Environmental opportunities facilitating cognitive development in preschoolers: development of a multicriteria index

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Abstract
Access to environmental opportunities can favor children’s learning and cognitive development. The objectives is to construct an index that synthesizes environmental learning opportunities for preschoolers considering the home environment and verify whether the index can predict preschoolers’ cognitive development. A quantitative, cross-sectional, exploratory study was conducted with 51 preschoolers using a multi-attribute utility theory (MAUT). The criteria used for drawing up the index were supported by the literature and subdivided in Group A “Resources from the house” extracted from HOME Inventory including: (1) to have three or more puzzles; (2) have at least ten children’s books; (3) be encouraged to learn the alphabet; (4) take the family out at least every 2 weeks. Group B “Screens” (5) caution with using television; (6) total screen time in day/minutes. Group C “Parental Schooling” (7) maternal and paternal education. Pearson correlation analyses and univariate linear regression were performed to verify the relationship between the established index with cognitive test results. The index correlated with the total score of the mini-mental state exam (MMC) and verbal fluency test (VF) in the category of total word production and word production without errors. Multicriteria index explained 18% of the VF (total word production), 19% of the VF (total production of words without errors) and 17% of the MMC. The present multicriteria index has potential application as it synthesizes the preschooler’s environmental learning opportunities and predicts domains of child cognitive development.

Keywords Cognitive development · Environmental opportunities · Learning

Introduction
Bioecological theories of human development (Bronfenbrenner 2005; Sameroff 2010) emphasize the importance of positive environments conducive to individual well-being over time (Black et al. 2017), given that the micro-system of the household (Bronfenbrenner 2005) has a direct effect on the child’s cognitive development (Black et al. 2017; Morais et al. 2021; Daelmans et al. 2017; Richter et al. 2017). A growing body of evidence has focused on the impact of environmental factors that affect cognitive development in early childhood, a critical phase in which environmental stimuli have a significant impact on brain architecture and cognition (Black et al. 2017; Morais et al. 2021; Johnson et al. 2016; McCoy et al. 2018; Britto et al. 2017). Academic difficulties during preschool can reflect long-term personal and social problems in adulthood (Camara-Costa et al. 2015; Salamon...
Studies have shown that learning difficulties in the preschool phase, such as math and reading skills (Rabiner et al. 2016), have consequences on cognitive performance from preschool to higher education (Camara-Costa et al. 2015; Salamon 2020) and have a negative impact on an individual’s ability to achieve high levels of education (Smart et al. 2017). Learning (defined as the acquisition of new knowledge and skills) is a complex human process primarily developed in early childhood when behaviors, skills, and knowledge are intensively acquired (Jirout et al. 2019).

Strategies applied to reduce academic difficulty early in the educational trajectory tend to reduce educational inequalities (Salamon 2020), and studies have shown that environmental opportunities that favor cognitive improvement are strongly related to economic status (Black et al. 2017; Camara-Costa et al. 2015; Romeo et al. 2018).

Parental education is a predictor of economic status, with the greatest education levels correlating to the highest wages and position levels (Christensen et al. 2014; Andrade et al. 2005; Krieger et al. 1997; Nahar et al. 2020). Maternal education is considered an important predictor of child development (Morais et al. 2021; Vernon-Feagans et al. 2020). Mothers with higher education levels feel more co-responsible for their child’s education than fathers and provide more opportunities that encourage child development (Christensen et al. 2014; Andrade et al. 2005). The home environment (Bronfenbrenner 2005) directly affects the child’s cognitive development (Black et al. 2017; Morais et al. 2021; Daelmans et al. 2017; Richter et al. 2017). Studies have shown a positive association between higher parental education levels and a home environment with more opportunities for a child’s learning (McCoy et al. 2018; Romeo et al. 2018; Christensen et al. 2014; Vernon-Feagans et al. 2020; Dickson et al. 2016). Thus, the home environment is crucial for a child’s cognitive development (Britto et al. 2017; Camara-Costa et al. 2015; Salamon 2020; Jirout et al. 2019).

Participation in stimulating experiences for development (e.g., walking and travel), availability of toys and materials that present a challenge to thinking (e.g., books, puzzles), encouragement for learning (Christensen et al. 2014; Bradley and Corwyn 2019), and access to family outings offer distinct possibilities for a child’s learning favoring its cognitive development (Britto et al. 2017; Christensen et al. 2014; Rosen et al. 2018). The use of screens at home is part of the daily lives of families in the contemporary context (Strasburger 2015; Guedes et al. 2019; Nobre et al. 2021); however, evidence indicates that using some criteria is essential to favor child development (Nobre et al. 2020). Excessive television exposure is associated with delays, for example, in language development (Valdivia Álvarez et al. 2014; Duch et al. 2013) and poorer performance on behavioral measures of executive function (EF) (Li et al. 2020).

