\beta = 0.60$, $p < 0.001$), although there was also a trend-level association with participant sex ($\beta = 0.20$, $p = 0.07$). Similarly, the overall model significantly predicted CF scores ($F(6, 206) = 2.02$, $p = 0.06$, $R^2 = 0.06$), but age was the only significant predictor ($\beta = 0.93$, $p = 0.002$). Finally, the overall model predicting IC was significant ($F(6, 205) = 5.05$, $p < 0.001$, $R^2 = 0.13$). Among

TABLE 1 Demographic, caregiver, household characteristics of the GM and SA cohorts.

Characteristic	GM (*N* = 172)	SA (*N* = 243)
Age (months)	*N* = 171	*N* = 217
Mean (SD)	52.8 (5.06)	57.0 (6.91)
Range	45–63	35–70
Median	54 (84/87)	57 (108/109)
Sex distribution (male: female)	86:85	117:126
Primary caregiver information		
Primary caregiver interviewed (*N*)		
Mother	169	175
Father	0	11
Grandmother	1	41
Aunt	1	12
Other	0	4
Primary caregiver age (years, *M*, SD)	34.5 (6.64)	37.0 (11.20)
Primary caregiver education (years, *M*, SD)	2.75 (4.04)	9.98 (2.02)
Caregiver educational attainment (*N*, %)		
South Africa		
Did not attend school	-	0
Completed primary school	-	228 (94%)
Completed secondary school	-	63 (26%)
Completed post school qualification	-	38 (16%)
Gambia		
Did not attend school	90 (57%)	-
Completed lower basic school	36 (23%)	-
Completed upper basic school	24 (15%)	-
Completed senior secondary school	7 (4%)	-
Completed post school qualification	n/a	-
Household SES information		
Household asset score (*M*, SD)	−0.06 (1.39)	7.81 (2.91)
Enrichment activities and diversity of caregivers		
No. of enrichment activities (*M*, SD, range)	2.54 (1.90), 0–6	6.77 (1.46), 2–8
No. of unique caregivers (*M*, SD, range)	1.49 (0.93), 0–4	2.32 (1.28), 0–7

TABLE 2 Summary of executive functioning performance (Working Memory, Inhibitory Control and Cognitive Flexibility task scores) in the Gambian and South African cohorts, and the distribution of participant numbers across the low, average and high bands of task performance.

	Gambia					South Africa				
EF	*N*	*M* (SD)	Low	Average	High	*N*	*M* (SD)	Low	Average	High
WM	163	0.89 (0.79)	45 (27.6%)	108 (66.3%)	10 (0.06%)	211	1.55 (0.81)	25 (11.9%)	147 (70.0%)	38 (18.1%)
CF	164	6.11 (2.05)	0	134 (81.7%)	30 (18.3%)	214	7.73 (2.15)	0	133 (62.1%)	81 (37.9%)
IC	160	0.46 (0.23)	50 (31.3%)	89 (55.6%)	21 (13.1%)	213	0.59 (0.24)	45 (21.2%)	115 (54.2%)	52 (24.5%)

Note: Low, Average and High represent the number and percentage of children falling into the bottom 20%, middle 60% and top 20% performance bands, respectively.

Abbreviations: CF, Cognitive Flexibility; EF, Executive Functioning; IC, Inhibitory Control; WM, Working Memory.

TABLE 3 Summary of regression analyses used to predict executive functioning scores from measures of household assets, caregiver education, number of enrichment activities and diversity of caregivers in The Gambia

