

Assessment of Neurocognitive Development in Young Children in Kaffrine (Senegal): Results of the OX NDA and INTER NDA Tests in a Region with High Nutritional Vulnerability

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Abstract

Introduction: The early years of life are crucial for neurocognitive development. Whilst the impact of malnutrition is well documented, the interaction between nutritional factors and the family environment remains poorly studied, particularly in rural African settings. **Methods:** A prospective study was conducted from June 2021 to September 2024 involving 226 children aged 22 to 26 months (INTER NDA) and 171 children aged 10 to 14 months (OX NDA). The aim was to assess infants' cognitive performance and the factors associated with it. Cognitive, language, motor and behavioural development were assessed. The family environment was measured using the IT-HOME questionnaire. Data analysis was performed using R software through descriptive and bivariate analyses. **Results:** The results show a high prevalence of delays. 76.6% of 12-month-old children exhibited a language delay (persisting in 70% at 24 months). We noted a high level of emotional responsiveness among caregivers to the child's needs (87% - 94% of the maximum score) despite limited access to educational toys. Protective factors appear to be the promotion of the child's development ($p = 0.02$) and the organization of the child's physical and temporal environment ($p = 0.004$). Paradoxically, no significant asso-



ciation was found between anthropometric indicators and developmental scores. **Conclusion:** This study highlights how responsive care could mitigate material limitations, whilst emphasizing the urgency of addressing persistent language deficits.

Keywords

Cognition, Infant, Family Environment, Nutrition, Senegal

1. Introduction

Neurocognitive development in early childhood lays the foundations for health, well-being and economic productivity throughout life [1] [2]. This critical period, often summarized under the concept of the “first 1,000 days”, is particularly vulnerable to nutritional deficiencies and insufficient psychosocial stimulation [3]. In low- and middle-income countries (LMICs), the combined burden of malnutrition and poverty puts millions of children at high risk of failing to reach their optimal developmental potential [3].

While the detrimental impact of protein-energy malnutrition and deficiencies in specific micronutrients (such as iron, iodine and zinc) on brain development is well documented [4], the influence of the family environment is emerging as an equally powerful determining factor [5] [6]. Tools such as the Home Observation for Measurement of the Environment (HOME) questionnaire have established that a stimulating home environment, offering emotional responsiveness and learning opportunities, is strongly associated with better cognitive and language outcomes in children [7]. However, in highly deprived settings, these two dimensions—nutritional and psychosocial—are often intertwined, making it difficult to identify priority areas for intervention.

In Senegal, as in many sub-Saharan African countries, population-level data on the neurocognitive development of infants and its modifiable determinants remain scarce. The Kaffrine region, identified as one of the poorest in the country and with the highest rate of chronic malnutrition [8], is a priority study site for investigating this issue. Most studies have focused either on nutrition or on stimulation, without always exploring their interaction within a specific population setting.

This study aims to address this gap by assessing the neurocognitive development of infants in a prospective cohort in Kaffrine and analysing the relative importance of nutritional factors and the quality of the family environment. Our specific objectives were:

- 1) to describe the prevalence of risks of neurodevelopmental delay across several domains (cognition, language, motor skills), and
- 2) to analyze the association between these outcomes and scores for family environment stimulation and nutritional status.

2. Materials and Methods

1. Study type and population

This is a prospective cohort study conducted in the Kaffrine department from June 2021 to 30 September 2024. As part of the global project “Action against malnutrition and stunting” in three countries (Senegal, India, Indonesia),

The study targeted all maternity hospitals in the designated area, where all consenting pregnant women in their first trimester of gestation were consecutively enrolled. The protocol involved a longitudinal follow-up of their offspring until 24 months of age.

2. Inclusion criteria

All children aged 10 to 14 months for the OX NDA and 22 to 26 months for the INTER NDA who were able to undergo these tests were included.

3. Exclusion criteria

Children with incomplete data were not included in the study.

4. Data collection

Local teams of investigators were trained to administer the various tests used. For the cognition and education team, these were pre-school teachers. The training phase was followed by a pre-test and then on-site supervision.

