Modeling the associations between socioeconomic risk factors, executive function components, and reading among children in rural Côte d'Ivoire

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Abstract

Executive Functions (EF; inhibitory control [IC], cognitive flexibility [CF] and working memory [WM]) mediate the relationship between socioeconomic status and reading. However, little is known of the roles of individual EF components in mediating the socioeconomic-reading achievement gap, especially in low- and middle-income countries. In Côte d'Ivoire, children experience many socioeconomic disadvantages (i.e., fewer household resources, maternal illiteracy), and kinship fostering (child in care of extended family while parents pursue economic opportunities elsewhere) is prevalent. This study examines the relation between EF components, socioeconomic risks, and reading among 5th grade children in rural Côte d'Ivoire (N=369). Poorer WM mediated the relationship between higher cumulative socioeconomic risk (poverty, maternal illiteracy, fostering) and lower reading scores. Further, WM fully mediated the negative effects of fostering risk on reading scores. Results suggest that EF components are differentially impacted by environmental socioeconomic risks and play different roles in supporting reading development.

Keywords: executive functions, working memory, literacy, socioeconomic risk, Côte d'Ivoire, sub-Saharan Africa

Introduction

Executive functions (EF[1]) refer to a set of cognitive mechanisms — including inhibitory control (IC), cognitive flexibility (CF), and working memory (WM) — that play a central role in supporting learning outcomes such as reading (Blankenship et al., 2019; Cartwright, 2012; Johann et al., 2020; Kieffer & Christodoulou, 2020; Morgan et al., 2019). The development of EFs in childhood is associated with family socioeconomic status (SES), including factors such as nutrition, access to resources, parental literacy, and stimulating home environments (Fernald et al., 2011; Hackman et al., 2014; Hackman & Farah, 2009; Netten et al., 2016; Pan et al., 2017; Sarsour et al., 2011). Existing literature suggests that EF may mediate the relation between SES and reading ability (Albert et al., 2020; Corso et al., 2016) such that SES influences EF development, which in turn influences reading skills. However, our understanding of how individual components of EF mediate the SES-reading achievement gap is limited, particularly among children in socioeconomically disadvantaged communities outside of high-income countries (HICs). The current study addresses this gap in the developmental literature by investigating links between EF components, SES, and reading ability in children growing up in rural Côte d'Ivoire. While a majority of previous research has focused on reading development in HICs, children from low- and middle-income countries (LMICs) often face unique social and economic risks that differ in severity and nature from those experienced in HICs. To more fully understand the cognitive pathways underlying the links between SES and reading achievement among children in LMICs we ask

[1] Abbreviations

EF	Executive Functions
IC	Inhibitory Control
WM	Working Memory
CF	Cognitive Flexibility
SSA	sub-Saharan Africa
HIC	High-Income Country
LMIC	Low- and Middle-Income Country

1) Do all EF components (WM, IC, and CF) similarly support reading? 2) Do all EF components mediate the relation between family risk factors associated with low SES and reading ability? By examining how individual EF components mediate the link between SES and reading ability, we can better understand how to leverage cognitive processes in supporting reading development among children from low SES backgrounds in LMICs.

Executive Functions

EF is an umbrella term that refers to a set of interrelated cognitive skills and processes supporting contextually appropriate, self-directed, and goal-oriented behavior. Individual differences in EF can translate into significant functional disparities and predict academic outcomes from early childhood (Montoya et al., 2019; Willoughby et al., 2019). EFs are typically conceptualized as three core components: IC, WM, and CF (Diamond, 2013).

IC involves selective attention (e.g., ignoring salient stimuli), cognitive inhibition (e.g. resisting unwanted thoughts), and self-control (e.g., controlling unwanted behaviors and emotions; Diamond, 2013). At its core, IC represents an effort to act in resistance to established impulses or environmental distractors and selectively behave in a contextually-appropriate manner.

WM involves maintaining and manipulating information in the mind, which is essential in relaying task-relevant information and adapting to novel tasks. The role of WM extends beyond simply storing information (referred to as short-term memory), to include manipulation of stored information. Diamond (2013) classifies WM as essential for anything that involves understanding information that "unfolds over time" (Diamond, 2013, pp.7) such as reading, understanding spoken language, and making connections between concepts.

CF refers to the ability to update and shift cognitive processes and behavior based on contextual demands (Diamond, 2013). This can involve problem-solving, creative thinking, simultaneously thinking about multiple concepts, and using multiple perspectives. CF often

builds on the other EF components (IC and WM; Peters & Crone, 2014). For instance, inhibiting irrelevant information is necessary to stay on task and to maintain/manipulate information within the mind to adapt to environmental demands.

EF and Reading

EF have consistently demonstrated significant influence on reading development, with all three components of EF associated with reading scores (Blankenship et al., 2019; Cartwright, 2012; Johann et al., 2020; Kieffer & Christodoulou, 2020; Morgan et al., 2019). IC supports the ability to inhibit reactions to distractions and selectively attend to reading material (Johann et al., 2020). WM, the most frequently studied of the three components, enables emergent readers to hold sounds and letters in mind and manipulate them to form words and sentences (Loosli et al., 2012; Nevo & Breznitz, 2014; Swanson et al., 2011; Welsh et al., 2010). CF, which facilitates mental shifts between perspectives and concepts, also plays an important role in the reading comprehension process and is predictive of overall reading achievement scores (Colé et al., 2014; Hung & Loh, 2021; Magalaes et al., 2020).

Unique Associations of EF Components with Reading

Although considerable literature demonstrates the relation between EF and reading, findings are mixed regarding the relative roles that each EF component plays. While some studies point to a greater role of CF and WM in predicting reading skills over IC (Engel de Abreu; Lan et al., 2011), other studies have found that IC significantly predicts reading over WM (Rezaei & Jeddi, 2020), or that both IC and WM predict reading while CF does not (Zou et al., 2022). Overall in previous studies conducted in HICs, WM displays the strongest predictivity for reading achievement among the EF components (Chang, 2020; Zou et al., 2022). A meta-analysis of 299 studies of children ages 3-16 years found that WM and IC, rather than CF, were more significantly associated with early reading

achievement (Spiegel et al., 2021). Specifically, for children in higher elementary grades, WM emerged as the strongest contributor to reading achievement among the three components. Similarly, another meta-analysis of children between the ages of 6-12 years examined how specific EF components contribute differentially to academic performance in primary school and observed that WM displayed the highest predictivity of academic performance compared to IC and CF (Cortés Pascual et al., 2019). Therefore, it is evident that EF components differentially support reading skills, with WM demonstrating the strongest contributions to reading and overall academic achievement.

