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Pakistani Preschoolers' Number of Older Siblings and Cognitive Skills: Moderations by Home Stimulation and Gender

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The present study examines the link between children's number of older siblings and their cognitive development, as measured by executive function (EFs) skills and verbal skills (VIQ) in a sample of 1,302 4-year-old children (54% boys) living in rural Pakistan. Specifically, we investigate whether the links between the number of older siblings and preschoolers' EFs and VIQ are moderated by preschoolers' quality of home stimulation and gender. Multivariate regressions revealed that the number of older siblings was positively associated with EFs for boys in homes with both higher and lower levels of stimulation, and for girls in homes with lower levels of stimulation ($p < .05$). However, the number of older siblings was *negatively* associated with EFs for girls from homes with higher levels of stimulation ($p = .03$). Further, the number of older siblings was positively associated with VIQ in homes with lower stimulation ($p < .05$), but not for higher stimulation homes. Gender was not a statistically significant moderator of the association between the number of older siblings and VIQ. Findings suggest that living with more older siblings may promote emerging EFs and VIQ among boys and girls with fewer opportunities for cognitive stimulation. However, more older siblings may hinder EF development for girls in the context of adequate home stimulation, perhaps due to inequitable allocation of resources among boys and girls in more affluent, larger families.

Keywords: executive functions, siblings, home stimulation, gender, low- and middle-income country

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Executive functions (EFs) are important cognitive skills that help children regulate their attention, behavior, and emotions, and support their school readiness, social skills, behavioral regulation, and academic achievement (Diamond, 2013). Considerable research has demonstrated that positive family experiences—such as responsive parenting behaviors—promote cognitive development in both high-income country and low- and middle-income country (LMIC) contexts (Fay-Stammbach et al., 2014; Haft & Hoeft, 2017; Obradović & Willoughby, 2019). However, comparatively less is known about whether other family members, such as older siblings, contribute to young children's EF development. A recent study in rural Pakistan revealed that the number of older siblings positively predicted 4-year-old children's EFs, after controlling for family resources, parental education, home stimulation, and child physical growth (Obradović et al., 2019). Drawing on the same sample in rural Pakistan, we extend this prior study by investigating whether the positive association between the number of older siblings and preschoolers' EFs varies as a function of preschoolers' gender and the quality of home stimulation. We further extend this work by examining whether and for whom the number of older siblings is associated with children's verbal skills, as indexed by acquired vocabulary knowledge and verbal reasoning abilities based on early reading experiences and communication (Stage et al., 2003). Verbal skills encompass more crystalized form of intelligence, such as children's capacity to process and integrate vocabulary, information, and knowledge, whereas EFs capture fluid intelligence, as reflected by inhibitory control (IC), working memory (WM), and cognitive flexibility (CF; Obradović et al., 2017). Our goal is to further illuminate the potential role of older siblings for these emergent cognitive skills in an LMIC setting.

Siblings and Cognitive Development

Children often have opportunities to engage with and learn from siblings in the home (Rabain-Jamin et al., 2003). Older children may also act as caregivers for their younger siblings

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(Bradley & Corwyn, 2005; Cook et al., 2019). Siblings may have a particularly important role in promoting early child development in LMIC contexts, such as rural Pakistan, where family sizes tend to be large, with an average of 6.8 members per household (United Nations, 2017), and sibling bonds are highly valued due to cultural norms (Zaman et al., 2009). Moreover, siblings may be important sources of socialization and cognitive stimulation in rural LMIC contexts, because access to and quality of formal early education experiences that are known to promote children's EFs in high-income contexts are limited (McCoy et al., 2021; United Nations International Children's Emergency Fund [UNICEF], 2013).

A limited body of research has linked the number of siblings to children's academic, language, and cognitive skills, including EFs and verbal skills. In high-income contexts, research has shown mixed results. The number of siblings (ages 1–12 years) was positively associated with performance on a battery of EF tasks in a study of Australian preschoolers (McAlister & Peterson, 2006). In contrast, the number of siblings was not correlated with performance on tests of theory of mind in a study of 2-year-olds in the United Kingdom (Hughes & Ensor, 2005). In LMIC contexts, research to date has shown more consistent results, possibly because this work focused on the number of *older* siblings, rather than the number of total siblings. A quasi-experiment of 1,800 households in rural Pakistan demonstrated positive educational spillover effects from adolescent sisters to younger brothers, such that a 1-year increase in the older sister's schooling led to half a year increase in schooling and literacy performance for her younger brothers at age 10 (Qureshi, 2018). In Kenya, having an older sister was associated with improvements in younger siblings' vocabulary and fine motor skills (Jakiela et al., 2020). Similarly, in Iran, toddlers with a preschool-aged sibling demonstrated better comprehension of words and phrases used by family members, measured through observations and coding of child speech samples, compared to those without a sibling (Malmeer & Assadi, 2013). In the present sample in rural Pakistan, the number of older siblings was positively associated with 4-year-olds' EFs, controlling for family wealth, maternal education, home stimulation, and physical growth (Obradović et al., 2019). This research suggests that in LMICs, older siblings may play an important role in promoting young children's cognitive development.

Siblings as a Source of Stimulation

One way that older siblings may foster their younger siblings' cognitive development is by engaging them in stimulating interactive and play opportunities that promote application and practice of EFs and verbal skills. A study of 60 low-income Latino children and their younger siblings in the United States revealed that during pretend play and teaching interactions, older siblings (4- to 7-year-olds) used didactic teaching strategies to promote the English language skills of their younger siblings (2.5- to 4-year-olds; Obregon, 2010). In a different Latino immigrant community living in the South Atlantic region of the United States, a series of in-home observations revealed that older siblings (7- to 10-year-olds) contributed to younger siblings' (4- to 6-year-olds) literacy learning skills by narrating events to them, sharing word knowledge, or translating texts to help them with reading and writing (Kibler et al., 2016).

