Child neurodevelopment and the quality of ecological environments for children in the Amazon

Neurodesenvolvimento infantil e a qualidade dos ambientes ecológicos de crianças da Amazônia

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Elson Ferreira Costa
ORCID: https://orcid.org/0000-0003-4115-9029
Universidade do Estado do Pará, Brasil
E-mail: elsonfcosta@gmail.com

Lília Iêda Chaves Cavalcante
ORCID: https://orcid.org/0000-0003-3154-0651
Universidade Federal do Pará, Brasil
E-mail: lilacavalcante@gmail.com

Samyra Said de Lima
ORCID: https://orcid.org/0000-0003-4906-9386
Universidade Federal do Pará, Brasil
E-mail: samyra_said@hotmail.com

Dalízia Amaral Cruz
ORCID: https://orcid.org/0000-0002-0474-7537
Universidade Federal do Pará, Brasil
E-mail: dalizia@ufpa.com

Luísa Sousa Monteiro Oliveira
ORCID: https://orcid.org/0000-0002-3120-1839
Universidade Federal do Pará, Brasil
E-mail: luisatomonteiro@gmail.com

ABSTRACT

The purpose was to analyse the relationship between the quality of the ecological environment and the neurodevelopment of children in an Early Childhood Education Unit in the Amazon. Seventy children from two to five years participated, assessed by the Denver-II neurodevelopment screening test, in three times in the year. The Home Environment Resources Scale, the Family Poverty Index, the Neighbourhood Quality Instrument, and the ECERS-R Scale were applied in two times. The results agreed with the hypothesis that there would be a longitudinal increase in the percentage of children with normal score according to Denver-II and in the environmental quality scores. The findings showed that children belonging to families with a higher poverty rate and poorer environmental quality obtained a higher percentage of delay in neurodevelopment. The explanatory-model showed that the most influential variables in suspect a delay were poverty index, few joint activities with parents, and the low interaction among the neighbours and, at school. However, family poverty is a multidimensional risk factor that cuts across ecological contexts.

Keywords: Child Development; Environmental Quality; Poverty Index; Amazon.
RESUMO

Objetivou-se analisar a relação entre a qualidade do ambiente ecológico (familiar, escolar e vizinhança) e o neurodesenvolvimento de crianças em uma Unidade de Educação Infantil da Amazônia. Participaram 70 crianças, avaliadas pelo teste de triagem do neurodesenvolvimento Denver II, em três períodos. Aplicaram-se, em dois momentos, o Inventário de Recursos do Ambiente Familiar, o Índice de Pobreza Familiar, o Instrumento de Qualidade da Vizinhança e a Escala ECERS-R. Os resultados concordaram com a hipótese de que haveria aumento longitudinal no percentual de crianças com desempenho normal pelo Denver II, e nos escores de qualidade ambiental. Porém, os achados mostraram que as crianças pertencentes a famílias com maior índice de pobreza e pior qualidade ambiental obtiveram maior percentual de suspeita de atraso no neurodesenvolvimento.

Palavras-chave: Desenvolvimento Infantil; Qualidade Ambiental; Pobreza

Introduction

Neurodevelopment refers to the sequential process of acquiring a set of cognitive, behavioral, and motor functions and skills, according to the maturation of the Central Nervous System and the child's chronological age. These characteristics are the result of the interaction between biological, genetic, epigenetic, and environmental potential (Araújo & Israel, 2017; Coelho, Ferreira; Sukiennik, & Halpern, 2016).

According to Bronfenbrenner (1996), as the child develops, he/she starts to interact in different ecological environments. This is conceived topologically as an organization of concentric structures, that is, subsystems that interact with each other and with the person in development. They are called micro, meso, exo, and macrosystem, the first of which is the immediate environment, where the child establishes activities, roles, and interpersonal relationships, therefore called family, school, and neighborhood microsystems. Thus, it is assumed that environments considered to be of good quality may favor the acquisition of developmental skills. In contrast, low quality can increase the risk of damage to the developmental trajectory (Iruka, De Marco, & Garrett-Peters, 2018; Pérez-De La Cruz, Ramírez, & Maldonado, 2020).

In these terms, the family microsystem is generally the first environment where the child is inserted. The quality of this corresponds to the material resources and the types of care and stimuli that are provided by the family, thus involving social and emotional support, support in daily activities, in the organization of the routine, and in the level of interactions (Marturano& Elias, 2016; Dourado, Carvalho, &Lemos, 2015; Marturano, 1999).

Another microsystem in which the child is inserted in early childhood is the neighborhood environment. Its quality can be determined by the access conditions of residents to public and private services, such as infrastructure, leisure and accessibility opportunities, low exposure to pollution and violence, and relational aspects such as cohesion and social interaction between neighbors. From an ecological point of view, the situation of social vul-
Vulnerability has macrosystemic characteristics that directly influence the quality of family and neighborhood environments and have an impact on the developmental processes that occur in the microsystem. Thus, studies have considered that the low quality of these environments is linked to the interference of multiple risk factors, including poverty (Iruka et al., 2018; Tran; Luchters, & Fisher, 2017).