EF & Reading in LMICs

Although most current findings on EF and reading are derived from research conducted in HICs, similar patterns of association between these two variables have been observed in LMICs. For instance, Wolf and McCoy (2019) examined longitudinal associations between Ghanaian kindergarten children's EF and reading skills across a two-year period. Their results suggested a bi-directional developmental association between EF and reading; earlier EF was predictive of higher future reading skills, and conversely, reading ability was also predictive of higher EF. Similar work by Ahmed et al. (2022) investigated how different approaches to measuring EF translate to reading outcomes. The finding indicated that although directly assessed EF skills were not significantly associated with reading, teacher and assessor-reported EF skills were significantly predictive of children's reading performance. Other studies in LMICs have also demonstrated significant contributions of EF to reading development among children in rural Côte d'Ivoire (Jasińska et al., 2022), Ghana (Suntheimer et al., 2022), and Kenya (Willoughby et al., 2019). Therefore, despite the considerable degree of contextual differences observed between HICs and LMICs, there is a growing body of literature demonstrating the

existence of similar patterns of association between EF and early reading within both contexts.

Socioeconomic Risk Framework

SES encompasses an array of co-occurring social and economic factors — such as financial status, educational attainment, and occupational standing — that predict access to resources for children across the globe (Larson & Halfon, 2010; Perry & Mcconney, 2010; Raso et al., 2005; Wolf & McCoy, 2019; Zhang, 2006; Zuilkowski et al., 2019). Limiting the measurement of SES to single risk factors may fail to accurately capture the developmental consequences of the various additive socioeconomic factors in a child's life. Cumulative risk is a widely used framework for establishing how multiple co-occurring socio-economic risks impact children's development. Cumulative risk scores are calculated by converting each risk factor (i.e. financial status, parental occupation, access to education etc..) into a dichotomous score of 0 or 1 (where 0 indicates no risk and 1 indicates risk), which are then combined as a way to indicate the degree of risk present within a child's environment. Evans and English (2002) observed that children living at or below the poverty line in America experience a greater number of risk factors in their environment, and this increase in the number of risk factors is directly associated with adverse outcomes in childhood (Appleyard et al., 2005; Atkinson et al., 2015; Bauman et al., 2006; Evans et al., 2013; Stanton-Chapman et al., 2004).

Most research examining the effects of adverse socioeconomic conditions has been conducted in HICs, where social and economic contexts differ significantly from those in LMICs. These disparities are especially pronounced in poverty-stricken areas such as rural Côte d'Ivoire, a sub-Saharan African (SSA) nation with a history of economic crises and social instabilities that have had far reaching effects on education systems and families. The comparatively sparse research on childhood development in Côte d'Ivoire limits our understanding of how socioeconomic determinants in poverty-stricken areas influence

cognitive development and academic outcomes.

Child Development Contexts in Côte d'Ivoire

Children in Côte d'Ivoire often fail to learn to read despite several years of primary education due to factors such as delayed school start, high rates of grade repetition, and multigrade classes (PASEC, 2014; Smith-Greenaway, 2015). Reading achievement gaps are especially pronounced in rural areas, where higher poverty rates and lack of social investment make children especially vulnerable to educational barriers (The World Bank, 2018; Strauss, 1990). Girls in particular are more susceptible to experiencing socio-cultural constraints — such as early marriage, gender based violence, and child labor — which is reflected in lower educational participation, progress, and completion (Ombati & Mokua, 2012; UNESCO Institute for Statistics, 2022). These factors can have intergenerational impacts; for example, maternal education and literacy has significant implications on children's overall health and development (Abuya et al., 2012; Monden & Smits, 2013). Practices surrounding reading and language within Côte d'Ivoire are also shaped by the multilingual nature of its institutions and local communities. French, the official language and lingua franca, is used for instruction in educational institutions across the nation, despite Ivorian children speaking various regional Ivorian languages (Djamou, 2006; Jasińska et al., 2023; Jasińska & Guei, 2022). Naturally, this puts children at a disadvantage as receiving early education in one's native language - as is often observed in HICs - is associated with improved educational outcomes and may therefore contribute to the poor reading achievement observed in Côte d'Ivoire (The World Bank, 2021).

Contextual differences in children's developmental experiences in Côte d'Ivoire also extend to basic household organization and practices. Across SSA, social structures center around extended family systems rather than nuclear family units, and this influences childcare practices as financial costs and responsibilities are often distributed across a network of kin

rather than falling solely on parents (Antoine & Guillaume, 1986; Stecklov, 2002). One such practice is fostering, defined as the occurrence of non-adopted/orphaned children living away from both parents (Ainsworth, 1989; Cotton, 2021). This is often an economic contract where the fostering households may expect to benefit financially or receive child-labor from the fostered child (Ainsworth, 1989, 1996). In Côte d'Ivoire, the rural population has decreased while migration to urban centers for economic opportunities has increased; the rate of urbanization increased from 17.7% in 1960 to 50% in 2018 (The World Bank, 2018). Although research on economic impacts on fostering practices in Côte d'Ivoire is scant, evidence from SSA suggests that economically-driven parental migration to urban centers may encourage child fostering (Cotton & Beguy, 2021). Household predictors of fostering-out children include maternal marital status (being unmarried), employment (working as opposed to being a homemaker), as well as the total number of children within the household (Cotton, 2021; Isiugo-Abanihe, 1985). Furthermore, children who are fostered tend to spend more time performing farm work and often display adverse educational outcomes such as lower school enrollment, attendance, and progression, especially when the fostering family is of distant kin (Hampshire et al., 2015; Hedges et al., 2019).