Observing and interacting with older siblings can be challenging in a way that encourages younger siblings' cognitive development in their zone of proximal development (Doolittle, 1995). In LMIC contexts of Mexico and Senegal, ethnographies of children, ages 3–13 years, revealed that older siblings promoted development of their younger siblings' skills by creating opportunities for multi-age play, verbal exchanges, wordplay, and group activities (Rabain-Jamin et al., 2003). These findings, coupled with research that demonstrates the importance of creative play and physical activities for cognitive development (Cook et al., 2019), suggest that older siblings may play a critical role in young children's cognitive development in LMIC contexts.

Home Stimulation as a Moderator of a Sibling Effect on Cognitive Development

To better understand when siblings promote younger children's EFs and verbal skills, it is important to examine the role of siblings within a larger family context. If siblings represent a source of cognitive stimulation for young children (Kibler et al., 2016; Obregon, 2010; Rabain-Jamin et al., 2003), it is feasible that the positive link between the number of older siblings and cognitive skills could be stronger in homes where children have fewer other opportunities for stimulation, as indexed by available learning materials, enrichment opportunities, family companionship and routines, and responsive parenting behaviors. For instance, a study in the United Kingdom found that home and neighborhood opportunities moderated the association between the test scores of older siblings and those of their younger siblings (Nicoletti & Rabe, 2019). Specifically, in a sample of more than 400,000 children (11- to 16-year-olds), the positive link between the older siblings' test scores and the test performance of younger siblings was stronger for children who had fewer opportunities for stimulation in their home and neighborhood environments, compared to children from more advantaged backgrounds (Nicoletti & Rabe, 2019). This study suggests that older siblings may be more relevant for younger siblings' cognitive development in home contexts where opportunities for other stimulating experiences are not available. However, this possibility has not been investigated in LMICs, despite larger average household sizes and cultural values of sibling bonds (Zaman et al., 2009).

Child Gender as a Moderator of a Sibling Effect on Cognitive Development

Across LMICs, there is significant variation in disparities in boys' and girls' daily experiences, ranging from household chores to family responsibilities, expectations of vocation, and differential investments in boys' and girls' education, such that girls on average are more disadvantaged than boys (Escueta et al., 2014). In Pakistan, for example, just 15% of poor, rural 10-year-old girls complete primary education compared to 40% of their male peers (Najam & Bari, 2017). Young boys in Pakistan are also often favored in the allocation of health care compared to girls (Hazarika, 2000).

These gendered experiences may influence the effect that siblings have on cognitive development in rural Pakistan. Particularly in larger families, girls might receive fewer family resources and educational opportunities and take on more household chores compared to boys (Escueta et al., 2014). In this way, lower levels of home stimulation in larger families with many children could undermine cognitive development in young girls, while leaving the boys comparatively less affected. Studies have provided evidence for such differential access to family resources and higher work burden for girls with many siblings. In Brazil, teenage girls were more likely than their teenage brothers to take responsibility for childcare and other household work when there was a young sibling at home and their mother was working (Connelly et al., 1996). In a sample of 14,355 households with children (6- to 15-year-olds) in Nepal, girls tended to work more both outside and at home, compared to their older brothers (Edmonds, 2006), and this extra work increased with the number of younger siblings. In rural Egypt, girls (7- to 17-year-olds) faced lowered levels of schooling, compared to their brothers (Rammohan & Dancer, 2008). In West Africa, girls (10- to 18-year-olds) with a higher number of younger siblings took on more domestic responsibilities compared to boys, leading to a negative association between the presence of siblings under the age of 5 years and these older girls' education in terms of girls' grade attainment, enrollment, and dropouts (Glick & Sahn, 2000). In Nepal, girls (7- to 9-year-olds) spent a disproportionate amount of time on household chores and on taking care of younger siblings, leaving them insufficient time to spend on schoolwork (Christian et al., 2010). Since research shows that girls have lower access to resources and disproportionately take on household work that increases with household size, the number of older siblings may not be as beneficial for girls' cognitive development compared to boys. Since family gendered expectations are established early (Bornstein et al., 2015), gender may moderate the association between the number of older siblings and preschoolers' cognitive skills.

Since young children's exposure to home stimulation and learning opportunities have been shown to vary for boys and girls in LMIC contexts (Christian et al., 2010; Escueta et al., 2014; Glick & Sahn, 2000; Rammohan & Dancer, 2008), it is important to consider whether the link between the number of older siblings and preschoolers' cognitive skills is moderated by both the quality of home stimulation and preschoolers' gender. For example, for boys, there may be a positive association between the number of older siblings and cognitive skills in both higher and lower levels of home stimulation environments—because boys receive the highest share of resources and educational opportunities in large households—and, additionally, benefit from the stimulation and care that older siblings may provide. In contrast, for girls, the number of older siblings may not be as strongly or positively associated with cognitive development, irrespective of the level of home stimulation. For girls, a greater number of older siblings may not relate to higher levels of cognitive skills due to unequal resource sharing and household work burden, as a result of the larger household size. In other words, siblings may not represent added value for girls in homes with both lower and higher levels of home stimulation. Given a lack of studies examining the interplay of both home stimulation and child gender to understand how family size affects cognitive development, these mechanisms are speculative and should be empirically examined.