Poverty is a multifactorial and multidimensional phenomenon, which is expressed asymmetrically in different populations and regions of Brazil. Particularly in the North region, in the Amazon, the high rate of children under six years old who belong to families in poverty and live in neighborhoods with precarious resources stands out (Cardoso & Denaldi, 2018; Morais, Carvalho, Magalhães, & Pinto, 2015). Also, the Child Development Index (CDI) is significantly lower in the northern states, compared to the national average. The CDI, created by the United Nations Children's Fund (UNICEF), incorporates variables related to access to health and education services, parental care, and the protection that the family provides to the child (Kisil&Fabiani, 2015), and summarizes important human needs throughout their development.

That said, it is considered that poverty affects the family and neighborhood microsystems, as well as the school environment of which the child is a part, thus composing a complex developmental ecology. Specifically, early childhood education institutions, where children have entered earlier and earlier (Black et al., 2017), must act to stimulate development in the so-called critical period of neurological maturation. However, the infrastructure of these spaces and the pedagogical proposals do not always have an adequate quality standard. For Harms, Cryer, and Clifford (1998), the quality of this environment results from seven dimensions, namely, space and furniture; personal care routines; language and reasoning; activities; interaction; program structure; and the relationship between parents and professionals. Such dimensions generally depend on the resources available or received by these institutions.

Therefore, about 85% of children with lower SES who attend Nursery Schools in Brazil attend public or philanthropic institutions of lower quality, further intensifying the inequality of opportunities. Besides, daycare centers and preschools in the South and Southeast region have twice the quality of those in the Northern region of the country (ABRINQ, 2017). Thus, as in the family and neighborhood microsystem, poverty is linked to the quality of the school environment, establishing with them correspondence relationships still little known in their effects on human development.

Evidence from current studies (Black et al., 2017; Tran et al., 2017; Worku et al., 2018) points out that the quality of the environments influences the developmental results in early childhood. However, there are still few studies that evaluated the association between the neurodevelopment of children and their ecological environments simultaneously, particularly in the Amazon region. Nevertheless, we highlight the research conducted by researchers from this region (Costa, Cavalcante, Silva, & Guerreiro, 2016), whose results showed that of the 319
children evaluated with the Denver II screening test, 77.7% presented a score of suspected delay, with family poverty being the main variable associated with this outcome. In this sense, the authors concluded that it is still necessary to clarify how the interrelationship between these variables occurs. That is, as children in poverty have their development affected by this multidimensional condition and by the characteristics of the environments that are constituents of their development ecology.

Therefore, this study continued the investigations of Costa et al. (2016), to deepen the analysis of child neurodevelopment, through screening tests and evaluation of the quality of ecological environments. This research was guided by Bronfenbrenner's Theory of Bioecology of Human Development (2011), which allows understanding development through four theoretical interrelated nuclei: process (P), person (P), context (C), and time (T). Thus, it is possible to analyze the characteristics of the person, who is involved in proximal processes based on interactions between organism and environment (immediate and remote), along time dimensions. In this theoretical perspective, the proximal process is the main driving mechanism of development. They are particular forms of reciprocal interactions with other people, objects, or symbols, which vary according to the complexity of the relationships and activities established (Bronfenbrenner, 2011).

Therefore, this study aimed to analyze the relationship between the quality of the ecological environment (family, school, and neighborhood) and the neurodevelopment of children in an Amazonian Early Childhood Education Unit. The hypotheses established and based on the bioecological model are that (1) the better the quality score of the environments, the better the performance on Denver II. (2) Neurodevelopment tends to improve over time if the quality of the environment also improves. (3) The family poverty rate has a negative association with neurodevelopment.

Method

This is a study with a longitudinal design, of descriptive-correlational nature, and a quantitative approach of the data.

The study was conducted in Belém do Pará, the largest city in the Amazon. The participating Early Childhood Education Unit (ECEU) is located in the District of Belém (DABEL), a central region of the municipality. The selection criterion of this ECEU was by non-probabilistic and intentional sampling since it is the only one in the DABEL where the children had the highest incidence (100%) of suspected delay in neurodevelopment in previous research (Costa et al., 2016), thus allowing further study.
Initially, all children enrolled in the ECEU (N=70) and a reference family member of each study participated in this study. None of them had diagnosed or easily discernible deficiency. In the end, 6 children who left the ECEU were excluded, with a final sample of 64 participants. This study and all the data collection, was approved by Research Ethics Committee of Nucleus of Tropical Medicine, at the Federal University of Pará (UFPA), process No. 1.846.658. In addition to following the norms of Resolution No. 466/12 of the National Council of Health for research involving human beings.