	B	SE	*t*	*p*	VIF	Tolerance
Working memory						
Intercept	0.50	0.18	2.71	0.01*	-	-
Age	0.38	0.14	2.71	0.01*	1.06	0.95
Sex	0.15	0.14	1.07	0.29	1.02	0.98
Household assets	−0.01	0.05	−0.11	0.91	1.02	0.98
Caregiver education	0.01	0.02	0.32	0.75	1.06	0.94
Enrichment activities	0.10	0.05	1.94	0.06+	2.06	0.49
Diversity of caregivers	−0.09	0.11	−0.81	0.42	2.07	0.48
Cognitive flexibility						
Intercept	5.38	0.46	11.69	<0.001**	-	-
Age	0.64	0.35	1.81	0.07+	1.05	0.95
Sex	0.68	0.35	1.94	0.06+	1.03	0.97
Household assets	−0.18	0.12	−1.43	0.16	1.02	0.98
Caregiver education	−0.02	0.04	−0.56	0.58	1.06	0.94
Enrichment activities	0.08	0.14	0.61	0.54	2.09	0.48
Diversity of caregivers	0.02	0.28	0.08	0.94	2.09	0.48
Inhibitory control						
Intercept	0.37	0.05	7.73	<0.001**	-	-
Age	0.19	0.04	5.24	<0.001**	1.05	0.95
Sex	0.04	0.04	1.20	0.23	1.03	0.97
Household assets	−0.000	0.01	−0.02	0.99	1.02	0.98
Caregiver education	0.002	0.004	0.53	0.60	1.06	0.95
Enrichment activities	0.001	0.01	0.10	0.92	2.11	0.47
Diversity of caregivers	−0.02	0.03	−0.68	0.50	2.12	0.47

*$p < .05$; **$p < .001$; +$p < .10$.

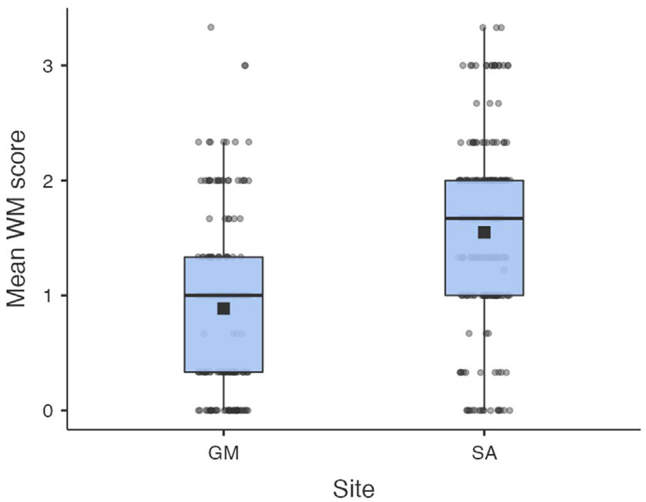

FIGURE 1 Boxplots showing the Mean, Standard Deviation and distribution of scores on the Working Memory (WM) task in both The Gambia (GM) and South Africa (SA). Black squares overlayed on the boxplots represent the mean scores, grey points are individual raw scores.

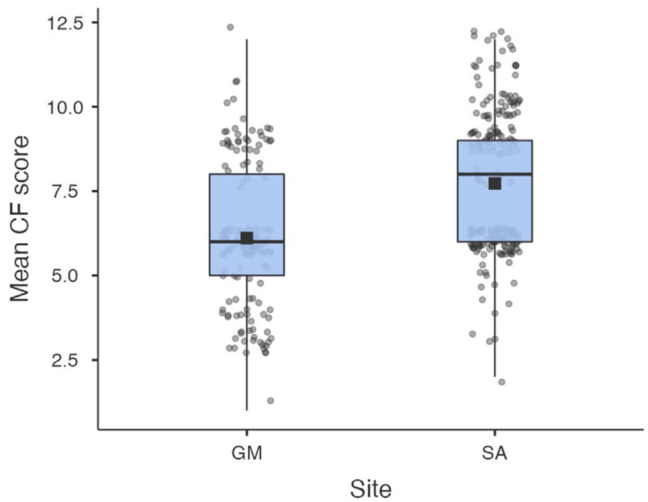

FIGURE 2 Boxplots showing the Mean, Standard Deviation and distribution of scores on the Cognitive Flexibility (CF) task in both The Gambia (GM) and South Africa (SA). Black squares overlayed on the boxplots represent the mean scores, grey points are individual raw scores.