The Present Study

The goal of this article was to follow up on prior work by Obradović et al. (2019) which revealed that the number of older siblings was positively associated with 4-year-olds' EFs in rural Pakistan. We investigated whether the quality of home stimulation and child gender moderated the positive association between the number of older siblings and preschoolers' cognitive development, as indexed by EFs and verbal skills. Consistent with previous work, we operationalized EFs as IC, WM, and CF. Extending the unique contribution of our study past that prior article, we also examined verbal skills (i.e., general verbal knowledge, vocabulary, and word reasoning) as a measure of cognitive development that is both distinct and complementary to EFs. Accordingly, the aims and methods of the present study are different from our previously published article with this sample (Obradović et al., 2019) because we (a) examine children's gender and experiences of home stimulation as moderators of the link between their number of older siblings and EFs and (b) we add an additional marker of cognitive development—verbal IQ—that may also be influenced by the interplay between children's number of older siblings, gender, and home stimulation.

We hypothesized that the number of older siblings would be positively associated with preschoolers' cognitive development in contexts of lower levels of home stimulation because siblings could serve as important sources of stimulation and care for children who otherwise experience lower levels of home stimulation and resources. Second, we hypothesized that the association between the number of older siblings and preschoolers' cognitive development would be stronger for boys than for girls because boys' needs might be prioritized in larger families from rural Pakistan. Third, we explored how the association between the number of older siblings and child cognitive development would vary as a function of both home stimulation and child gender. The three-way interaction was an exploratory analysis.

Method

Procedure

Children in this study were recruited at birth to participate in the Pakistan Early Child Development Scale Up (PEDS) trial, a community-based, cluster-randomized control trial with a 2 × 2 factorial design that evaluated the impact of integrating early responsive stimulation (RS) and enhanced nutrition (EN) interventions within government community health services to promote child development (Yousafzai et al., 2014). The *RS* intervention promoted early stimulation through a variety of play and communication activities as well as sensitive and responsive caregiving via individualized coaching, support, and feedback during monthly home visits and community group meetings, whereas the *EN* intervention expanded on existing health, hygiene, and basic nutrition education, and included the delivery of multiple micronutrient supplements from 6 months of age.

Participants included 1,302 children (46% girls) and primary caregivers (99% mothers) who were enrolled in the original PEDS trial from birth to age 2 years and were included in a longitudinal follow-up at age 4 years. They resided in the predominantly agricultural Naushero Feroze District in Sindh province, Pakistan, and were exposed to high levels of poverty. Monthly household income averaged \$100 USD (SD = \$140). Primary school attendance in the region was low, and in this sample, 68% of mothers and 31% of fathers were illiterate.

A birth cohort of children born between April 1, 2009, and March 31, 2010, was invited to enroll in the PEDS trial with their primary caregivers. This study analyzed data collected during the PEDS trial and at the 48-month follow-up. Children were assessed within a month of their birthday at each time point. The assessment team received extensive training on interacting with children and families, understanding the evaluation constructs, administering measures, and dealing with assessment barriers. Throughout the PEDS trial, data were collected during home visits. At age 4 years, data were collected during a 3-hr center visit and a 3-hr home visit by the team on separate days. Child and maternal assessments were alternated in a predetermined sequence to give both participants time to rest, and cognitive tests were administered at the beginning of the center visit to ensure that children's performance did not suffer from fatigue. In addition to the set rest periods, independent assessors were trained to identify when participants needed to take a break for refreshments, naps, playtime, or use of the bathroom. All questionnaires and child assessments were administered in the local language, Sindhi. A multidisciplinary team of experts and local staff spent 6 months adapting all selected measures for administration in a new cultural context with a highly disadvantaged population.

We report how we determined our sample size, all data exclusions (none), all manipulations, and all measures in the study. Sample size was determined by using all the available data from the original randomized control trial study for which a power analysis was conducted (see Yousafzai et al., 2014, for more information). No additional data were excluded. All data and syntax are available upon request from the authors. This study was not preregistered. The research ethics committee (e.g., institutional review board) at the sponsoring institution approved all study procedures.

Measures

Child EFs

Since there was no existing EF battery for preschoolers in a rural LMIC context, an extensive process of task selection, adaptation, and evaluation was developed. The process began with an extensive literature review of frequently used child EF tasks. These criteria determined the initial selection: (a) tasks were developmentally appropriate for both 3- and 4-year-old children; (b) tasks were widely used and had well-established psychometric properties; (c) tasks included materials and instructions that could be adapted to the local context and were not computerized; (d) performance required minimal verbal response (e.g., two-word responses, pointing, tapping), as children can be shy in the unfamiliar context of a standardized assessment; and (e) administration was feasible both in terms of the community assessors' skill level and the length of the assessment session.