The Denver Developmental Screening Test – Denver II (Frankenburg et al., 1992) was applied, which evaluates children between zero and six years old. It is subdivided into four domains: Personal-social, Fine motor, Language, and Gross Motor. The version of Denver II administered in this study was Denver II already translated and culturally adapted for the Brazilian child. The test consists of 125 items/tasks that are administered from the examiner's observation, although some items can be punctuated by statements from parents or caregivers. The items are interpreted as "passed", "failed", "without opportunity" or "refused". Thus, the "Normal" score is assigned when the child "passes" in the task related to the item; “Caution” when he/she "fails" to perform a task whose 75% to 90% of children of the same age, of the reference population, already performed. Finally, the "Delay" score is assigned when the child "fails" to perform a task in which 90% or more already performed. The final interpretation of the test presents the indicators: a) Normal: when there is no item of "delay" or, at most, one of "caution"; b) Suspected delay: when there are two or more “caution” and/or one “delay” items; c) Untestable: if there are “refusal” marks on one or more items.

To assess the quality of the school environment, the Early Childhood Environment Rating Scale - Revised Edition - ECERS-R (Harms et al., 1998) was used, which assesses the quality of early childhood environments for children between 2 and 5 years old, it was translated and adapted to Brazilian Portuguese (Campos et al., 2011). Its observation script contains seven subscales (space and furniture; personal care routines; language and reasoning; activities; interaction; program structure; and parents and staff) and has a whole 43 items and 470 indicators. For the indicators, the "yes", "no" or "not applicable" markup is marked, and each item will have a score ranging from 1 to 7 points. In the end, the mean for each subscale and then the general average are generated, which also range from 1 to 7 points, with the following scores: inadequate, for scores from 1 to 2.9; minimum/basic, for 3 to 4.9; good, for 5 to 6.9, and excellent for score 7 (Harms et al., 1998). Regarding its psychometric qualities, the scale presents internal consistency (Cronbach’s alpha) of 0.92 and interobserver fidelity of 71%.

To assess the quality of the family environment, the Family Poverty Index - FPI (Barros, Carvalho, & Franco, 2006) was applied. It consists of 48 social indicators, divided into six dimensions (vulnerability; access to knowledge; access to work; availability of resources; child development, and family housing conditions or deficiencies). Each indicator is answered
with "yes" (1 point) or "no" (0 points) revealing the presence or absence of a given characteristic.

For the analysis of the FPI, initially, the value of 1 (maximum score) was divided by 6 (number of dimensions), and each of them was assigned the value 0.167. After that, for each dimension, this value was divided by the number of indicators existing in each of them, resulting in the values of 0.0167 for each vulnerability indicator, 0.0278 for access to knowledge, 0.0278 for access to work, 0.056 for income availability, 0.0151 for development and 0.0138 for housing conditions. The instrument's gross score ranges from zero to 48, but the weighted final score ranges from zero to one.

To investigate the resources of the family environment and its social support, the Inventory of Home Environment Resources Scale – HERS (Marturano, 1999) was used. It is composed of ten questions, divided into three dimensions: (1) Resources that promote proximal processes, composed of subscales: routine organization; opportunity for stimulating experiences, for example, tours and trips; access to scheduled learning activities; joint activities with parents; availability of toys; availability of reading materials. (2) Parental practices that promote family-school connection, formed by the subscale monitoring the child in school activities; and (3) Activities that signal family stability, formed by the subscales: routines and regular family meetings, and cooperation of the child in household tasks (Marturano, 1999). The score for the subscales from one to seven is worth one point for each item. In subscales eight, the score for each item marked ranges from zero to three; on the nine and ten, the score ranges from zero to two points. The score in each topic is standardized by the sum of the points obtained, divided by the number of items that make up this topic and multiplied by 10. The total score corresponds to the sum of the scores obtained in the ten topics used. The HERS has an internal consistency coefficient equal to 0.76 (Cronbach's alpha).

The Neighborhood Environment Quality Instrument (NQI) was used (Morais, 2013). This was applied through an interview with the child's guardian. It is structured in the following subscales: (1) Infrastructure; (2) Services and convenience; (3) Quality of services; (4) Institutional activities; (5) Interaction and trust; (6) Intervention and retaliation; (7) Assistance; (8) Satisfaction; (9) Safety; (10) Mobility; (11) Social disorder. Regarding the NQI score, for subscales 1 and 2, the items are worth 1 to 2 points, if the family has used the service in the last three months. In subscale 3, items are scored on an ordinal scale of 0 to 5 points. In the other subscales, the answers range from 1 to 3 points. All subscales were then standardized to 10 points. In the end, the total points are calculated and a gross score is generated: the higher the value, the higher the quality of the environment. The NQI has an internal consistency coefficient equal to 0.78 (Cronbach's alpha).