TABLE 4 Summary of regression analyses used to predict executive functioning scores from measures of household assets, caregiver education, number of enrichment activities and diversity of caregivers in South Africa

Predictor	*B*	SE	*t*	*p*	*VIF*	Tolerance
Working memory						
Intercept	1.36	0.41	3.34	<0.001**	-	-
Age	0.60	0.11	5.54	<0.001**	1.02	0.98
Sex	0.20	0.11	1.84	0.07+	1.02	0.98
Household assets	−0.01	0.02	−0.50	0.62	1.12	0.89
Caregiver education	−0.01	0.03	−0.36	0.72	1.15	0.87
Enrichment activities	−0.02	0.04	−0.49	0.63	1.08	0.93
Diversity of caregivers	0.01	0.04	0.21	0.83	1.12	0.89
Cognitive flexibility						
Intercept	6.49	1.13	5.73	<0.001**	-	-
Age	0.93	0.30	3.10	0.002*	1.02	0.98
Sex	−0.10	0.29	−0.33	0.74	1.02	0.98
Household assets	−0.02	0.05	−0.32	0.75	1.12	0.89
Caregiver education	0.03	0.08	0.44	0.66	1.15	0.87
Enrichment activities	0.02	0.10	0.19	0.85	1.07	0.93
Diversity of caregivers	0.17	0.12	1.4	0.16	1.13	0.89
Inhibitory control						
Intercept	0.35	0.12	2.85	0.01*	-	-
Age	0.17	0.03	5.26	<0.001**	1.02	0.98
Sex	0.04	0.03	1.15	0.25	1.03	0.97
Household assets	0.003	0.01	0.61	0.54	1.13	0.88
Caregiver education	0.01	0.01	1.69	0.09+	1.15	0.87
Enrichment activities	−0.01	0.01	−0.49	0.62	1.09	0.91
Diversity of caregivers	−0.000	0.01	−0.07	0.94	1.12	0.90

*$p < .05$; **$p < .001$; +$p < .10$.

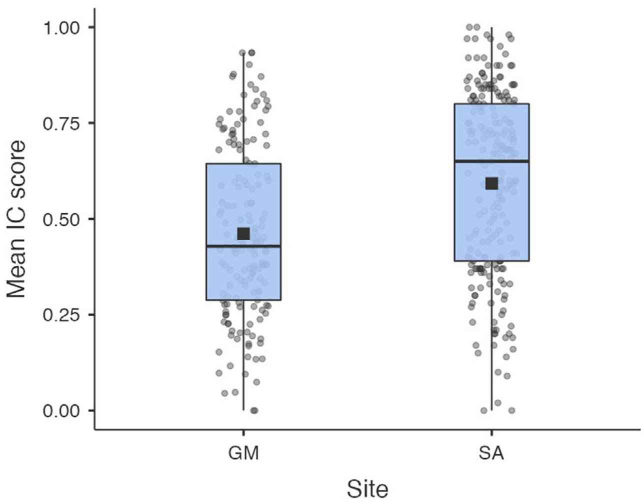

FIGURE 3 Boxplots showing the Mean, Standard Deviation and distribution of scores on the Inhibitory Control (IC) task in both The Gambia (GM) and South Africa (SA). Black squares overlayed on the boxplots represent the mean scores, grey points are individual raw scores.

individual predictors, only age was significantly associated with IC scores ($\beta = 0.17$, $p < 0.001$), although there was a trend-level association with caregiver education ($\beta = 0.01$, $p = 0.09$).

4 | DISCUSSION

The present study was among the first to examine EF skills (WM, CF and IC) and their psychosocial correlates among pre-school aged children in two distinct LMIC contexts, urban SA, and rural GM. The tablet-based EF assessments were successfully implemented into both settings and participant scores were largely within the expected range for their age on all tasks. There were no relationships between SES or family factors and EF skills, except for trend-level associations between enrichment activities and WM in GM, and caregiver education and CF in SA. With this work, we challenge the notion that growing up in a low-income context predisposes children to having poorer EF abilities. However, we also highlight the importance of further investigation into factors that do contribute to individual differences within these contexts.

4.1 | EF skills and evaluation of task performance

The three EYT tasks worked well in both GM and SA, based on multiple metrics that have previously been applied to evaluate performance on tablet-based EF tasks in other settings (Yuan et al., 2022). Valid data were collected from almost all participants and there were only several children that refused to partake in the tasks. Older children performed better than younger ones across tasks, which aligns with prior work demonstrating rapid EF development during pre-school age (e.g., Willoughby et al., 2012). It is important to highlight that the EF measures were developed and normed in Australia, a different cultural context from the ones examined in this study. However, these EYT assessments have been successfully implemented to assess EFs in a number of diverse cultural contexts, including SA, Brazil, and South Korea (Chung et al., 2018; Cook, Draper, et al., 2022; Cook, Howard, et al., 2022; Cook et al., 2019; Howard et al., 2020; Murray et al., 2019).