The final EF assessment consisted of six tasks that assessed children's IC, WM, and CF. For all tasks, the team increased the number of practice trials to improve task comprehension, since many aspects of the testing procedure were novel to this population, and children tended to be reticent in this context. The Fruit Stroop (IC task) assessed the child's ability to focus on a subdominant perceptual feature of an image, rather than on a dominant feature (Carlson, 2005). Children were shown three pictures, each depicting a small fruit embedded within a different larger fruit (e.g., a small apple inside a large banana) and were asked to point to the small fruit, which required suppressing the inclination to choose the large, more salient fruit. The total score reflected the percent correct across three test trials ($\alpha = 0.65$). The Knock–Tap Game (IC task) assessed children's ability to implement a set of rules and suppress an imitation of the assessor's actions (Molfese et al., 2010). Children were asked to tap on the table using their hand after the assessor knocked on it, and, conversely, to knock after the assessor tapped. The total score reflected the percent correct across 16 test trials ($\alpha = 0.83$). The Big/Little Game (IC task; Carlson, 2005) assessed children's ability to state a contradictory rather than a salient perceptual feature of an image. Children were asked to say "little" when presented with a picture of a big cat and to say "big" when presented with a picture of a little cat. The total score reflected the percent correct across 16 test trials ($\alpha = 0.92$). The Go/No-Go Game (IC task) assessed children's ability to perform an action following a frequent "go" stimulus and to inhibit that same action following a less frequent "no-go" stimulus (Willoughby et al., 2010). Children were asked to press a desk bell when presented with an image of a cat and not to press the bell when presented with an image of a dog. The total score reflected the percentage of correct "no-go" trials ($\alpha = 0.89$) for children who demonstrated at least 76% accuracy on "go" trials. During the Forward Word Span (WM task), children were asked to repeat verbally presented word sequences of increasing length. The total score represented the longest span for which at least two test trials were repeated correctly, plus 0.5 if one longer sequence was correctly repeated at the next level (Noël, 2009). Children who could not repeat any words, or only one word were given a score of 1 ($\alpha = 0.93$). The Separated Dimensional Change Card Sort (S-DCCS, CF task; Carlson, 2005) measured children's ability to switch attention between two different dimensions, using a set of colored cards (green or yellow) featuring the black silhouette of a common shape (star or truck). Children were asked to complete six color trials, and then, after a rule switch, six shape trials. The total score reflected the percentage of correct postswitch trials ($\alpha = 0.86$). Comprehension of task rules was determined by performance on practice trials. Children who did not pass task-specific comprehension criteria did not receive a valid test score. A final EF composite score was calculated as an average of valid scores across the six tasks (Cronbach's $\alpha = 0.60$), with a standardized mean at 0, and range = -1.70 to 1.66. The EF composite included scores for children who passed comprehension criteria for three or more tasks (89% of children), since a three-task battery is considered acceptable to measure children's overall EFs (Willoughby et al., 2013).

Child Verbal Skills

To assess children's verbal skills (also known as verbal intelligence), we used the Wechsler Preschool and Primary Scale of Intelligence-III (WPPSI-III; Wechsler, 2012) after culturally adapting the measure for the Pakistani context (Rasheed et al., 2018). A verbal IQ composite (VIQ) was calculated from scale scores from information, vocabulary, and word reasoning subtests (Cronbach's $\alpha = 0.88$, $M = 77.47$, $SD = 9.95$), each of which required spoken responses to the presentation of pictures or information. Items were scored as *correct* (1) or *incorrect* (0). The subtest was assigned a raw score by summing the scores on all items and then converted to a t score using normed tables provided in the WPPSI-III manual. We present VIQ in the main article and Performance IQ and Full Scale IQ in the Supplemental Materials.

The number of older siblings was reported by mothers at birth of the target child ($M = 2.5$, $SD = 2.31$, range = 0–11).

Home stimulation was measured using the adapted Home Observation for Measurement of the Environment Inventory (HOME; Caldwell & Bradley, 1984), which has been used widely in LMIC (Aboud & Yousafzai, 2015; Obradović et al., 2016). Items representing six dimensions (responsivity, acceptance, organization, learning materials, involvement, and variety) of the infant/toddler version and eight dimensions (responsivity, acceptance, language stimulation, learning materials, physical environment, academic stimulation, modeling, and variety) of the early childhood version were scored as absent or present, based on mothers' report of family living patterns and habits, observation of spontaneous mother–child interactions, and orderliness and enrichment potential of the physical home environment. Each item was dichotomous (1 = *plus*, 0 = *minus*). The final score was generated by summing all plus scores in 48 items at 18 months of the child's age ($M = 30.81$, $SD = 5.44$, range = 16–44).

Child gender was reported by mothers, with 54% of the children in the sample identified as males, and 46% as females. Male gender was coded 1, and female gender was coded 0.

Covariates

Family wealth was assessed using 44 items that reflect ownership of property, livestock, and household assets (e.g., television, bicycle, car); dwelling characteristics (e.g., access to water, sanitation facilities, type of flooring material); and the number of bedrooms in the home. Principal component analysis was used to generate a single standardized factor score that represents cumulative family wealth. *Maternal education* was obtained by a maternal report of the number of years the mother attended formal school ($M = 2.19$, $SD = 3.69$). Trained assessors measured children's height to the nearest 0.1 cm in accordance with standardized guidelines (Cogill, 2003). Height was converted into a standardized *height-for-age* index ($M = -2.33$, $SD = 1.12$) using World Health Organization Anthro software V3.2.2. Furthermore, we controlled for family *food insecurity* (Coates et al., 2007) at 24 months, which was assessed using a binary measure of whether the family had access to adequate food (0 = *food secure*, 1 = *food insecure*; 32.74% were food insecure).

Consistent with previous work, we employed two binary variables to control for the published effects of the RS (1 = RS intervention exposure) and the EN interventions (1 = EN intervention exposure) on children's developmental outcomes (Armstrong-Carter et al., 2020). In prior research published from this sample (Yousafzai et al., 2016) it is known that children who received the RS had significantly higher EFs at age 4 compared to those who did not receive the intervention. Children who received EN did not differ in EFs at age 4 compared to those who did not receive the EN intervention, and there were no additive benefits when the RS was combined with the nutrition intervention. In prior articles, there was no effect of either intervention on verbal skills at age 4 (Yousafzai et al., 2016).

Data Analysis

We used ordinary least squares (OLS) regression to assess the effects of both the moderators on the positive association between the number of older siblings and child EFs/VIQ. The regression models accounted for the clustering of data within the 80 community-based team members who administered the original intervention trial (Yousafzai et al., 2014) with robust clustered standard errors. The percentage of missing data was small, ranging from 1% to 2.22%, except for the child EF composite (12.14%), which was largely due to children's inability to understand task rules (please see Obradović et al., 2019 for more details). Missing data on all predictors were imputed using chained equations with 20 data sets. Imputation models included a robust set of covariates: all demographic variables used in analyses, as well as all other covariates collected as part of the larger study including measures of children's cognition, language, and motor skills, prosocial behavior, socioemotional behaviors, inhibition, positive and negative affect, maternal engagement, and home environment. All variables exceeding ±4 *SD* were considered outliers and were truncated to 4 *SD*. All continuous variables were standardized to make coefficients interpretable as effect sizes.