The classes were observed by ECERS-R, by two researchers, in the morning and afternoon periods, at the beginning of the year and the end of the year. Six observations were
made in each class, three in each semester. The children were evaluated with Denver II individually and by the same researcher in the three evaluations, in alternate months. The instruments of quality of the family and neighborhood environment were applied with the parents at the time of entry and/or departure of the children, prioritizing that it was the same respondent person, if the interview could not be completed on the same day. These instruments were applied at the beginning and end of data collection.

The data were tabulated in spreadsheets using the SPSS 22.0 software. For the use of statistical tests, it was first verified normality and linearity of the data, by the Kolmogorov-Smirnov and Levene tests, respectively.

The dependent variable of the study was the result of Denver II (normal or suspected delay). On the other hand, the independent variables were those obtained by environmental quality instruments. The mean scores were compared in both times by the Student's T-test for independent samples and the Mann-Whitney nonparametric test. Additionally, the number of correct answers performed in Denver II was verified employing the total sum of the items. Thus, based on the study by Silva et al. (2018), the standard of a maximum number of items in each domain was adopted, based on the critical items that the child should get right from his/her age group, namely, personal-social (N=6), fine motor (N=7), language (N=9) and gross motor (N=6) with a maximum of 28 correct answers. For the comparison of the means of correct answers in the three times, the Variance Analysis (ANOVA) and the posthoc analysis of Bonferroni (F) were used.

Finally, to investigate the predictability of the child having or not suspected delay in neurodevelopment, by Denver II (Dependent Variable=Y), associated with the quality of environments (Independent Variables=X), the analysis of Multiple Binary Logistic Regression was performed. The non-automatic Stepwise Forward method was chosen. The inclusion of each variable in the model was verified using the likelihood ratio test and the Akaike criterion. Also, the Odds Ratio (OR) of occurrence of a variable was considered to be associated with the Denver II result, estimated by 95% confidence intervals. In all analyses, a significance level of 5% was adopted.

Results

Regarding the Denver II result, it was observed that there was an increase in the percentage of children with normal performance, over the three assessments. The results presented from this section refer to Time 1. Thus, the sample consisted of 70 children aged 24 to 62 months, with an average of 43.03 months (DP = 9.58), 38.6% (27) being female, and 61.4% (43) male.
Regarding the number of Denver II items scored as adequate, it is observed that it also had an increase in hits. Thus, the ANOVA with repeated measures showed that there was an effect of time on the evaluations $F=4.51; p=0.02$. The Posthoc Test of Bonferroni ($F$) showed that the greatest variety of Time 1 compared to others. Regarding the Denver II domains, significant differences were identified regarding the number of correct answers in the areas of fine motor, language, and gross motor, the latter being the one that increased the most.

**Table 1** - Analysis of the variance of Denver II means, over the three times

<table>
<thead>
<tr>
<th>Denver II</th>
<th>Time 1</th>
<th>SD</th>
<th>Time 2</th>
<th>SD</th>
<th>Time 3</th>
<th>SD</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Score</td>
<td>19.17$^{bc}$</td>
<td>4.22</td>
<td>20.15$^{a}$</td>
<td>4.41</td>
<td>20.63$^{a}$</td>
<td>5.37</td>
<td>4.51</td>
<td>0.02*</td>
</tr>
<tr>
<td>Personal-social</td>
<td>4.31</td>
<td>1.22</td>
<td>4.46</td>
<td>1.23</td>
<td>4.41</td>
<td>1.31</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>Fine motor</td>
<td>4.50$^{bc}$</td>
<td>1.41</td>
<td>4.94$^{a}$</td>
<td>1.46</td>
<td>4.89$^{a}$</td>
<td>1.61</td>
<td>4.86</td>
<td>0.01*</td>
</tr>
<tr>
<td>Language</td>
<td>5.31</td>
<td>2.16</td>
<td>5.18$^{c}$</td>
<td>2.28</td>
<td>5.84$^{b}$</td>
<td>2.27</td>
<td>4.66</td>
<td>0.01*</td>
</tr>
<tr>
<td>Gross motor</td>
<td>5.04$^{bc}$</td>
<td>1.16</td>
<td>5.57$^{a}$</td>
<td>0.87</td>
<td>5.44$^{a}$</td>
<td>1.01</td>
<td>8.82</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

Note: $^a_p<0.05$ versus T1, $^b_p<0.05$ versus T2, $^c_p<0.05$ versus T3. *ANOVA-1-way/Bonferroni.