A cognitive assessment was carried out using the Oxford Neurodevelopment Assessment (OX NDA) for children aged 10 to 14 months and the Intergrowth Neurodevelopment Assessment (INTER NDA) for children aged 22 to 26 months.

An assessment of the socio-familial environment was carried out using the IT-HOME questionnaire (Infant and Toddler Home Observation Measurement of the Environment). The assessment comprises seven domains: the caregiver’s emotional and verbal responsiveness, avoidance of restriction and punishment, promotion of the child’s development, organization of the child’s physical and temporal environment, provision of appropriate play materials, opportunities for daily stimulation, and the child’s hygiene. The maximum score is 48 points.

An assessment of nutritional status was carried out at 18 months of age by measuring height and weight and using weight-for-height, weight-for-age and height-for-age ratios.

5. Statistical analysis

Data analysis was performed using the R software package. The descriptive analysis of quantitative variables was carried out by calculating the mean and standard deviation, whilst that of qualitative variables was carried out using their frequencies (absolute and relative).

Bivariate analysis was performed using the chi2 test for categorical variables, while continuous variables were analyzed using mean comparisons (t-tests). Odds ratios (OR) with 95% confidence intervals (CI) were calculated to evaluate the strength of associations, and significance was defined as $p < 0.05$.

6. Ethical considerations

The mothers had freely consented to participate in the study proposed by the maternity ward staff. General ethical approval had been obtained from the na-

tional ethics committee under number SEN19/78 dated 31 December 2019.

3. Results

OX NDA results

1. Descriptive results

171 infants aged 11 to 14 months were assessed.

Age: the mean age was 13.14 months $\pm$ 1.89 months. The median age was 13 months, with a range of 11 to 14 months (**Table 1**).

Table 1. Distribution of OX NDA scores by mother's age.

	Cognition		P value
	Normal	Delay	
Mother's age	26.8 (5.85)	27.8 (6.04)	0.387
	Motor skills		P value
	Normal	Delay	
Mother's age	27.0 (6.11)	27.7 (5.85)	0.551
	Language		P value
	Normal	Delay	
Mother's age	26.3 (5.52)	27.7 (6.08)	0.317

Mother tongue: a very large majority of 127 children (85.8%) had Wolof as their mother tongue. This was followed by Peulh with 15 children (10.1%), Serer with 3 children (2%), Bambara with 2 children (1.4%) and Diola with 1 child (0.7%). Mother tongue data were not specified for 23 children.

Bilingualism: of the 171 children assessed, 152 children (88.9%) were not exposed to a second language in addition to their main language for more than 30 minutes a day. In contrast, 19 children (11.1%) were exposed to two languages.

Mothers' age: the mean age of the mothers was 27.39 years $\pm$ 5.95. The median was 26 years, with ages ranging from 19 to 40 years.

Mothers' occupations: of the 171 mothers for whom an occupation was recorded, an overwhelming majority of 146 mothers (85.4%) were housewives. Other occupations were represented in smaller proportions, with 11 shop assistants (6.4%), 4 students (2.3%), 2 seamstresses or embroiderers (1.2%), 2 teachers (1.2%), 1 hairdresser (0.6%), 1 accountant (0.6%), 1 student (0.6%), 1 housekeeper (0.6%), 1 nurse (0.6%) and 1 working in a hairdressing salon (0.6%).

Description of assessment results:

- **Language:** Of the 171 children assessed for cognition at 12 months, 131 children (76.6%) scored in the range indicating neurodevelopmental delay.
- **Cognition:** Of the 171 children assessed for cognition at 12 months, 94 children (55%) scored in the range indicating neurodevelopmental delay.
- **Motor skills:** Of the 171 children assessed for motor skills at 12 months, 89

children (52%) scored in the range indicating neurodevelopmental delay.

- **Positive behavior:** The mean score for positive behavior was 72.79 ± 27.67 . The median was 80, with extremes ranging from 0 to 100 months.
- **Negative behavior:** The mean score for negative behavior was 34.36 ± 37.77 . The median was -50, with scores ranging from -50 to 125.