SES, EF, and Reading

Associations between socioeconomic factors (e.g. household resources, access to schooling, parental education) and the development of EF are well documented (Bradley et al., 2001; Fernald et al., 2011; Hamadani et al., 2014). For instance, Jasińska et al. (2022) observed that factors associated with home learning environments (e.g. having literate parents and receiving help with homework) and adequate nutrition for physical development were predictive of EF development among primary school children residing in rural Côte d'Ivoire. SES-related achievement gaps have also been observed from the early stages of reading acquisition as children develop skills such as letter naming, sound knowledge, and early word

reading (Aram et al., 2013; Dodd & Carr, 2003; Horton-Ikard & Weismer, 2007). A growing body of evidence from HICs indicates that these gaps can be understood by considering SES-related differences in home literacy environments (HLEs), as parents with greater economic resources tend to provide their children with more books (Liu et al., 2018), engage their children in more daily verbal interactions (Hart & Risley, 1995), and are more likely to adjust their speech based on the age of their children (Farran & Haskins, 1980; Heath, 1983). Similarly, in low-income contexts, an increase in reading materials within the home as well as parent-child reading interactions were associated with improved reading among children (Mendive et al., 2020; Zuilkowski et al., 2019). However, a study by Dulay et al. (2018) in the Philippines reported limited associations between home-literacy activities, literacy resources, and children's literacy skills. Their findings suggested that the presence of literacy resources and activities may not be sufficient to support children's literacy skills if those resources are not adequately used/understood and parents' own literacy skills or scaffolding abilities are inadequate. Therefore, contextual factors within populations living in LMICs may influence the replication of previously observed associations between home-based SES factors and reading achievement in HICs.

Mediating Role of EF

EF has a mediating effect on the well-known relation between SES and reading. However, the existing literature on the mediating role of EF between SES and reading is limited, often inconsistent, and concentrated in high-income contexts. While some studies report a mediation of EF in the SES-reading achievement gap (Corso et al., 2016; Crook & Evans, 2014; Albert et al., 2020), other studies have failed to observe this association (Fitzpatrick et al., 2014; Lawson & Farah, 2017; Waters et al., 2021), contributing to gaps in our understanding of the underlying role of EF in the SES-reading gap. Several questions remain regarding how EF predicts reading among low SES children living outside of HICs.

However, evidence from a growing number of recent studies in LMICs indicates that EF may continue to mediate between SES and reading within these contexts. For instance, Jasińska et al. (2022) observed a mediation effect of EF in the relation between SES and literacy among primary school children in rural Côte d'Ivoire. Similarly, Suntheimer et al. (2022) studied literacy outcomes among 3rd and 4th graders living in Ghana and observed that EF accounted for 65.3% of the total effect of cumulative socioeconomic risk on literacy. However, these studies examine the role of EF as a single variable without considering its composite nature and how individual components may contribute uniquely to reading development. By using a component-based approach to studying EF, we can more accurately decipher whether EF plays a mediating role in the SES-reading achievement gap and gain further insight into how distinct EF processes support the development of reading skills in impoverished contexts.

Current Study

The current study aims to extend our understanding of the relation between socioeconomic risks, EF components, and emergent reading skills of children in rural Côte d'Ivoire. Although the SES-reading achievement gap is well-documented in the existing literature, little is known about the underlying cognitive mechanisms that mediate the relation between socioeconomic risks and reading, especially among children living in impoverished communities in LMICs. Building on previous findings demonstrating a mediating role of EF between family SES and reading, the current study investigates individual components of EF (IC, WM, and CF) in relation to a cumulative framework of socioeconomic risk (including household resources, maternal literacy, presence of parents at home/fostering) and children's reading skills. We asked the following research questions: *Do IC, WM, and CF similarly support reading? And, do all three EF components mediate the relation between family socioeconomic risks and reading?*

Given that IC, WM, and CF may differentially predict reading outcomes, we hypothesized that the role of each component in mediating the SES-reading achievement gap may also vary. We predicted that family socioeconomic risk factors will be negatively associated with IC, WM, and CF, and in turn, reading skills, however, the mediating role may vary for each EF component. Such insights have important implications for developing reading intervention programs in low SES contexts, and provide insight into how various aspects of children's family life contribute to reading achievement gaps.

Methods

Participants

Three hundred and sixty-nine 5th grade children (N_{Males}=193) participated in this study. The children were between ages 9 to 11 years (M=10.09, SD=0.78) and were enrolled in 32 public primary schools in the rural Adzope region of Côte d'Ivoire. Children who were more than 2 years outside of the age range for their grade (i.e. 9-11 years for 5th grade) or who had any overt developmental disorders were excluded from the study; however, children with developmental disorders rarely attend public school in Côte d'Ivoire and schools do not document these disorders. We did not encounter any children who met these criteria. Children were participating in a larger reading intervention study (Jasińska & Ogan, 2020; pre-registered on OSF [Madaio et al., 2020]; Madaio et al., 2019), and data were collected at baseline prior to treatment assignment.

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Measures

Executive Function Measures

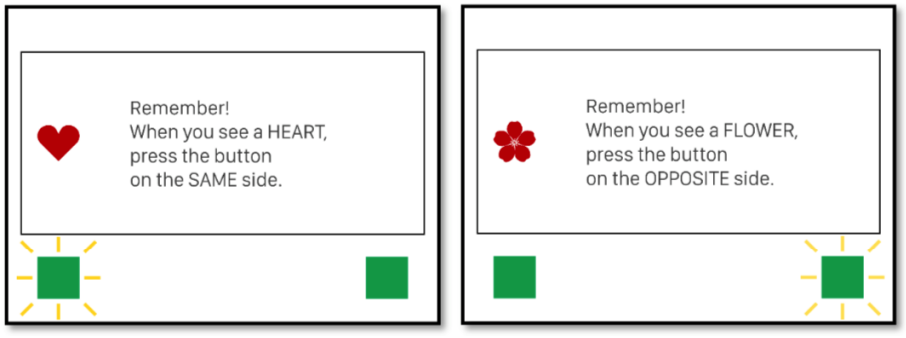
EF components were measured using the Assessment of Motivation, Effort, and Self-Regulation (AMES), which is a tablet-based app (Obradovic, 2019). This assessment was designed for children between the ages of 5-12 years to engage children in games that assess

a range of cognitive and social-emotional skills.