Regarding the Family Poverty Index, there were statistically significant differences between Denver II and the dimensions “resource scarcity”, “housing deficiency” and the total score. Regarding the Home Environment Resources Scale, the areas of HERS 1 (Resources that promote proximal processes) and HERS 3 (Activities that signal family stability), together with the total score presented a statistically significant association with the outcome of Denver II. Relating to the quality instrument of the neighborhood environment, it was observed that the subscales “interaction and trust”; “intervention and retaliation”; "assistance"; “safety” and “social disorder”, as well as the total score, showed a statistically significant association. It is also noted that in both instruments, the means of the group of children with suspected delays were lower.
Table 2 - Comparison of means of family, neighborhood and school environments quality

<table>
<thead>
<tr>
<th></th>
<th>Normal M(SD)</th>
<th>Suspected delay M(SD)</th>
<th>p</th>
<th>Normal M(SD)</th>
<th>Suspected delay M(SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Family Poverty Index</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resources Scarcity</td>
<td>0.04 (.03)</td>
<td>0.03 (.02)</td>
<td>0.03**</td>
<td>0.04 (.03)</td>
<td>0.03 (.02)</td>
<td>0.03**</td>
</tr>
<tr>
<td>Total</td>
<td>0.25 (.08)</td>
<td>0.22 (.08)</td>
<td>0.05</td>
<td>0.27 (.07)</td>
<td>0.24 (.09)</td>
<td>0.04**</td>
</tr>
<tr>
<td><strong>Home Environment Resources Scale</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resources that promote proximal processes</td>
<td>24.0 (6.2)</td>
<td>17.1 (6.9)</td>
<td>&lt;0.001*</td>
<td>24.7 (6.0)</td>
<td>17.4 (6.7)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Joint activities with parents</td>
<td>6.32 (1.3)</td>
<td>3.30 (1.9)</td>
<td>&lt;0.001*</td>
<td>6.36 (1.4)</td>
<td>3.54 (2.0)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Activities that indicate family stability</td>
<td>11.0 (2.7)</td>
<td>8.0 (2.7)</td>
<td>&lt;0.001*</td>
<td>11.3 (2.5)</td>
<td>8.0 (2.7)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Family activities</td>
<td>5.47 (1.5)</td>
<td>4.12 (1.0)</td>
<td>&lt;0.001*</td>
<td>5.31 (1.6)</td>
<td>4.07 (1.2)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Total Score</td>
<td>40.8 (6.4)</td>
<td>30.7 (8.3)</td>
<td>&lt;0.001*</td>
<td>41.9 (6.5)</td>
<td>31.1 (8.0)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td><strong>Neighborhood Quality Instrument</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institutional Activities</td>
<td>4.2 (2.3)</td>
<td>3.0 (2.2)</td>
<td>0.03**</td>
<td>4.4 (2.2)</td>
<td>3.1 (2.4)</td>
<td>0.02**</td>
</tr>
<tr>
<td>Interaction and Trust</td>
<td>4.4 (2.4)</td>
<td>3.5 (1.8)</td>
<td>0.04</td>
<td>4.7 (2.1)</td>
<td>3.5 (1.8)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Intervention and Retaliation</td>
<td>2.9 (1.0)</td>
<td>1.5 (0.9)</td>
<td>&lt;0.001*</td>
<td>3.1 (1.2)</td>
<td>1.7 (0.7)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Assistance</td>
<td>7.5 (2.6)</td>
<td>5.3 (2.0)</td>
<td>&lt;0.001*</td>
<td>7.6 (2.6)</td>
<td>5.4 (2.1)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>3.2 (1.1)</td>
<td>2.2 (1.2)</td>
<td>0.003*</td>
<td>3.3 (1.3)</td>
<td>2.1 (1.2)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Safety</td>
<td>2.8 (1.1)</td>
<td>1.7 (1.2)</td>
<td>&lt;0.001*</td>
<td>3.0 (1.1)</td>
<td>1.7 (1.2)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Social Disorder</td>
<td>2.0 (1.2)</td>
<td>0.6 (.08)</td>
<td>&lt;0.001*</td>
<td>2.0 (1.2)</td>
<td>0.7 (.07)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Total</td>
<td>56.8 (10.2)</td>
<td>43.1 (10.7)</td>
<td>&lt;0.001*</td>
<td>58.6 (9.9)</td>
<td>43.9 (10.5)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td><strong>ECERS-R</strong></td>
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</tr>
<tr>
<td>Language and Reasoning</td>
<td>4.27 (.68)</td>
<td>4.08 (.64)</td>
<td>0.05*</td>
<td>4.60 (.71)</td>
<td>4.25 (.59)</td>
<td>0.04*</td>
</tr>
<tr>
<td>Interaction</td>
<td>6.24 (1.0)</td>
<td>5.70 (1.1)</td>
<td>0.05*</td>
<td>6.30 (1.1)</td>
<td>6.02 (1.0)</td>
<td>0.03*</td>
</tr>
<tr>
<td>Overall Score</td>
<td>3.56 (.33)</td>
<td>3.46 (.34)</td>
<td>0.07</td>
<td>3.74 (.38)</td>
<td>3.53 (.40)</td>
<td>0.04*</td>
</tr>
</tbody>
</table>

Note: **p<0.05; *p<0.001

It was found that, in Time 1, the classes obtained the following general means: Nursery I - 3.88, Nursery II - 3.62, and Kindergarten I - 3.07. In Time 2, it was noted that the means increased, namely 4.08 (NI), 3.89 (NII), and 3.18 (KI). This average per group, in both times, framed the classes in the basic quality category. The subscales that presented lower means were "personal care routines", in the KI class, followed by the subscales "personal care routines", "space and furniture" and "activities", in the NI and KI classes and "program structure".
Conversely, the subscales with higher means among the classes were "interaction" and "language and reasoning". The Mann-Whitney test showed that the means of the subscales "language and reasoning" and "interaction" was higher for children who obtained a normal score, and this difference was statistically significant.