Model 1 tests the direct effects of the independent variables on child EFs/VIQ. Model 2 tests the hypothesized moderators by inclusion of two two-way interaction terms: (a) number of older siblings by home stimulation and (b) number of older siblings and the target child gender. Model 3 tests the three-way interaction of the number of older siblings, home stimulation, and the target child's gender. Significant interactions were further probed using the simple slopes technique (Aiken & West, 1991) by testing the associations between the number of siblings and EFs/VIQ for girls and boys with high (1 *SD* above the mean) and low (1 *SD* below the mean) levels of home stimulation (Aiken & West, 1991).

Results

Bivariate Correlations

Table 1 displays bivariate correlations and descriptive statistics split by gender, for both EFs and VIQ. Starting with EFs, for boys, the number of older siblings was positively correlated with EFs ($r = .08$, $p < .05$), but not for girls ($r = -.05$, $p > .05$). In addition, for boys, the covariates that were significantly related to EFs are home stimulation ($r = .20$, $p < .05$), family wealth ($r = .18$, $p < .05$), maternal education ($r = .15$, $p < .05$), food insecurity ($r = -.11$, $p < .05$), height for age ($r = .22$, $p < .05$), and the RS intervention ($r = .14$, $p < .05$). For girls, the covariates that were significantly related to EFs are home stimulation ($r = .18$, $p < .05$), maternal education ($r = .22$, $p < .05$), food insecurity ($r = -.14$, $p < .05$), height for age ($r = .24$, $p < .05$), and the RS intervention ($r = .12$, $p < .05$).

For VIQ, the number of older siblings was not statistically significantly correlated with and VIQ for both boys and girls. Among boys, VIQ was positively correlated with home stimulation ($r = .31$, $p < .05$), family wealth ($r = .29$, $p < .05$), maternal education ($r = .27$, $p < .05$), height for age ($r = .28$, $p < .05$), and the RS intervention ($r = .10$, $p < .05$), and negatively correlated with food insecurity ($r = -.21$, $p < .05$). Among girls, VIQ was positively correlated with home stimulation ($r = .21$, $p < .05$), family wealth ($r = .14$, $p < .05$), maternal education ($r = .15$, $p < .05$), and height for age ($r = .30$, $p < .05$), and negatively correlated with food insecurity ($r = -.13$, $p < .05$). These bivariate correlations were relatively small.

Multivariate Regression Analysis

Table 2 displays the three regression models for each cognitive outcome (i.e., EFs, then VIQ). We first report associations with EFs.

Table 1

Bivariate Correlations and Descriptive Statistics Among Girls (Below Diagonal, n = 600) and Boys (Above Diagonal, n = 702)

Variable	1	2	3	4	5	6	7	8	9	10	*M*	*SD*	*Min*	*Max*
1. Number of older siblings	—	.08*	−.03	−.14***	−.14***	−.18***	.12**	−.11**	.05	.03	2.51	2.30	0.00	1.00
2. EFs	−.05	—	.52***	.20***	.18***	.15***	−.11**	.22***	.14***	−.00	−0.01	0.97	−2.60	2.68
3. VIQ	−.08	.52***	—	.31***	.29***	.27***	−.21***	.28***	.10*	−.01	77.44	9.96	55.00	116.97
4. Home stimulation	−.19***	.18***	.21***	—	.32***	.31***	−.24***	.21***	.41***	.09*	−0.02	1.01	−2.72	2.42
5. Family wealth	−.10*	.08	.14**	.27***	—	.40***	−.25***	.29***	.05	−.00	−0.01	1.02	−1.02	4.02
6. Maternal education	−.15***	.22***	.15***	.25***	.32***	—	−.23***	.21***	−.01	.13***	0.01	1.03	−0.59	3.75
7. Food insecurity	.12**	−.14**	−.13**	−.23***	−.25***	−.20***	—	−.18***	−.05	−.11**	0.34	0.48	0.00	1.00
8. Height for age	−.09*	.24***	.30***	.24***	.26***	.24***	−.16***	—	−.05	.02	−2.35	1.13	−5.96	0.91
9. RS intervention	−.01	.12**	.03	.38***	.03	−.00	−.09*	−.03	—	.02	0.52	0.50	0.00	1.00
10. EN intervention	−.09*	.03	.00	.11**	−.01	.04	−.18***	.04	−.04	—	0.46	0.50	0.00	1.00
M	2.49	0.01	76.65	0.03	0.01	−0.02	0.31	−2.31	0.49	0.51				
SD	2.31	1.03	9.48	0.99	0.98	0.96	0.46	1.11	0.50	0.50				
Min	0.00	−2.75	53.00	−2.72	−1.02	−0.59	0.00	−6.63	0.00	0.00				
Max	11.00	2.76	116.97	2.42	4.02	3.75	1.00	1.11	1.00	1.00				

Note. EFs = executive functions; VIQ = verbal IQ; RS = responsive stimulation; EN = enhanced nutrition.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Extending previous direct effect findings replicated in Model 1, Model 2 revealed a significant two-way interaction effect between the number of older siblings and the target child's gender (β = .11, *SE* = .05, $p < .05$) in predicting EFs. This effect was further qualified by a significant three-way interaction with the quality of home stimulation in Model 3 (β = .11, *SE* = .04, $p < .05$). As shown in Figure 1, there was a positive association between the number of older siblings and child EFs for boys in context of both higher (β = .13, $p < .001$) and lower (β = .10, $p < .001$) levels of home stimulation. The number of older siblings was positively related to EFs only for girls from families with lower levels of home stimulation (β = .12, $p < .001$). In contrast, for girls from families with higher levels of home stimulation, there was a negative association (β = −.11, $p = .031$) between the number of older siblings and EFs. These standardized βs indicate relatively small effect sizes.