Analytical results

The mean age of mothers of children with motor delays (27.7 years), cognitive delays (27.8 years) and language delays (27.7 years) is not significantly different from that of mothers of children without delays.

There was no correlation between cognitive score and the mother's occupation, the language spoken, or whether or not the child was bilingual.

INTER NDA results

1. Descriptive results

This study involved 226 subjects.

Age: Age data were collected for 221 children, with a mean age of 23.60 months (standard deviation: 0.62 months). The median age was 24 months, ranging from 22 to 25 months (**Table 2**).

Mother tongue: among the 226 children, Wolof was the mother tongue of a very large majority of 197 children (87.2%). The other languages represented were Peulh, Serer, Bambara and Toucouleur, forming a secondary linguistic diversity. The mother tongue of 2 children (0.9%) was not recorded.

Table 2. Breakdown of participants by age and mother's language.

Variable	Categories	Absolute frequency	Relative frequency (%)
Age (months)	Mean = 23.60 (Standard deviation) = 0.62		
Mother's language			
	Wolof	197	87.2
	Peulh	13	5.8
	Serer	8	3.5
	Bambara	4	1.8
	Toucouleur	2	0.9

Description of assessment results (**Figure 1**):

- **Language:** Of the 226 children assessed, 132 children (58.4%) scored in the moderate-risk category for neurodevelopmental delay or disorder. 70 children (31.0%) and 24 children (10.6%) were classified in the low-risk and high-risk categories respectively.
- **Cognition:** 165 children (73%) scored in the low-risk category for neurodevelopmental delay or disorder. In contrast, 35 children (15.5%) and 26 children (11.5%) were classified in the moderate-risk and high-risk categories respectively.

- **Gross motor skills:** 166 (73.5%) showed a low risk of neurodevelopmental delay or disorder.
- **Fine motor skills:** 175 children (77.4%) scored in the low-risk category for neurodevelopmental delay or disorder.
- **Positive behavior:** 139 (61.5%) showed a low risk of neurodevelopmental delay or disorder. In contrast, 68 children (30.1%) were identified as being at high risk and 18 children (8.0%) at moderate risk. One child could not be assessed for this item.
- **Negative behavior:** 132 children (58.4%) obtained a score indicating a moderate risk of disorders related to the presence of negative behaviors (easily distracted child, negative affect). In contrast, 68 children (30.1%) and 25 children (11.1%) were classified in the low-risk and high-risk categories respectively. One child was not assessed on this item.

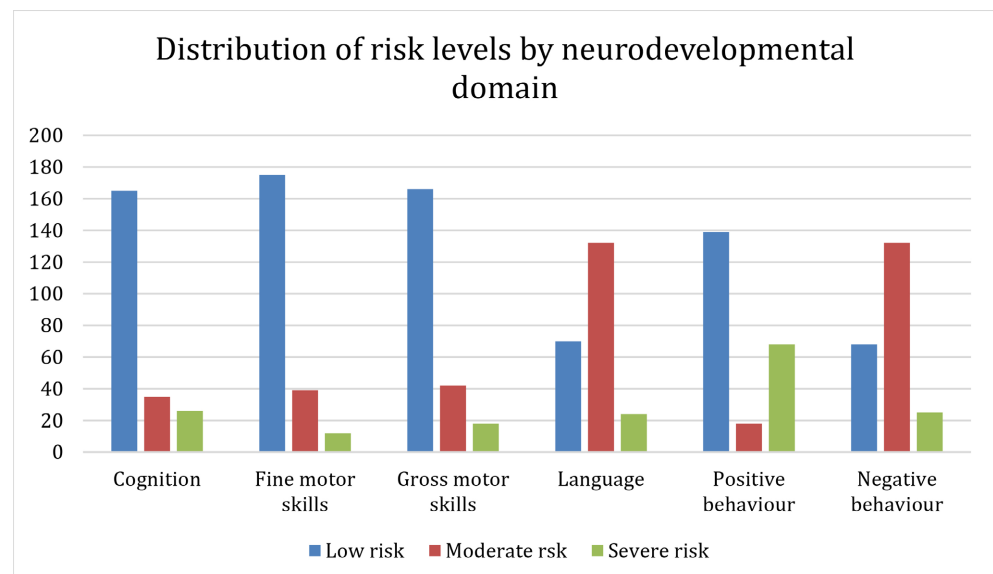


Figure 1. Distribution of risk levels by neurodevelopmental domain (INTER NDA results).