Hearts and Flowers (HF) Task. This task measured IC and CF (Davidson et al., 2006). It consists of three different trial types organized by three separate blocks: congruent (heart game), incongruent (flower game), and mixed (heart & flower game) blocks. Each block begins with a maximum number of 6 practice trials out of which participants must complete two correct trials in a row in order to proceed with the game. During the congruent (heart) block, each trial includes presentation of a heart image on either the left or right side of the screen and participants are instructed to press the green square on the same side as the heart. This block includes 8 test trials. In the incongruent (flower) block, flowers are presented on the left or right side of the screen, signaling incongruent trials, participants are asked to press the green square on the opposite side of the flower. During mixed trials, participants are presented with both the heart and flower and are therefore required to switch between the congruent and incongruent instructions. The flower and mixed blocks both include 12 test trials. IC was measured using accuracy scores on the incongruent (flower) block, while CF was measured using accuracy scores on the mixed block.

Figure 1

Hearts and Flowers Screen

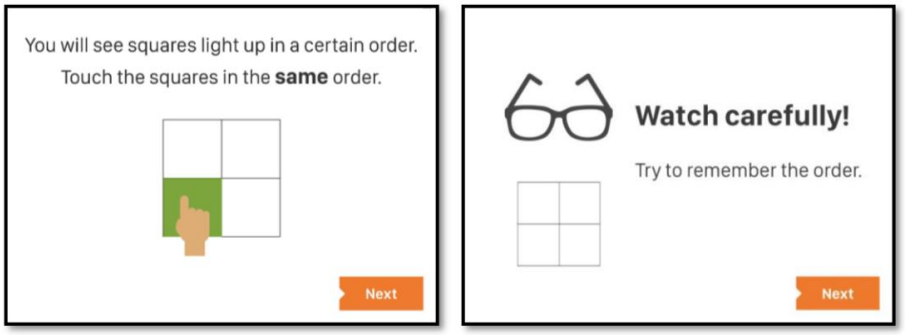


Note. Reprinted from Obradovic (2019)

Dot Matrix Task. This task was used to measure WM by instructing participants to reproduce sequences presented on square tiles on a 3x3 grid in backwards order. The sequence lengths (i.e. number of squares that lit up in a pattern) increased until they became too long for participants to reproduce correctly (Alloway & Copello, 2013). The sequences started off with a span of two squares and increased to a maximum length of nine squares. Each sequence length included three trials and each square within a sequence was displayed for a duration of 0.75 seconds. Participants were allotted three wrong answers (i.e. squares reproduced incorrectly) before moving forward with the next trial. The task was preceded by four practice trials and participants were given the option to terminate at any point of the game. WM was measured using the maximum correct sequence length in backwards order.

Figure 2

Dots Matrix Screen



Note. Reprinted from Obradovic (2019)

Reading Measures

Reading ability was measured using the French language Early Grade Reading Assessment (EGRA; RTI International, 2011), previously used to measure reading in primary school children in Côte d'Ivoire (see Akpé et al., 2021; Ball et al., 2022; Brice et al., 2023; Jasińska, Akpe, et al., 2022; Jasińska, Zinszer, et al., 2022; Whitehead et al., 2022; Zinszer et al., 2023a, 2023b). Research has shown that the EGRA meets psychometric standards as a

reliable and valid measure of early reading skills (Dubeck & Gove, 2015), including in rural Côte d'Ivoire (Sobers et al., 2023). Three subtasks associated with decoding skills were assessed: letter read ing, word reading, and nonword reading. Before each subtask, children completed practice items and received feedback and guidance from the experimenter. In each subtask, children had to read as many graphemes, words, or nonwords as possible in 60 seconds. Performance was scored as the total number of correctly read items in each subtask. A subtask was terminated if participants failed to provide at least one correct response in the first 10 trials.

Letter reading. Children were presented with 100 graphemes (including both single letters and letter combinations that represent a single sound e.g. "ch")

Word reading. Children were presented with 50 familiar French words (usually one or two syllables) frequently used in children's books and other reading materials.

Nonword reading. This subtask measured decoding ability for nonwords (words that cannot be recognized by sight). Children were presented with a list of 50 one and two syllable non-existent words that conform to typical French language structure.

Cumulative Risk Score

Risk scores from three variables (household asset poverty, maternal illiteracy, and fostering) were added to create a cumulative socioeconomic risk score for each child. Household asset poverty and maternal illiteracy are well-established predictors of children's reading outcomes (e.g., Bowey, 1995; Horowitz-Kraus, 2018; Zhang et al., 2013). Fostering — a common practice in SSA — is associated with negative impacts on academic outcomes (Hampshire et al., 2015). Therefore, our cumulative risk score includes all three measures. Each risk variable was scored on a dichotomous scale where a 1 indicated the presence of risk and 0 indicated no risk as detailed below. The resulting cumulative socioeconomic risk scores were

therefore ordinal values between 0-3.

Household Asset Poverty. Household asset scores were obtained using a child-reported 15-item household inventory from the EGRA (RTI International, 2009; Gove & Wetterberg, 2011). This includes general household resources such as running water, electricity, indoor plumbing, and educational resources such as books and toys. The continuous raw scores (range: 0-15) were then converted to dichotomous risk scores. A risk score of 1 was assigned when participants scored one standard deviation below the mean or lower (this approach has previously been applied to construct risk scores from continuous variables; see Gerard & Buehler, 2004; Hebron et al., 2016; Ashworth & Humphrey, 2020). All participants who scored above one standard deviation below the mean were assigned a score of 0, indicating no risk.

Maternal illiteracy. Children who reported that their mother was illiterate were assigned a risk score of 1. Children with a literate mother were assigned a risk score of 0.

Fostering. Children who reported living with either a mother, father, or both parents were assigned a risk score of 0. The remaining children (who did not have either parent living at home and were fostered) were assigned a risk score of 1.

Protocol

All children included in the study completed the EF, reading, and SES measures on a one-on-one basis with a native Ivorian French-speaking experimenter. All testing took place at the child's school, in the school's courtyard. All experimenters were, at a minimum, required to have a bachelor's degree in a relevant field (e.g., psychology, sociology, education, linguistics).

Analytic Framework

Structural equation modeling (SEM) was used to test whether specific components of EF (IC, CF, and WM) similarly support reading and whether all three EF components mediate the

relation between socioeconomic risk factors and reading. Two separate SEM models were generated. Model 1 (the cumulative socioeconomic risk model) included four manifest variables: cumulative socioeconomic risk score and the three components of EF (IC, CF, and WM), and one latent variable: reading (letter, word, nonword reading). Model 2 (the individual socioeconomic risk model) was conducted as a secondary analysis to explore how individual components of socioeconomic risk related to EF. This model included three additional manifest variables (household asset poverty, maternal illiteracy, and fostering) in place of the cumulative socioeconomic risk Score.