We next report associations with VIQ. As shown in Figure 2, there was a positive association between the number of older siblings and VIQ for homes with lower stimulation (β = .08, $p = .016$). The number of older siblings was not significantly related to VIQ among higher stimulation homes ($p > .05$). Gender was not a statistically significant moderator of the association between the number of older siblings and VIQ. However, gender significantly moderated the association between home stimulation and VIQ. As Figure 3 illustrates, home stimulation was positively associated with VIQ for boys (β = .26, $p = .000$), but not for girls. These standardized βs indicate relatively small to moderate effect sizes.

Discussion

The goal of this study was to understand whether the association between young children's number of older siblings and their emergent cognitive skills, as indexed by EFs and verbal skills, is conditional on the quality of their home stimulation and their gender. A previous study using the same research sample of 4-year-old children living in rural Pakistan demonstrated a direct, positive association between the number of older siblings and EFs (Obradović et al., 2019). The present study extends these findings by exploring the quality of home stimulation and child gender as moderators of this association. Further, we examined verbal skills as a complementary but distinct cognitive outcome. Our findings revealed that among children who live in homes with lower levels of stimulation, both boys and girls who have more older siblings show higher levels of both EFs and verbal skills than those with fewer older siblings. However, among preschoolers who live in homes with higher levels of cognitive stimulation, the association between the number of older siblings and their EFs diverges by gender—boys show higher EFs, whereas girls show lower EFs as the number of older siblings increases. Preschoolers' gender did not moderate the significant association between the number of older siblings and verbal skills.

Siblings as a Compensatory Source of Stimulation

Our hypothesis that siblings serve as compensatory sources of cognitive stimulation in rural Pakistan was partially confirmed. First, supporting evidence emerged from the finding that children with more older siblings displayed greater verbal skills only in homes where stimulation opportunities were lower. In contrast, in

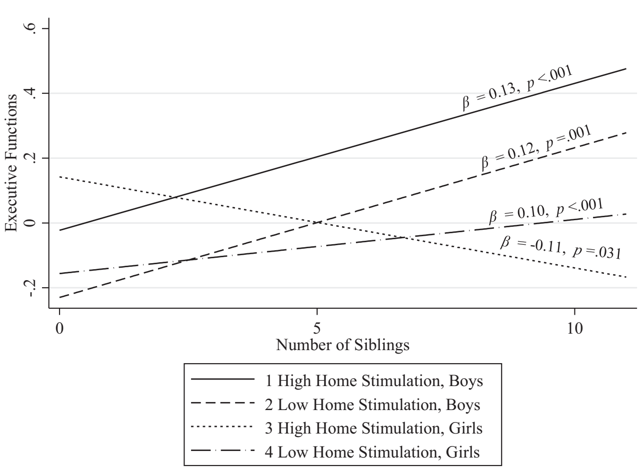
Table 2
Regression Models Predicting EFs and VIQ From Family Factors and Developmental Correlates

	EFs						VIQ					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
Variable	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*
Intercept	−.06	(.06)	−.07	(.06)	−.08	(.06)	.07	(.06)	.07	(.05)	.07	(.05)
Number of siblings	.07*	(.03)	.01	(.05)	−.00	(.05)	.01	(.03)	.01	(.03)	.00	(.03)
Male child	−.02	(.06)	−.02	(.06)	.00	(.06)	.09+	(.05)	.10+	(.05)	.10*	(.05)
Home stimulation 18 months	.07	(.04)	.07	(.04)	.06	(.05)	.17***	(.03)	.17***	(.03)	.16***	(.03)
Family wealth	.01	(.03)	.01	(.03)	.02	(.03)	.07*	(.03)	.07*	(.03)	.06*	(.03)
Maternal education	.11***	(.03)	.11***	(.03)	.11***	(.03)	.09***	(.03)	.08**	(.02)	.08**	(.03)
Food insecurity	−.12*	(.06)	−.12*	(.06)	−.12*	(.06)	−.16**	(.05)	−.16**	(.05)	−.16**	(.05)
Height for age	.18***	(.03)	.18***	(.03)	.18***	(.03)	.21***	(.03)	.21***	(.03)	.21***	(.03)
Responsive stimulation	.19**	(.06)	.19**	(.06)	.18**	(.06)	.01	(.07)	.01	(.06)	.01	(.06)
Enhanced nutrition	−.07	(.06)	−.07	(.06)	−.07	(.06)	−.10	(.07)	−.11	(.07)	−.11	(.07)
Siblings × Gender			.11*	(.05)	.13*	(.06)			.04	(.05)	.06	(.05)
Siblings × Home			−.04	(.03)	−.10**	(.04)			−.07*	(.03)	−.06*	(.03)
Home × Gender					.02	(.06)					.12*	(.05)
Siblings × Home × Gender					.11*	(.04)					.00	(.05)
Observations	1,302		1,302		1,302		1,302		1,302		1,302	
R^2	.09		.09		.10		0.15		0.15		0.16	

Note. EFs = executive functions; VIQ = verbal IQ; Home = home stimulation; *SE* = standard error.
$^{*} p < .05$. $^{**} p < .01$. $^{***} p < .001$.

homes where stimulation was higher, there was no benefit from having more older siblings. Secondary evidence emerged from the finding that girls showed higher levels of EFs as the number of older siblings increased only if they lived in homes with lower levels of cognitive stimulation. These findings corroborate previous evidence suggesting that the link between the number of older siblings and cognitive skills is likely to be stronger within family contexts where children have fewer other opportunities for stimulation (Kibler et al., 2016; Obregon, 2010; Rabain-Jamin et al., 2003). In such contexts, older siblings might be more relevant for younger sibling's cognitive development because they serve as compensatory sources of cognitive stimulation and provide opportunities for practicing cognitive skills through sibling interactions, observations, and play.