2. Analytical results

The distribution of INTER NDA results by age shows no statistically significant association with P-values greater than 5% for all INTER NDA items.

Regarding the distribution of items by mother's language (Wolof, Peul, Serer, Bambara and Toucouleur), we found no significant link between these languages and the INTER NDA items.

IT-HOME Results

1. 12-month assessment

154 participants were assessed (**Table 3**).

- A very large majority of 153 children (99.4%) had their mother as their primary caregiver. The mean value of the total HOME 12 score was 32.546 ± 5.386 , or 67.8% of the total score (48 points). The median was 33, with extremes of 16 and 45.

Table 3. IT-HOME results at 12 months by sub-score.

	Mean	Standard deviation	Median
Receptivity	9.57	2.16	11
Avoidance of punishment	1.28	1.93	0
Promotion of development	4.55	0.61	5
Environmental organization	8.14	1.83	8
Play equipment	0.53	0.91	0
Variety	5.83	1.36	6
Cleanliness	2.64	0.91	3
TOTAL HOME 12	32.55	5.39	33

- Caregiver Emotional and Verbal Responsiveness: The mean value was 9.57 ± 2.16 , representing 87% of the maximum score. The observed median was 11, with values ranging from 1 to 11.
- Avoidance of Restriction and Punishment: The mean value was 1.28 ± 1.93 ; the median was 0, with values ranging from 0 to 5.
- Promotion of Child Development: The mean score was 4.55 ± 0.61 , representing 91% of the maximum score. The median was 5, and scores ranged from 2 to 5.
- Environmental Organization: The mean was 8.14, with a standard deviation of 1.83; the median was 8, and scores ranged from 4 to 12.
- Learning Materials: The mean was 0.53 with a standard deviation of 0.91, representing 18% of the maximum score; the median was 0, and scores ranged from 0 to 3.
- Daily Stimulation Variety: The mean was 5.83 ± 1.36 ; the median was 6, with scores ranging from 1 to 9.
- Toilet Training: The mean score was 2.64, with a standard deviation of 0.91; the median was 3, and scores ranged from 0 to 3.

2. 24-month assessment

327 participants were assessed. Of the 327 children, a very large majority of 322 children (98.5%) had their mother as their primary caregiver (Table 4). The mean HOME 24 score was 32.30 ± 4.21 , representing 67.3% of the total score. The median was 32, with scores ranging from 17 to 43.9 (Table 5).

Table 4. Primary caregiver of the children studied.

Variable	Modalities	Absolute frequency	Relative frequency (%)
Person responsible for the child			
	Mothers	153	98.5
	Father	2	0.6
	Grandmother	2	0.6
	Aunt	1	0.3

Table 5. IT-HOME results at 24 months by sub-score.

	Mean	Standard deviation	Median
Receptivity	10.30	1.33	11
Avoidance of punishment	0.94	1.49	0
Promotion of development	4.68	0.61	5
Environmental organization	8.07	1.79	8
Learning materials	0.54	0.83	0
Variety	5.38	1.09	5
Cleanliness	2.37	1.13	3
TOTAL HOME 24	32.30	4.21	32

- Caregiver Emotional and Verbal Responsiveness: The mean score was 10.3 ± 1.33 , representing 94% of the maximum score. The median was 11, with scores ranging from 3 to 11.
- Avoidance of Punishment and Restriction: The mean was 0.94 ± 1.49 ; the median was 0, and scores ranged from 0 to 5.
- Promotion of child development: The mean score was 4.68 ± 0.61 , or 94% of the maximum score. The median was 5, and scores ranged from 2 to 5.
- Environmental Organization: The mean score was 8.07, with a standard deviation of 1.79; the median was 8, and scores ranged from 3 to 12.
- Appropriate play materials: The mean score was 0.54 ± 0.83 , or 18% of the maximum score; the median was 0, and scores ranged from 0 to 3.
- Daily Stimulation Variety: The observed mean was 5.38 ± 1.09 ; the median was 5, and scores ranged from 3 to 9.
- Cleanliness: The mean score was 2.37 ± 1.13 ; the median was 3, and scores ranged from 0 to 3.