Increasing usage of tablet devices and smartphones in Sub-Saharan Africa, and the rest of the world, provides an opportunity for the implementation of these relatively low-cost devices into research and healthcare settings (Bhavnani et al., 2019; Chipps et al., 2015; Johm et al., 2021). We add to a growing literature, which suggests that tablet-based assessments of EFs can be successfully implemented into diverse cultural settings across LMICs (Amukune et al., 2022; Toor & Hanif, 2022). Furthermore, prior qualitative work in rural areas suggests that acceptability of tablet-based cognitive assessments is high among both caregivers and children (Bhavnani et al., 2019). In spite of this, it is currently not possible to be certain of the ecological validity of these tasks. Gaskins and Alcalá (2023) highlight the importance of using contextualised EF tasks, which are more embedded in children's real-world contexts. Therefore, additional work is needed to better understand the types of cognitive skills that are important for children across a more diverse range of contexts and populations.

Participants in SA scored higher on all three EF tasks, even after controlling for age (SA participants were slightly older on average) and sex. It is difficult to establish the reason for these site differences because the two settings are highly varied (e.g., one is urban and the other rural) and the two countries differ greatly in their economic and societal structures. We also used different measures and metrics to assess SES, making direct comparisons impossible. However, based on the information we were able to attain, there is evidence of disparity between the two sites. For example, on average, caregivers in SA had significantly higher educational attainment than in GM – most caregivers in SA had several years of secondary education, whilst fewer than half of mothers in GM had attended school at all. Caregiver education has been highlighted as an important predictor of child cognitive outcomes in low-resource contexts for a number of reasons; more educated caregivers tend to adopt more directive communicative strategies (Chavajay, 2008, 2016; Chavajay & Rogoff, 2002), provide more scaffolding (Obradović et al., 2017b) and are more likely to have a higher income and enrol children into early learning centres (Rao et al., 2021). Thus, it is possible that differences in resources and caregiver education between the two sites contributed to differences in scores, but this would need to be evaluated using measures that allow direct comparison.

In spite of this, children in both sites predominantly scored within the expected range for their age group on all tasks, based on task norms developed in an Australian sample (Howard & Melhuish, 2017). We replicate findings from prior work (Howard et al., 2020), which found that South African children (even those in the lowest SES-groups) had equivalent, or higher, performance than high-SES children in Australia on the EYT EF tasks. Therefore, we propose that, in spite of associations found between SES and EF skills in HICs (Hackman & Farah, 2009; Hackman et al., 2015), growing up in a low-income environment does not predispose children to having poorer EF skills. This supports the idea that we need to reconceptualise the context in which EFs are evaluated and be mindful of equating adversity with deficit (Miller-Cotto et al., 2022).

It is also noteworthy that participants at both sites performed well on the CF task, where no child fell into the bottom 20% quintile. It has been posited that childhood adversity may, in some instances, promote CF skill development, because efficient attentional shifting is a useful skill in unpredictable environments (Mittal et al., 2015). This notion is in line with prior work that examines CF skills in different risk groups. For example, Dahlman et al. (2013) found no differences in CF between homeless and housed children living in poverty in Bolivia. The authors propose that the additional risk of homelessness may be tempered by the skills that homeless children gain in self-management. Therefore, it is possible that the poverty-associated risks that are present in both the SA and GM settings contributed to greater attentional flexibility and regulation.

4.2 | Associations between EFs and household assets and caregiver education

In spite of the widely reported associations between EF skills and SES in HICs (Lawson et al., 2018), we did not find a relationship between household assets and EFs in GM or SA. It is important to note that there is more inconsistency in research that examines EFs and SES in LMICs (Mousavi et al., 2022). Taken together, these contrasting findings possibly reflect the complexity of adequately conceptualising SES in LMIC settings. In this study, we used household assets because this has been reported to be a more stable indicator of relative SES within communities where income fluctuates by season (Howe et al., 2012). However, a multitude of other factors that are associated with SES, such as undernutrition and food insecurity (Obradović & Willoughby, 2019), could contribute to EFs more than household assets alone.