Figure 1
Three-Way Interaction Among the Number of Older Siblings, Home Stimulation, and Child Gender



Siblings as an Additional Source of Stimulation

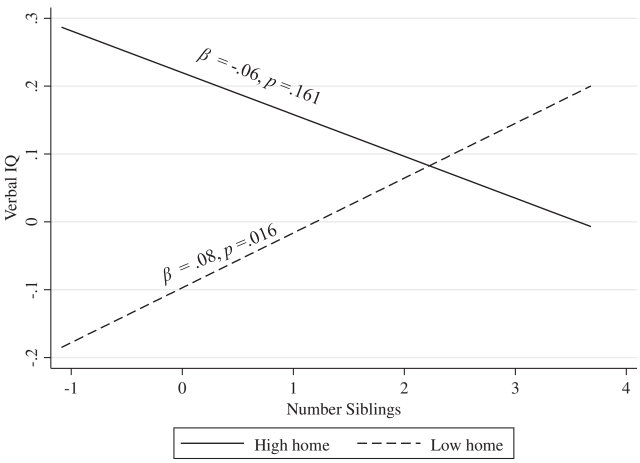
We found that with an increasing number of older siblings, preschool boys in rural Pakistan showed higher levels of EF skills in the context of rural Pakistan, regardless of the levels of stimulation in their home environment. This finding suggests that the presence of older siblings may create unique, additional experiences for younger children to apply and practice cognitive skills. By examining EF skills, this finding extends prior correlational evidence that a greater number of siblings was associated with better language skills and academic test performance (Malmeer & Assadi, 2013; Nicoletti & Rabe, 2019). Further, we build on prior research by showing that the positive association between the number of older siblings and EF skills did not depend on levels of home stimulation for 4-year-old boys. The presence of older siblings may create unique experiences to apply and practice EF skills that are independent of home stimulation levels. Future research should investigate whether and how older siblings create opportunities for cognitive stimulation and self-regulation practice through shared experiences. For instance, when young boys observe, play, and interact with older siblings, they may cognitively manipulate information, using their WM, and fine motor movements (Kibler et al., 2016; Obregon, 2010). Alternatively, older siblings may take on a greater share of household chores allowing younger brothers to spend more time engaging in other stimulating activities that promote EFs. More qualitative and ethnographic studies can help to clarify the mechanisms through which older siblings could potentially enhance EFs in rural LMIC contexts, by examining the patterns of sibling interactions and family dynamics.

Gender Disparities in Cognitive Stimulation

While girls from more stimulating homes showed relatively high levels of EF skills when they had fewer older siblings, this group showed declining levels of EF skills as the number of their older

Figure 2

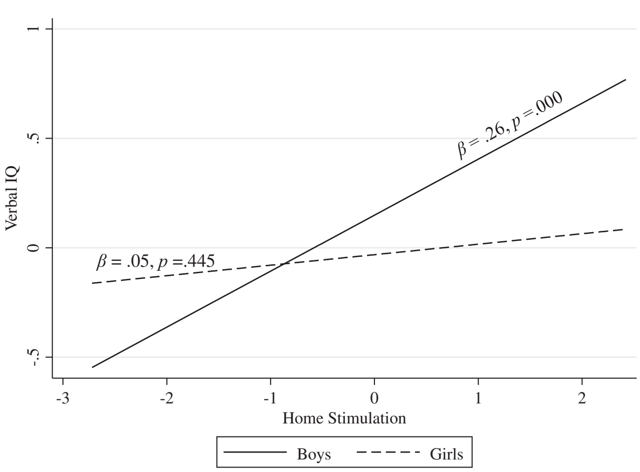
Two-Way Interaction Between the Number of Older Siblings and Home Stimulation Predicting Verbal IQ



siblings increased. This opposing association between the number of older siblings and girls' EFs as a function of home stimulation levels may shed some light on potential underlying mechanisms related to differential gender socialization. For instance, it is feasible that preschool girls from more resourced and stimulating homes may forgo family investments in educational opportunities due to greater family size and inequitable allocation of resources. In rural Pakistan, although progress has been made, considerable sex disparities remain (Najam & Bari, 2017). Just 15% of poor rural 10-year-old girls complete primary education, compared to 40% of their male peers (Najam & Bari, 2017), and girls tend to receive a smaller share of scarce household resources (United Nations Development Programme [UNDP], 2014). Further, gender-based inequities in familial educational investments and opportunities can be even more pronounced in relatively wealthier families who have more resources to allocate to their children's informal and formal education (Lloyd et al., 2009). In this way, a greater number of older siblings

Figure 3

Two-Way Interaction Among Home Stimulation and Gender Predicting Verbal IQ



may hinder girls' EF development in relatively wealthier families with higher levels of home stimulation in part because families may allocate more opportunities and resources to older siblings and brothers. In contrast, in lower home stimulation environments, stimulating opportunities and educational investments that promote EFs may be low overall, but their distribution may be more equal between boys and girls. Future research should investigate why the association between the number of older siblings and child EFs was positive among boys and among girls with low levels of home stimulation, but negative among girls with high levels of home stimulation. For instance, access to schooling, nutritional intake, level of parental engagement, sibling interactions, or amount of time spent on housework could all be included in future household surveys to capture how these factors changed for girls versus boys in homes with higher stimulation, as the number of siblings increases.