Results of the nutritional assessment

219 infants underwent nutritional assessment at 18 months. In this sample, 55.3% were girls, representing a balanced distribution but with a slight bias towards the female sex.

- Weight-for-age ratio: The majority of children (nearly 43.4%) are slightly underweight (**Figure 2**).
- Height-for-age ratio: 50.2% of children have a ratio considered normal (**Figure 3**).
- Weight-for-height ratio: 38.8% of children are slightly underweight, whilst 38.8% have a normal weight (**Figure 4**).

Bivariate analysis

1. Cognitive assessment and family environment at 12 months

18 subjects who underwent the IT-HOME 12-month family environment assessment also received the OX NDA (**Table 6**). The bivariate analysis shows the following results:

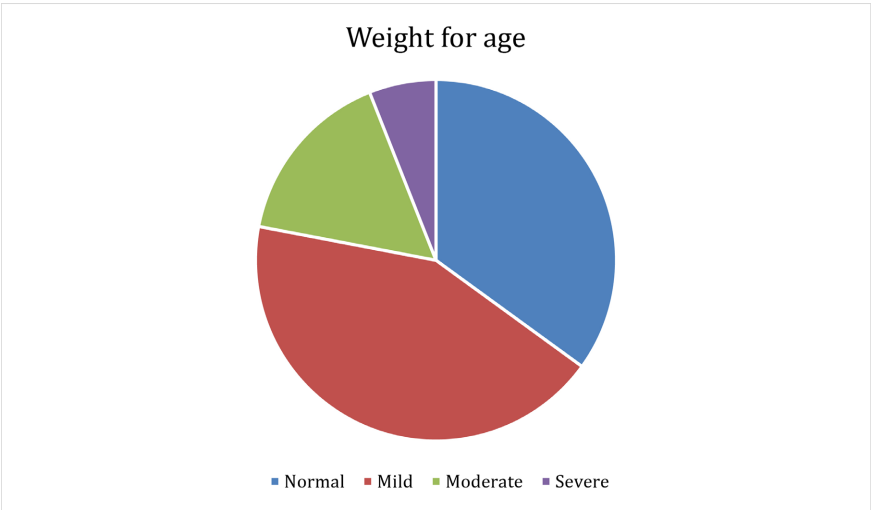


Figure 2. Weight for age ratio at 18 months.

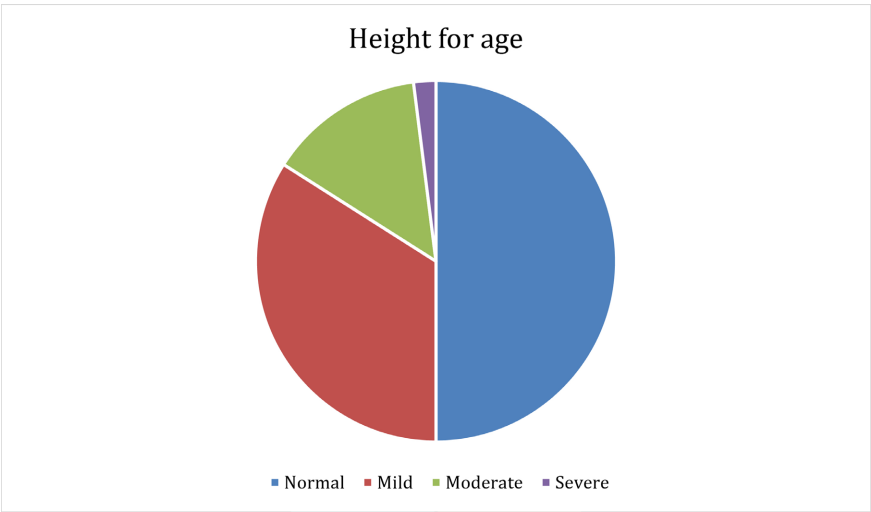


Figure 3. Height for age ratio at 18 months.