The analysis of logistic regression allowed the creation of a prediction model in which the OR indicated that the probability of a child coming to suspect a delay in neurodevelopment is 96% less, the more joint activities they perform with their parents (OR = 0.04), 72% lower, the greater the interactions at school (OR = 0.28), 69% less, the greater interaction and trust in the neighborhood (OR = 0.31) and, and is 6.21 times greater, the lesser the scarcity of resources in the family environment (OR = 6.21).

Table 3 - Logistic Regression

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>SE</th>
<th>Wald Test</th>
<th>p</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint activities with parents</td>
<td>-4.462</td>
<td>1.31</td>
<td>12.3</td>
<td>0.002</td>
<td>0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>Resources Scarcity</td>
<td>1.802</td>
<td>0.64</td>
<td>8.312</td>
<td>0.001</td>
<td>6.21</td>
<td>1.70</td>
</tr>
<tr>
<td>Interaction and Trust</td>
<td>-1.295</td>
<td>0.63</td>
<td>4.140</td>
<td>0.03</td>
<td>0.31</td>
<td>0.06</td>
</tr>
<tr>
<td>ECERS-R Interaction</td>
<td>-1.463</td>
<td>0.62</td>
<td>6.112</td>
<td>0.04</td>
<td>0.28</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Finally, to illustrate the relationship between children's factors and the quality of the environments, an explanatory model was developed demonstrating the synthesis of the variables that were statistically significant concerning neurodevelopment.

Figure 1 - Synthesis of the explanatory model of variables associated with the outcome of Denver II, time 2
Discussion

The prevalence of children with suspected neurodevelopmental delays in the first assessment was 68.6%, with a decrease to 62.5% in the third assessment. Regarding the number of items scored as adequate, it was found that the average of the total score also increased, that is, it went from 19.1 (DP = 4.2) points in the first assessment to 20.6 (DP = 5.3) points in the last. Besides, it was found that children increased the number of correct answers in all domains of the test. These findings are in line with the established hypothesis that neurodevelopment tends to improve over time. This may have occurred due to the neurological maturation acquired by the child and the already existing developmental potential. Also, the quality scores of the environments have increased, which may have contributed to the acquisition of new developmental skills and the increase in Denver II scores.

In general, the percentage of children with suspected delay in this study was lower than the previous study carried out in Belém, which was 77.7% (Costa et al., 2016), even so, with a still-high percentage, above 60%. However, other studies were found with a percentage above 50% (Coelho et al., 2016; Pereira et al., 2017; Worku et al., 2018; Yorulmaz, Sert, Yilmaz, Kara, &Cinarlidere, 2018).
Regarding the FPI, the majority of children with suspected delays belonged to families with greater poverty in the sample. Similar results were found in other studies (Black et al., 2017; Tran et al., 2017; Iruka et al., 2018) that also identified this relationship. It is known that poverty can interfere with the structure and functioning of the central nervous system (Nampijja et al., 2018). However, one of the most striking explanations for the damaging effect of poverty on child development is the association between cumulative exposure to risk factors, duration, and chronicity. That is, when compared to their peers with higher SES, children living in poverty are disproportionately exposed, and for a longer time to these conditions, collaborating for the intergenerational transmission of it (Black et al., 2017; Worku et al., 2018). In this study, FPI has a multidimensional perspective, that is, children were under the influence of several risk factors, and those who obtained a result of suspected delay were exposed to a greater number of these factors or for a longer time. This also agrees with the hypotheses of this study.

About the Family Environment Resource Inventory, the means of the group of children with suspected delays were also lower, at both times. The statistical analysis showed a relationship between neurodevelopment, by Denver II, and the general score of the FER, and of the categories FER 1 (resources that promote proximal processes) and FER 3 (activities that signal family stability). Other studies have also pointed out associations between poor performance in assessing child development and fewer resources in the family environment (Dourado et al., 2015; Hurt & Betancourt, 2017; Nampijja et al., 2018). These surveys suggest that among the quality indicators of the family microsystem, the opportunities for interactions in shared activities and the availability of stimulating materials are among the most critical for neurodevelopment.