Each SEM was constructed using the lavaan package (Rosseel, 2012) in R (R Core Team 2020). The models were estimated using weighted least squares estimation with robust means and variances (WLSMV; Bandalos, 2014; Flora & Curran, 2004; Muthén et al., 1997; Rhemtulla, et al., 2012) applying the Yuan-Bentler correction (Satorra & Bentler, 1988; 1994; Yuan & Zhang, 2012) to describe directional relations between variables. Our model included skewed variables (IC: -2.18, kurtosis: 7.74, CF: -1.83, kurtosis: 5.91, WM: 1.33, kurtosis: 4.10, Letter: 1.00, kurtosis: 3.27, Word: 1.36, kurtosis: 3.58, Nonword: 1.60, kurtosis: 4.62), and categorical variables (socioeconomic risk factors; Model 2), therefore WLSMV with Satorra-Bentler correction was chosen. The Yuan-Bentler method incorporates scaled chi-squared test with robust standard errors, and it is recommended for non-normal variables (Hu, Bentler, & Kano, 1992; Curran, West, & Finch, 1996) and appropriate for sample sizes greater than 250 (Hu & Bentler, 1999). All data are publicly available at Open Science Framework at https://osf.io/bnpyg/.

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Results

Descriptive Results

SES Scores

Overall, 19% of children scored one standard deviation below the mean on the household asset index (M=6.64, SD=2.6; See Table 1). Therefore, children who had four or less items out of 15-item household inventory were given a risk score of 1 for this measure. 40% of children had an illiterate mother and 17% of children lived in a fostering setting (did not live with either their mother or father).

Executive Function and Reading

Reading (letter, word, and nonword reading) and EF (IC, WM, and CF) scores are presented in Table 1. Lower scores were observed for nonword reading (17% average score) in comparison to word (24% average score) and letter (25% average score) reading. There were no significant differences by gender on reading (Letter: $t(358)=0.96$, $p=0.34$; Word: $t(359)=0.64$, $p=0.52$; Nonword: $t(365)=0.34$, $p=0.74$), as well as IC: $t(356)=0.99$, $p=0.33$; and CF: $t(358)=0.93$, $p=0.35$. However, boys had significantly better performance on the WM task in comparison to girls: $t(363)=3.97$, $p=<0.001$. As such, we control for gender in the structural equation models that follow.

Table 1. Means and Standard Deviations for all measures.

Measure	M	SD	Min.	Max.
Age	10.09	0.78	9	11
Reading Scores				
Letter Reading (0-100)	25.05	19.95	0	89
Word Reading (0-50)	12.02	14.52	0	50

Nonword Reading (0-50)	8.53	11.74	0	49
EF Scores				
Working Memory	2.54	0.76	2	5
Inhibitory Control	0.84	0.22	0	1
Cognitive Flexibility	0.86	0.19	0.03	1
SES Scores				
socioeconomic risk Score	0.64	0.79	0	3
Household Asset Poverty (% below 1SD of mean)	0.19	-	-	-
Maternal Illiteracy (% with illiterate mother)	0.40	-	-	-
Fostering (% living with neither parent)	0.17	-	-	-

Note. M = Mean, SD = Standard Deviation

Bivariate Correlations

None of the EF scores (IC, WM, and CF) were associated with age. In contrast, a significant negative correlation was observed between age and letter ($r(358)= -0.13$, $p=0.014$), word ($r(367)=-0.12$, $p=0.007$), and nonword ($r(365)=-0.13$, $p=0.011$) reading, with older children being worse readers. In addition, older children were also more likely to have higher socioeconomic risk scores ($r(365)= -0.13$, $p=0.011$) and children of illiterate mothers were more likely to be older ($r(367)=0.18$, $p<0.001$). No correlations between age and the remaining socioeconomic risk variables (household asset poverty and fostering) were observed.

Maternal illiteracy was also found to be significantly associated with letter ($r(358)=-0.10$, $p=0.048$) and nonword ($r(365)=-0.11$, $p= 0.043$) reading, but not word reading. WM was

significantly correlated with all three reading measures (letter: $r(354)=0.18$, $p<0.001$; word: $r(355)=0.16$, $p=0.003$; nonword: $r(361)=0.17$, $p<0.001$) and IC was correlated with letter reading ($r(348)=0.12$, $p=0.026$).

We also tested correlations between the three SES and EF measures, and only observed a significant relation between WM and fostering ($r(363)=-0.10$, $p=0.05$). Having at least one parent present at home was associated with higher WM scores.

Table 2. Correlation matrix for all measures.

Measure	1	2	3	4	5	6	7	8	9	10	11
1. Age	-										
2. Letter Reading	-0.13*	-									
3. Word Reading	-0.12*	0.81***	-								
4. Non-Word Reading	-0.13**	0.80***	0.96***	-							
5. Socioeconomic Risk Score	0.14**	-0.09	-0.07	-0.08	-						
6. Household Asset Poverty	-0.01	0.02	-0.05	-0.04	0.29***	-					
7. Maternal Illiteracy	0.18***	-0.10*	-0.09	-0.11*	0.84***	0.12*	-				
8. Fostering	0.03	-0.05	-0.03	-0.05	0.70***	0.05	0.35***	-			
9. Working Memory	-0.04	0.18***	0.16**	0.17***	-0.09	-0.10	0.02	-0.10*	-		
10. Inhibitory Control	0.02	0.12*	0.08	0.10	0.05	0.04	0.05	0.01	0.15**	-	
11. Cognitive Flexibility	-0.07	0.10	0.03	0.06	0.02	-0.00	-0.00	0.03	0.19***	0.37***	-
12. Gender	0.09	0.05	0.03	0.02	0.01	-0.02	-0.01	0.05	0.20*	0.05	0.05

**

* indicates $p < .05$. ** indicates $p < .01$. *** indicates $p < .001$

Structural Equation Models

We conducted a structural equation model (SEM) to test whether IC, WM, and CF similarly support reading, and whether these EF components mediated the relation between family socioeconomic risk and reading (Model 1). Next, we explored how IC, WM, and EF mediate the relationship between different components of socioeconomic risk (household asset poverty, maternal illiteracy, and fostering) and reading (Model 2). We controlled for gender at the levels of EF and reading.