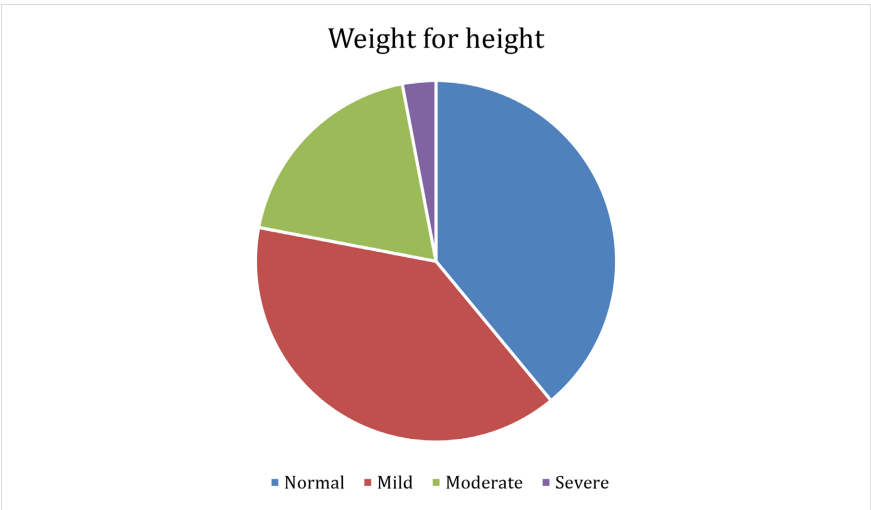


Figure 4. Weight for height ratio at 18 months.

Table 6. Results of the OX NDA assessment based on the IT-HOME score.

	Cognition		OR	p-value
	Delay	Normal		
Emotional receptivity	9.44 (1.59)	10.2 (1.39)	1.47 [0.74; 2.90]	0.286
Avoidance of punishment	1.11 (2.20)	0.89 (1.62)	0.94 [0.56; 1.56]	0.811
Promotion of development	4.22 (0.67)	4.89 (0.33)	13.9 [1.18; 163]	0.020
Environmental organization	7.33 (0.87)	9.56 (1.67)	3.98 [1.11; 14.2]	0.004
Play equipment	0.00 (0.00)	0.44 (1.01)	21034306 [0.00; -]	0.225
Types of stimulation	5.78 (0.67)	6.00 (1.32)	1.26 [0.48; 3.30]	0.661
Cleanliness	2.67 (1.00)	2.44 (1.13)	0.80 [0.31; 2.05]	0.665

- Cognition: The variables “Promotion of development” and “Organization of the child’s environment” show a statistically significant association with cognitive delay, with respective p-values of 0.02 and 0.004 and odds ratios (OR) with their confidence intervals of 13.9 [1.18 - 163] and 3.98 [1.11 - 14.2].
- Motor skills: No factor is statistically significant at $p < 0.05$, but Organization of the child’s environment shows a trend ($p = 0.053$): this may warrant further investigation in a larger study.
- Language: Extremely unbalanced sample (17 vs 1). Not interpretable.

2. Psychomotor assessment and family environment at 24 months

36 infants who underwent the IT-HOME family environment assessment at 24 months also received the INTER NDA. Of these 36 children, the average number of people living in the household was 5.36, with a median of 5 and a range of 2 to 12 people.

The bivariate analysis shows the following results:

- Cognition: Comparisons of the means of the HOME sub-items according to levels of cognitive risk show no statistically significant differences.
- Language: a statistically significant association was noted with the quality of the organization of the child’s physical and temporal environment ($p = 0.038$).
- Gross motor skills: No sub-item showed a statistically significant difference.
- Fine motor skills: No HOME sub-item reaches the threshold for statistical significance.

3. Nutritional and psychomotor assessment

In the four domains studied (cognition, language, gross motor skills and fine motor skills), no p-value is below 0.05, indicating that the differences between the weight-for-age, weight-for-height and height-for-age categories according to INTER NDA risk levels are not statistically significant.