In this study, it is assumed that the performance in Denver II had a direct influence on the organization of routines and the performance of joint activities with parents, which are considered promoters of proximal processes and stability in the family microsystem, such as storytelling, reading, playing, among others. These can promote, according to Bronfenbrenner, reciprocal and progressively complex interactions between the developing child and the people, objects, and symbols of their immediate environments, which result in proximal processes of competence, with effect in the enhancement of genetic and biological capacities and/or in the acquisition or improvement of skills.

However, it is known that the socioeconomic level is composed of three main dimensions, which are family income, education, and professional occupation. Rindermann and Baumeister (2015) suggest that in this triad, the most important variable for stimulating developmental skills is the educational one. It should be noted that the level of parental education is also one of the main indicators of the Child Development Index and that children in the Northern region have occupied the last positions in the national ranking. In this study, families
with the worst situation of poverty were also the ones with the lowest level of education of adults, which may have influenced the quality of interactions and the content of joint activities between parents and children.

In this sense, to reach their development potential, children must have stimulating family environments and engaged parents, who actively promote learning, through teaching and providing new opportunities. However, parents who live in poverty often have a lower educational level, lack resources, and knowledge about promoting child development, in addition to less time available to carry out joint activities with their children (Tran et al., 2017). Thus, when the environment is not conducive to manifestations of the proximal processes that lead to competence, the effect can be the opposite, that is, dysfunction, represented by the difficulties in maintaining the regulation of behavior in the different developmental domains (Bronfenbrenner, 2011; Cassells & Evans, 2020; Ferguson & Evans, 2019).

Regarding the Neighborhood Quality Instrument, the means for the group of children with suspected delays were also lower, at both times. This means that these children lived in neighborhoods considered, by this instrument, of low quality. Some researchers (Minh et al., 2017; Morais, 2013; Nieuwenhuis & Hooimeijer, 2016; Otero, Carranza, & Contreras, 2017) share the hypothesis that living in poverty-stricken neighborhoods can jeopardize life opportunities of residents, both at the community level and in family relationships and individual characteristics, including neurodevelopment. However, the results identified in this study allow us to understand that the characteristics of the neighborhood environment and their effect on neurodevelopment also seem to be associated with the family microsystem. In ecological terms, this constitutes a mesosystemic relationship, in which inter-environment connections can influence the environmental quality and boost or inhibit proximal processes (Bronfenbrenner, 2011; Cassells & Evans, 2020; Ferguson & Evans, 2019).

It was noted that children with normal scores, according to Denver II, had higher means in all NQI categories, however, the dimensions “institutional activities” and “interaction and trust” are emphasized. These are related to social cohesion and collective effectiveness and can be predictive of child neurodevelopment (Iruka et al., 2018; Otero et al., 2017). This is because participation in religious, commemorative, or organizational activities, for example, and the interaction between neighbors can trigger proximal processes of competence and expose the child to a complex ecology, marked by stimuli conducive to the acquisition or improvement of skills, just like activities shared in the family environment.

The dimensions “intervention and retaliation”, “satisfaction with the neighborhood”, “security” and “social disorder” indicated that the families of children with suspected delay consider that their neighborhood is unsafe and unhealthy, it is not a good place to live and raise children, and are less cooperative. Besides, the families with the highest poverty rate were also the ones with the worst conditions of infrastructure and services in the neighborhood. In this
sense, the Metropolitan Region of Belém has precarious characteristics in terms of urban infrastructure, housing, basic sanitation, and access to services, mainly in the slum areas (Cardoso & Denaldi). These aspects are associated with the high levels of poverty and the socio-economic conditions of the inhabitants.

In ecological terms, urban poverty is manifested in all subsystems. At the level of the family-neighborhood mesosystem, this condition can indirectly interfere in the parents' mental health, in parental care, and directly affect the quality and stimuli of the family environment and, consequently, in child development. Thus, in neighborhoods with lower quality of the environment and a higher poverty rate, parents tend to perceive the neighborhood as a negative influence on development, besides fear of retaliation, which decrease the likelihood of children being involved in the community (Minh et al., 2017; Nieuwenhuis & Hooimeijer, 2016; Otero et al., 2017).

The classes evaluated by ECERS-R fell into the category of basic or minimally adequate quality. The means of the subscales of the group of children with a normal score in Denver II were higher, in both times, with emphasis on the subscales "interaction" and "language and reasoning". It can be considered that the quality indicators of these dimensions have undergone positive changes and have positively altered the quality of the school environment. These results are consistent with that of other studies, which also had a higher average in the interaction subscale (Alves, Carvalho, Pereira, Escarce, Goulart, & Lemos, 2017; Setodji, Schaaack, & Le, 2018).

For Mayer and Beckh (2016), daily interactions between teachers and students are one of the main aspects that promote development in preschool. However, for Pianta, Dower, and Hamre (2016), few children experience consistent and lasting interactions with teachers, due to the teacher-child ratio and the other demands of the environment. In this study, for these reasons, it was found that the interactions were also not very long-lasting. However, children with the greatest developmental skills were the ones most involved in the most stable and long-lasting interactions with teachers. Thus, it can be hypothesized that during the school term, the degree of complexity of these interactions increased. What makes these findings consonant with those related to other environments, which indicate the strength that person-environment interactions have to establish proximal competency-type processes.