Overall, the model fit indices indicated a good fit on several metrics for both Model 1 and Model 2. The chi-square was not significant, and the RMSEA and Standardized RMR were below the 0.08 level for both models. Further, the Comparative Fit Index (CFI) was above the .9 criterion in both models.

Table 3. Model fit diagnostics for Model 1 and 2 (see Hooper, Coughlan, & Mullen, 2008 for criteria)

Metric of Model Fit	**Model 1 (Cumulative Socioeconomic Risk) Statistic**	**Model 2 (Individual Socioeconomic Risks) Statistic**	**Criterion**
Robust Chi-Squared (*df*=8)	p=0.218	p=0.140	*p*>0.050
Chi-Squared with Yuan-Bentler scaling correction factor	p=0.979	p=0.977	
Root Mean Square Error of Approximation	90% CI: 0.070,0.000	90% CI: 0.068,0.000	<0.080
Standardized Root Mean Square Residuals	0.015	0.014	<0.080
Incremental fit indices			

Comparative Fit Index (CFI)	0.997	0.996	>=0.900
Normed Fit Index (NFI)			>=0.950
Non-Normed Fit Index (NNFI)	0.994	0.988	>=0.950
Akaike Information Criterion (AIC)	5831.045, df:27	6049.981, df:39	

In the measurement model, all of the included measures for reading were found to significantly contribute to the latent variable estimates.

Do IC, WM, and CF similarly support reading?

In Model 1 (Figure 3), the cumulative socioeconomic risk model, WM was a significant predictor of children's reading skill. No significant relation was observed between reading and the remaining EF components (IC and CF), see Table 4.

Do EF components mediate the relation between socioeconomic risk and reading?

Probing the relationship between SES and EF components, Model 1 revealed that cumulative socioeconomic risk was a marginally significant predictor of WM, but not IC or CF. Model 1 showed no significant *direct* relation between cumulative socioeconomic risk and reading.

Model 2 (Figure 4) investigated the three SES variables and revealed that fostering and household asset poverty were significant predictors of WM, but not IC or CF. Model 2 showed no significant *direct* relation between fostering and reading, and household asset poverty and reading. WM fully mediated the relation between fostering and reading. In other words, though fostering does not directly impact reading ability, it is significantly related to poorer working memory thereby impacting literacy. No mediating effects between household asset poverty or maternal illiteracy and reading were observed for IC or CF.

Neither model revealed a direct relation between the socioeconomic risk (cumulative or individual) and reading, although, in Model 2, maternal illiteracy had a marginally significant

direct relation with reading. Additionally, in both models, gender was positively and significantly associated with WM; boys outperformed girls on WM tasks. See Table 4 and 5 for statistics.

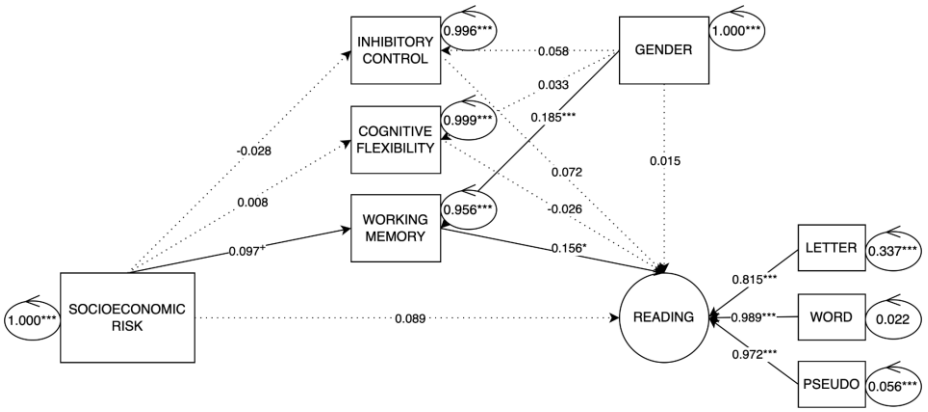

Figure 3. Model 1: Cumulative Socioeconomic Risk. Visualization of the structural equation modeling results. Squares indicate manifest variables, and circles indicate latent variables. Arrow weight approximates the magnitude of the directed connection. Dotted arrows were tested in the model and found not to be statistically significant. Reported values are standardized beta coefficients.

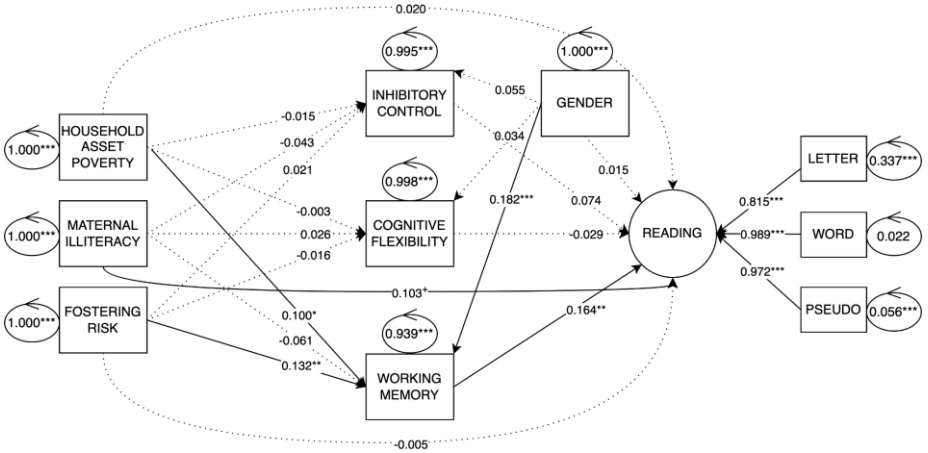

Figure 4. Model 2: Individual Socioeconomic Risk.