Furthermore, it is possible that heterogeneity in assets becomes relevant only above a certain threshold of SES (Husseini et al., 2018). For example, in a Madagascan sample, Fernald et al. (2011) only found significant differences in EFs between children from the highest and lowest SES quintiles, and those whose mothers had secondary education versus no education. It is possible that neither the GM nor SA samples had sufficient variation in SES and caregiver education for there to be a significant relationship with EF skills. However, the trend-level association between caregiver education and CF scores in SA signals a potential relationship, which could be elucidated in future work by including caregivers with more diverse educational backgrounds.

4.3 | The protective role of caregiver enrichment

There is growing interest in how enrichment activities and social stimulation from caregivers can offset the adverse impacts of poverty on both EF skills (Obradović & Willoughby, 2019) and general cognitive development (Perkins et al., 2017). Prior work in LMICs has demonstrated that educational play (e.g., reading with caregivers) results in gains in EF development (Jasińska et al., 2022; Wolf & McCoy, 2019b). In spite of this, we only found a trend-level association between enrichment activities and WM in GM, and no other relationships in either site. It could be argued that enrichment activities and social stimulation are particularly beneficial for cognitive development among children who are at risk of adverse cognitive outcomes or those who are severely under stimulated (Perkins et al., 2017). However, neither the children in GM nor SA showed evidence of poor EF development on average, as the majority scored within expectation for their age. It may be important for future research to re-evaluate these associations among children who show very poor performance on EF tasks or those who have exposure to other risk factors (e.g., poor health, undernutrition, very unstimulating environments). Within our study, there were too few children in either site that had very poor EF skills to conduct meaningful subgroup analyses.

In spite of this, the trend-level association between enrichment activities and WM in GM is encouraging and suggests that a relationship may be detected with a more diverse sample of children. However, this association did become non-significant when the extreme outlier (very high score) was included.

There were no associations between diversity of caregivers and EF skills. It is possible that the complexity of the family structure and interactions goes far beyond what could be captured using a single variable to compute the number of distinct caregivers. While the kin-based living arrangements in LMICs have previously been discussed (Bradley & Corwyn, 2005; Weber et al., 2021), very little investigation has actually been done into the role of different caregivers in child rearing and more qualitative work needs to be done to better characterise family dynamics in global contexts. We were also unable to capture the number of siblings partaking in enrichment activities, which is limitation given that prior work in Pakistan has highlighted that having more older siblings promotes EF development (Rathore et al., 2022). It is also possible that an increased number of caregivers has a dual effect, representing both protective and risk factors. While extended family can be a source of stimulation, they can also signal household overcrowding and reduced availability of primary caregivers.

Finally, the role of preschool education was not assessed in this study and that the SA sample specifically consisted of children who were not enrolled in ECCE centres. There is a multitude of evidence around the world, linking preschool attendance with improved cognitive and educational outcomes (Bietenbeck et al., 2019; Rao et al., 2021; Woldehanna, 2012). Preschool attendance is posited to be particularly beneficial for children from low-income families, who may have fewer resources enriching activities at home (Rey-Guerra et al., 2022). However, the association between formal education and EFs in LMICs is not reported consistently (Dutra et al., 2022) and future work is needed to examine the impact of preschool and school attendance on EFs in communities similar to the ones studied here.

5 | CONCLUSION

The present study contributes to a growing body of research that examines EF development in LMICs. In line with prior work (Howard et al., 2020), we challenge the notion that conclusions drawn about SES and EF development drawn in HICs are applicable globally. We found no evidence that growing up in a low-income setting predisposed children to having poorer EF skills or any association with SES within each site. However, there is now a pressing need to identify the factors that contribute to EF development in low-resource settings in the global south. In particular, there needs to be better characterisation of SES and family dynamics to better understand both the risk and protective factors in low-resource environments.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data supporting this paper will be made available subject to established data sharing agreements.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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