Regarding the psychometric properties of ECERS-R, Setodji et al. (2018) suggest that this instrument is effective for assessing the quality of the environment up to a score of 3.4 points. From that score, the score considered “minimum” has the same quality provision as the score “good”. Also, the factor analysis carried out by Perlman, Zellman, and Le (2004) revealed that the scale does not measure seven distinct dimensions of quality, but two factors that are "Language and Interaction" and "Materials and Activities". Thus, the inconsistency observed in the results of this study is highlighted, in which the Denver II “language” domain was the one
with the highest prevalence of suspected delay. In contrast, in the subscale “language and reasoning” of ECERS, one of the highest means were obtained.

It was also suggested that there is redundancy between the 43 items and that the seven subgroups provided similar measures (Fujimoto, Gordon, & Hofer, 2018; Perlman et al., 2004). Therefore, it can be assumed that these factors may have contributed to the smallest statistically significant association between the subscales of ECERS-R and neurodevelopment, measured by Denver II. Furthermore, the three classes were located in the same unit, and with the same standard of operation and infrastructure. However, from the findings of the three environments investigated, it can be inferred, according to the premise of Bronfenbrenner (2011), that the developmental results were not manifested in isolation, but were the product of the interaction between the children's characteristics and the predictive factors of the quality of the environments, over time.

Conclusions

This study aimed to analyze the relationship between the quality of the ecological environment (family, school, and neighborhood) and the neurodevelopment of children in an Early Childhood Education Unit in the Amazon. The findings suggest that the participants belonging to the highest poverty rate in the sample, and with the worst quality of environments, had a higher percentage of suspected delay in their neurodevelopment. Which goes against the established hypotheses that the better the quality score of the environments, the better the performance in Denver II would be. And that the family poverty index would be associated with neurodevelopment.

The synthesis of the explanatory model showed that the most influential variables in this result were the scarcity of resources and housing deficiency, referring to the family poverty index; the opportunities to perform joint activities with parents, the availability of reading materials, and family meetings, related to the resources of the family environment. Regarding the quality of the neighborhood environment, the interaction and frequency of institutional activities among the neighbors were found; retaliation; social disorder, and insecurity were the categories most critical to child development. In the school environment, the model pointed out that social interaction and the appropriate use of language were the dimensions most associated with performance in Denver II. Thus, these variables are interrelated and can have a cumulative and chronic effect.

As for the limitations of this study, it is considered that the sample was not a probabilistic type, which does not allow generalization of the results. Additionally, the participants had a similar socioeconomic profile. For this reason, it is recommended to contrast
the data between children of different SES and/or with a representative sample. Even though the participants constituted a homogeneous sample, mostly with characteristics expected for families who are in a situation of vulnerability in the Amazon, it was possible to see that in the same socioeconomic stratum there are children less affected by risk factors. That is, they had neurodevelopment appropriate to their chronological age, did not live in environments with low quality in all indicators, and/or that improved over time. This means that it is evident that the condition of poverty does not affect everyone in the same way, as there are risk and protection variables.

Thus, the strengths of this study were the longitudinal design and the analysis of the relationship between neurodevelopment and the quality of three environments in the theoretical perspective of developmental bioecology. It was then found that the bioecological aspects, in addition to being associated with better results, are also good predictors of development. Which met the expectation that the child’s ecological resources would have a positive and cumulative influence on Denver II scores. However, family poverty is a multidimensional risk factor that cuts across ecological contexts. However, it is considered that the driving factors of development, which occurred in an environment, may have fostered proximal processes of competence that remained active in the others, especially in children with better performance in Denver II and with better environmental quality.

Based on the analyzes executed and the reflections raised, it is expected that this research may generate repercussions for the improvement of the ecological conditions of children in the Amazon region and their families. Since the results showed that some of these children were unable to improve their performance in the screening test, probably due to the situation of vulnerability and low environmental quality. For this reason, the importance of investing in public policies focused on access to education for young people and adults is emphasized, since parental education is one of the main indicators evaluated by the Child Development Index. Consequently, adults with better schooling are expected to achieve better socioeconomic resources and greater knowledge about how to stimulate child development in the family environment.

Being the North region, where the Amazon is located, and which presents negative indicators related to child health, such policies and investments must be considered with equity. In order to early identify children at risk of delay in the DNMP and families in situations of greater social vulnerability, to execute interventions on time. In addition to improvements in the school environment, since it is where many children can supply the lack of stimuli that are not adequately provided by the family and neighborhood. This ignores that more than allowing each individual to reach their full potential and break out of intergenerational poverty, it is investing in the country's social future and reducing the existing inequality between children in the north and south of Brazil.
 References