Table 4. Results of structural equation modeling - Latent Variable & Regressions

Measurement Model		**Model 1 Cumulative Socioeconomic Risk**		**Model 2 Individual Socioeconomic Risk**	
Latent Variable	**Manifest Variable**	***Std. β***	***p***	***Std. β***	***p***
Reading	Letter Reading	0.815	<0.001	0.815	<0.001
	Word Reading	0.989	<0.001	0.989	<0.001
	Nonword Reading	0.972	<0.001	0.972	<0.001
Regression	**Predictor**	***Std. β***	***p***	***Std. β***	***p***
Reading	Working Memory	0.156	0.012*	0.164	0.008**
	Inhibitory Control	0.072	0.219	0.074	0.202
	Cognitive Flexibility	-0.026	0.691	-0.029	0.652
	Socioeconomic Risk Score	0.089	0.091		
	Gender	0.015	0.792	0.015	0.789
	Household Asset Poverty			0.020	0.686
	Maternal Illiteracy			0.103	0.056+
	Fostering Risk			-0.005	0.915
Working Memory	Socioeconomic Risk Score	0.097	0.051+		
	Gender	0.185	<0.001	0.182	<0.001
	Household Asset Poverty			0.100	0.038*
	Maternal Illiteracy			-0.061	0.273

	Fostering Risk			0.132	0.004**
Inhibitory Control	Socioeconomic Risk Score	-0.028	0.610		
	Gender	0.058	0.289	0.055	0.308
	Household Asset Poverty			-0.015	0.768
	Maternal Illiteracy			-0.043	0.411
	Fostering Risk			0.021	0.693
Cognitive Flexibility	Socioeconomic Risk Score	0.008	0.882		
	Gender	0.033	0.543	0.034	0.532
	Household Asset Poverty			-0.003	0.966
	Maternal Illiteracy			0.026	0.645
	Fostering Risk			-0.016	0.764

Table 5. Results of structural equation modeling - Mediations

Predictor → Independent Variable	**Mediator**	***Std. β***	***p***
Model 1: Socioeconomic Risk Score → Reading	Working Memory	0.015	0.150
	Inhibitory Control	-0.002	0.642
	Cognitive Flexibility	-0.000	0.893
Model 2: Household Asset Poverty→ Reading	Working Memory	0.016	0.102
	Inhibitory Control	-0.001	0.774

	Cognitive Flexibility	0.000	0.965
Model 2: Maternal Illiteracy→ Reading	Working Memory	-0.010	0.276
	Inhibitory Control	-0.003	0.484
	Cognitive Flexibility	-0.001	0.744
Model 2: Fostering Risk→ Reading	Working Memory	0.022	0.048*
	Inhibitory Control	0.002	0.700
	Cognitive Flexibility	0.000	0.808

Discussion

Although previous literature reports lower reading achievement among children who experience socioeconomic risks, the mechanisms by which socioeconomic risks influence reading ability remain poorly understood, particularly in contexts outside of HICs (Aikens & Barbarin 2008; Dolean et al. 2019; So & Chan 1984; Zuilkowski et al. 2019). Recent findings have indicated that EF may mediate the SES-reading achievement gap, although the results are often mixed. This may be attributed to the fact that most studies typically examine EF as an independent latent variable without considering how individual EF components support academic achievement. In the current study, we examined whether individual EF variables – IC, WM, and CF – mediate the relation between socioeconomic risk and reading ability for children in rural Côte d'Ivoire.

In support of our hypothesis, our results showed that higher cumulative socioeconomic risk was related to poorer WM, which was associated with lower reading scores. While we did not find a significant mediation effect of EF between socioeconomic risk and reading, we did observe that WM fully mediated the negative effects of fostering on reading. In contrast, no mediating role of IC or CF was observed. Furthermore, no indirect effects of household asset

poverty or maternal illiteracy on reading were observed through any of the EF measures (IC, WM, or CF), rather, maternal illiteracy had a direct impact on children's reading, which we discuss below.

Differential Roles of EF Components for Reading

Our findings demonstrated that EF components differentially contribute to reading; WM significantly predicted reading, but neither IC nor CF predicted reading. Cumulative socioeconomic risk was negatively associated with WM scores; particularly, fostering was significantly associated with lower WM scores and household asset poverty was marginally associated with lower WM scores. Furthermore, the relation between fostering and reading was fully mediated by WM. In comparison, IC and CF were not directly or indirectly associated with cumulative socioeconomic risk, individual socioeconomic risk variables (in our exploratory model 2), or reading.

These findings corroborate previous research indicating that WM may be the most important domain within EF in predicting reading ability (Engel de Abreu et al., 2014; Chang, 2020; Lan et al., 2011; Spiegel et al., 2021; Zou et al., 2022) and suggest that WM acts as a mediator for SES-related reading gaps. Few studies have investigated the role of individual EF components as mediators between SES and reading, however, a study by Waters et al (2021) found similar results; independent effects of SES indicators (income-to-needs and parent education) were observed only for WM, not IC or CF. Furthermore, although no mediation effect for either of the EF components were found between SES and reading, a mediation effect for WM between parent education and math achievement was observed. Albert et al (2020) also evaluated the relative contributions of individual EF components to the SES-achievement gaps. They found that verbal WM had a larger mediation effect between SES and reading than other EF variables. In combination, these findings demonstrate how specific EF components can differ in their sensitivity to socioeconomic risks and in their relative support of reading and

overall academic development, reinforcing the importance of assessing EF components individually. Evidence from the current study specifically points to a principal role of WM within EF in explaining SES-related reading achievement gaps, suggesting the applicability of WM as an evaluative tool to identify children at risk of reading delays or difficulties. This highlights the importance of supporting WM development from an early age as it is not only beneficial to reading outcomes, but can also act as a protective factor for early readers from impoverished backgrounds.

Critically, we found that boys significantly outperformed girls on WM tasks. Given the critical role of WM in the relation between SES and reading achievement, it is important to consider the disadvantages that girls face in learning to read. While we control for gender in the current study, future work that examines literacy development among socioeconomically underprivileged girls is imperative.

SES and Context of Côte d'Ivoire

The associations between SES and EF development in childhood are well established (Hackman & Farah, 2009; Mezzacappa, 2004; Farah et al., 2006; Noble et al., 2005; Sarsour et al., 2011), however, our findings indicate that specific socioeconomic risk factors may differentially influence EF. Specifically, the presence of both parents at home (i.e., child is not fostered) and access to household resources (i.e., indicated by household asset poverty), but not maternal literacy, were predictive of WM. However, it is important to note that most previous studies were conducted in HICs where social, developmental, and economic contexts vary widely compared to LMICs.