After controlling for contextual covariates, girls' verbal skills were not related to levels of home stimulation, whereas boys' verbal skills are positively associated with the degree of home stimulation. Subsequent research should further investigate how measures of home stimulation relate to girls' and boys' everyday experiences and opportunities for learning. Further, it is unclear why the number of older siblings was negatively related to EFs in girls from higher stimulation homes, but this finding was not observed for verbal skills. It is possible that girls have equal access to experiences that foster vocabulary knowledge and verbal reasoning abilities (e.g., informal conversation and interactions with caregivers) in both lower and higher stimulation homes, regardless of family size.

Future research could also focus on birth order effects, to evaluate how the results of this article reconcile with the well-documented "first-born" advantage. Prior studies looking at intra-household resource allocation have underscored the better outcomes for first-born children in terms of educational attainment in France (Mechoulan & Wolff, 2015), variety of food consumption in Indonesia (Calimeris & Peters, 2017), and educational aspirations in the United Kingdom (Bu, 2016). Given that the number of older siblings is correlated with birth order but does not directly reflect birth order, it is important to assess how the potential first-born advantage plays out in LMICs and interacts with any cognitive development benefits for younger siblings. It is also important to study how birth order divergently impacts the development of young girls compared to boys, particularly in contexts with pronounced gender inequalities.

Our article highlights the need for a family systems perspective in early childhood development programs. Prior work has emphasized the important role of fathers in early child development: across 38 LMICs, children who had more highly engaged fathers (i.e., fathers who routinely participated in play and learning activities with them) showed more advanced early developmental milestones (Jeong et al., 2018). Our results provide a compelling case for a family-centered approach to early childhood development programs and policies to move beyond promoting only maternal stimulation to actively involve fathers and siblings. Home visitation programs could be refined to provide mentoring and coaching to older children for supporting their younger siblings' self-regulation and cognitive development. An example of such an intervention comes from the United States, where a program for 95 families taught siblings emotional and social competencies to practice with each other (Kennedy & Kramer, 2008). This preventative intervention targeted sibling pairs from ages 4 to 8 years. Specifically, the program taught children how to initiate play with a sibling, accept or appropriately decline invitations to play, practice taking their sibling's perspective, practice identifying and discriminating their sibling's emotions, regulate their own emotions, and solve and manage interpersonal conflicts and challenges. This randomized trial successfully improved sibling relationship quality and emotional regulation skills (Kennedy & Kramer, 2008) and illustrates how initiatives focused on sibling interactions could improve emotional regulation and perspective taking among young children in LMICs. Importantly, any intervention should be tailored to specific LMIC contexts and take special care to avoid exacerbating any gender inequities by increasing the burden on elder sisters or reducing their access to educational opportunities.

Further, such mentoring could focus on helping older sisters and brothers support their younger siblings at home through interactions conducive to cognitive development. For example, older siblings could engage younger siblings in various games involving songs and rhymes, imitation, or puzzles, as a way of focusing their attention on a goal (Center on the Developing Child at Harvard University, 2014); conversations, storytelling, and talking about feelings with younger siblings can also contribute to their language skills and emotional regulation; imaginary play can train young children to follow rules and control any impulse that does not fit the assigned "role." These sibling-directed activities could play a role in enhancing young children's cognitive development.

Limitations

We acknowledge several limitations. First, while the sample is large and representative of Pakistani children living in rural areas, the participants' experiences may differ from those in other LMICs, particularly children in urban settings who may have greater educational opportunities. Second, longitudinal measurements of EFs and verbal skills would have enabled us to examine how proximal and distal factors contribute to growth and change in these cognitive skills, a critical question for future cognitive developmental research in LMICs. We also lacked data on the nature of the interactions between the siblings and younger children. Future research should investigate this through qualitative studies exploring the precise processes through which older siblings may play a role in influencing their younger siblings' cognitive development. Furthermore, we could not investigate the gender of the older siblings related to their younger siblings' EFs and verbal skills—it is feasible that male versus female older siblings divergently influence their younger siblings' cognitive development due to differential gender socialization processes.

In addition, our study focused on three specific aspects of EFs—IC, WM, and CF—that are developmentally appropriate for age 4, and that prior research had demonstrated could be validly measured in rural Pakistan (Obradović et al., 2019). There are other EF processes that we did not measure, such as the ability to plan, pursue, and achieve goals (Best et al., 2009), and future research may benefit from measuring these other EF processes among children in LMIC settings. Indeed, more work is needed to develop culturally appropriate measures of children's EFs that are applied to learning and goal-directed behaviors in LMICs (Obradović & Steyer, 2020; Obradović & Willoughby, 2019). In addition, it is possible that the RS and nutrition interventions administered in this sample at baseline partially influenced our findings, although we controlled for their effects in the regression models. Finally, the effect sizes for our primary findings and bivariate correlations were relatively small. Small effect sizes limit the practical implications of our findings and suggest that other factors (beyond the number of older siblings, home stimulation, gender, and our covariates) affect EFs and VIQ. Future research should examine other potential influences, such as the quality of relationship with siblings, the frequency of sibling interactions, specific experiences of gender socialization and homelife, and formal and informal learning opportunities.

Conclusion

This article is one of the first to investigate how the number of older siblings could be related to cognitive development for preschool-aged children in an LMIC context. This is especially important for a context such as rural Pakistan, where access to formal education during early childhood is limited, and where parents may be struggling to make ends meet due to high levels of poverty and inequality. We found correlational evidence pointing toward the promising role of older siblings for child EF development, and revealed that the association between older siblings and EFs differs based on the quality of home stimulation and child gender. These findings suggest that the number of older siblings, home stimulation environment, and gender interplay to predict children's emerging EFs, which support readiness to engage in informal and formal learning environments. Further, we found that the association between older siblings and verbal skills differs based on the quality of home stimulation only, but not gender, which suggests that verbal skills are affected less by gendered preferential treatment than EFs.

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