4. Discussion

This prospective study provides valuable insights into the neurocognitive development of young children and the role of their family environment in a rural re-

gion of Senegal characterized by high nutritional vulnerability. Our main findings reveal a mixed picture: an alarming prevalence of developmental delays, particularly in the area of language, coexists with notable strengths in family interactions, some of which prove to be significant protective factors.

High prevalence of delays, particularly in language

The rate of language delay observed in 78% of children at 12 months (OX NDA), which persists for the majority of them at 24 months (INTER NDA), is particularly concerning. This prevalence exceeds that often reported in other disadvantaged settings [9]. Several factors specific to our sample may explain this. Almost all the mothers (85.4%) were housewives, which, in this context of poverty, could be associated with social isolation and a low level of education, limiting rich and varied language interactions with the child. Furthermore, extremely limited access to learning materials and books (only 18% of the maximum IT-HOME score) deprives children of crucial stimulation for the acquisition of vocabulary and concepts. The lack of association with bilingualism suggests that this language deficit is structural and linked to a general lack of stimulation, rather than to exposure to a second language.

The quality of care as a protective factor against material adversity

One of the key findings of this study lies in the dissociation between material resources and the quality of interactions. Whilst scores relating to material possessions (toys, books) are very low, scores for caregivers' behaviors—particularly emotional responsiveness (87% - 94% of the maximum score) and active promotion of development (91% - 94%)—are remarkably high. This indicates that, despite poverty, mothers in Kaffrine provide constant emotional support and attention to their children.

The bivariate analysis confirms the protective role of these behaviors. The significant association between higher scores for “Promotion of development” and “Organization of the environment” and better cognitive performance at 12 months should be interpreted as an exploratory association given the small linked subsample size. It corroborates the literature suggesting that a structured and stimulating family environment, even in the absence of sophisticated toys, can promote cognitive development by offering security and opportunities for exploration [5] [6]. This organization, which likely includes stable routines and a predictable framework, appears to promote early learning.

The paradoxical lack of association with nutritional status

The lack of a significant association between anthropometric indicators at 18 months and developmental scores is a surprising finding, given the abundant evidence linking malnutrition to developmental delay. Several hypotheses may explain this. Firstly, the anthropometric measure may not capture cumulative exposure to malnutrition or specific micronutrient deficiencies most critical for brain development (such as iron or iodine). Secondly, the protective effect of the psychosocial environment, as measured by the IT-HOME, may have mitigated the potential negative impact of mild to moderate nutritional deficiencies. Finally, the

lack of variability in nutritional scores (with a large proportion of the population clustered in the “mild deficiency” or “normal” categories) may have reduced the statistical power to detect an association.

Our findings have important implications for public health policy and early interventions. They suggest that in settings such as Kaffrine, early childhood development programs should not be limited to providing toys, but should also strengthen existing parenting skills. Simple interventions, focusing on the importance of talking, singing and reading to children, and on establishing structured routines, could have a considerable impact. The fact that high-quality responsive care can exist despite extreme material deprivation is a message of hope and a powerful lever for action. Targeting these psychosocial strengths could be a more efficient and sustainable strategy for mitigating the effects of material deprivation on child development.

Limitations: This study has certain limitations. The cross-sectional linkage between the IT-HOME and neurodevelopmental tools resulted in small analytical subsamples, reducing statistical power. Additionally, unmeasured socioeconomic confounders, such as maternal education levels and precise household income, were unavailable and should be considered in future larger-scale cohort studies.

5. Conclusion

Despite severe nutritional and material vulnerability, the cognitive development of children in Kaffrine appears to be partially protected by the quality of care and the structure of the family environment. Targeting these psychosocial strengths offers a promising avenue for effective interventions, which must, however, directly address the massive deficit in language stimulation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviations

INTER-NDA	Intergrowth Neurodevelopment Assessment
OX NDA	Oxford Neurodevelopment Assessment
IT-HOME	Infant and Toddler Home Observation Measurement of the Environment