The current study focused on rural Côte d'Ivoire, where children's EF development is disadvantaged by a greater prevalence of socioeconomic risks present within the home, including lack of access to resources, maternal illiteracy, and fostering practices. The findings demonstrate that among these household factors, fostering, in particular, has negative

implications on children's WM. Fostering within the SSA context has previously been associated with greater exposure to child labor, lower school enrollment and attendance (Ainsworth, 1989; Hampshire et al., 2015; Hedges et al, 2019; Lachaud et al., 2016), lack of access to health services (Deininger & Okidi, 2003) and greater nutritional deficiencies (Madhavan & Townsend, 2007; Prall & Scelza, 2017) compared to children who live with a parent. Living with extended kin in childhood also increases the overall number of children within the household, putting greater demand on caregivers time and resources, which could result in inadequate caregiving, which may adversely impact children's cognitive development. Therefore, children living in fostering arrangements could benefit from additional support to ensure they reach their cognitive potential. However, due to various social and economic factors including family resources, cultural practices, and child labor practices (Ainsworth, 1989), fostering remains a common practice in SSA. Given the prevalence of fostering, more research is needed to understand the implications of this practice. For example, a greater understanding of how household factors (e.g., nutrition, chores, parental attention) differ between homes with and without foster children and how these factors impact child development is required. This high prevalence of fostering represents a notable and understudied difference in childhood development contexts between HICs and LMICs.

Moreover, in the current sample of 5th grade children between ages 9-11 years, we observed a significant negative relation between age and reading. In rural Côte d'Ivoire, children often enroll in school at a later age and repeat grades. Therefore, our sample included children of different ages within the same classroom and the results showed that older 5th grade students had higher socioeconomic risk scores, were more likely to have an illiterate mother, and had significantly worse reading scores than their younger classmates. Interestingly, older children did not show higher scores on EF measures in comparison to their younger peers, as might typically be expected with age. In a study by Willoughby and colleagues (2019), a similar lack

of age effects for EF scores was observed among children in Kenya enrolled in pre-primary school, some of whom had repeated grades and were therefore older for their grade. While these older children would be expected to show better EF scores, they are also more likely to experience socioeconomic risks (that contribute to their late enrollment in school) associated with poorer EF scores, which may have contributed to the lack of age effect on EF in this study.

Although few studies have examined the role of SES, EF, and reading in LMICs, some of the existing research reported that children with higher family wealth or children whose mothers are more highly educated performed significantly better on cognitive and reading assessments (Berkes et al., 2019). For example, Fernald and colleagues (2011) observed that cognitive gaps between low and high SES children in Madagascar were greatest for WM. Furthermore, the current study suggests that different socioeconomic risk factors may contribute uniquely to EF and reading development. This corroborates with findings from McCoy and colleagues (2015) who observed that maternal education factors, such as maternal literacy, were more strongly associated with Kenyan children's reading abilities while factors associated with household wealth were associated with cognition. Similarly, in the current results, maternal illiteracy was marginally significantly associated with reading scores and there was also a marginal significance between household asset poverty and WM. This suggests that perhaps having access to household assets (learning materials, television, books, etc.) provides greater cognitive stimulation which fosters the development of WM. In contrast, household resources may not have as much of an impact on reading skills without the mediation of a literate parent who can support reading.

Limitations and Future Directions

The current results emphasize the importance of examining EF components individually as they uniquely relate to SES and reading achievement. However, task-related factors may also provide context in interpreting these results. IC and CF scores were measured using the same

Hearts & Flowers (HF) task, while WM scores were measured using a separate task — the Dot Matrix task. Although the HF task is a developmentally appropriate, valid, and sensitive tool for measuring IC and CF (Davidson et al., 2006; Diamond et al., 2007), in the current sample, accuracy scores for IC and CF had lower variance and were negatively skewed indicating that the task may not have been sensitive in capturing IC and CF skills. Furthermore, the WM scores reflected the average span of blocks that participants recognized rather than an accuracy score (which was used to measure IC and CF). Therefore, the nature of the two tasks and measures were significantly different, and this may have been reflected in the findings observed. Another limitation in this study involved the measurement methods for individual socioeconomic risks. In the case of household asset poverty, the scoring method was sample specific (risk scores were given for children who scored one standard deviation below the mean) and therefore can only be interpreted in the context of the current sample. Furthermore, the scores for maternal literacy and fostering were based on child report measures. However, a recent study in Côte d'Ivoire showed that child reports may be more reliable than parent reports that may be more susceptible to social desirability biases, particularly in impoverished communities (Lichand & Wolf, 2022). Also, fostering was measured based on whether the child reported living with at least one parent, however, this method might fail to capture the complexity and flexibility of such living arrangements. For instance, the arrangement could be permanent or temporary and the parents might visit frequently or live in the home part-time. Therefore, this measure may have failed to account for the various child fostering dynamics observed in Côte d'Ivoire.

Conclusion

It is well documented that low-SES children experience disadvantages in reading achievement. The current research aimed to look beyond the SES-reading link, and rather focused on the underlying pathways behind this association; *how* SES influences reading development. EF is an important predictor of overall academic ability among children in low

SES settings, and it is therefore important to continue examining how this applies to reading, and how specific components of EF contribute differentially. Secondly, a majority of research on SES related reading achievement gaps focuses on high income settings with limited research being conducted in LMICs. This is unfortunate considering the greater prevalence of household socioeconomic risk factors within these countries, there are also unique socioeconomic conditions that contribute to children's development including factors such as lack of access to schooling, caregiving through extended kinship networks, child labor, and delayed reading. Therefore, it is essential to devote attention to the relation of EF with SES and reading within these contexts in order to inform interventions and effectively support cognitive and reading development in communities that need it most.

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Highlights

- Socioeconomic risk influences cognitive pathways that support literacy development
- Developmental impact of kinship fostering (prevalent in Côte d'Ivoire) is understudied.
- Poor WM mediated the relationship between socioeconomic risk and poorer reading
- Kinship fostering was associated with decreased EFs and literacy
- It is critical to examine which EFs influence the SE-literacy achievement gap