On the other hand, if used with caution (Nobre et al. 2020; Price et al. 2015), interactive media may contribute to child development (Price et al. 2015; Council on Communications Media. Media and young minds 2016; Radesky et al. 2015; Russo-Johnson et al. 2017; Anderson and Subrahmanyan 2017; Skaug et al. 2018), especially in the domains of language and fine motor (Souto et al. 2020) during early childhood (Nobre et al. 2020). The Brazilian Society of Pediatrics (Eisenstein et al. 2019) recommends up to 1 h/day of exposure time to all screens for children aged 2–5 years, corroborating with other international guidelines (Council on Communications Media. Media and young minds 2016; World Health Organization 2019). However, recent studies demonstrate difficulties in complying with this recommendation (Nobre et al. 2020; Tamana et al. 2019), and the majority of preschoolers are exposed to screens for longer periods of time than is advised (Tamana et al. 2019), particularly after the onset of the COVID-19 pandemic (Eyimaya and Irmak 2021; Kracht et al. 2021). Given the difficulty of families in following the current recommendations on maximal daily exposure time to screens for children (Nobre et al. 2020; Council on Communications Media. Media and young minds 2016; Radesky et al. 2017; Anderson and Subrahmanyan 2017; Skaug et al. 2018), the risks and benefits of screens exposure to children’s cognitive development have been a hot topic of debate (Gerwin et al. 2018). Heller’s study (Heller 2021), for example, highlights the disparity between the current screen time recommendations and children’s actual habits, pointing out the need to increase the use of interactive media to favor children’s cognitive development (Heller 2021).

Taking into account that the cognitive function is a multidimensional construction that reflects general cognitive functioning, executive functioning, learning, and memory (Assari 2020), dificulting the evaluation of learning environments (Munoz-Chereau et al. 2021); the present study aimed to construct an index that synthesizes environmental learning opportunities for preschoolers considering the home environment and verify whether the index can predict preschoolers’ cognitive development.

Materials and methods

Study design

This is a quantitative, exploratory, cross-sectional study with a Multi-Attribute Utility Theory (MAUT) analysis. The study was approved by the Research Ethics Committee of the Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM) (Protocol: 2.773.418). Parents provided written informed consent for children’s participation. The data collection period took place from July to December 2019.
Participants

Preschool children (aged 3–5 years) from public schools in a Brazilian municipality were eligible. Children born preterm or with low birth weight, complications in pregnancy and childbirth, children with signs of malnutrition or diseases that interfere with growth and development were excluded from the study.

The sample size was estimated using the OpenEpi software, version 3.01, following a study with a similar design (Nobre et al. 2020). Initially, 1,241 children were from public schools enrolled in the city (Viegas et al. 2021), with a prevalence of 4.58% of language alterations in Brazilian preschoolers from public schools (Melchior Angst et al. 2015), with a target precision of 10%, a confidence interval of 90% and an effect size of 1 (Cordeiro 2001) would require 51 preschoolers.

Instruments

A questionnaire was created with data on the child’s birth and health to characterize the participants. In addition, the education of parents and the economic level of the child’s family were recorded.

The Brazilian economic classification criterion from the Brazilian Association of Research Companies (ABEP) was applied to verify the economic level of the families. The questionnaire stratifies the general economic classification from A1 (high economic class) to E (class economic very low) (ABEP 2019), and considers the assets owned by the family, the head’s education and housing conditions, such as running water and street paving.

The environment in which the child lived was assessed through the Early Childhood Home Observation for Measurement of the Environment (EC_HOME) (Caldwell and Bradley 2003). The EC_HOME is standardized for children aged 3–5 years and analyzed through observations and semi-structured interviews during home visits. The instrument contains 55 items divided into 8 scales: I—Learning Materials, II—Language Stimulation, III—Physical Environment, IV—Responsiveness, V—Academic Stimulation, VI—Modeling, VII—Variety, and VIII—Acceptance. The sum of the raw scores of the subscales generates the classification in an environment of low, medium and high stimulation. For the elaboration of the index, dichotomous variables (presence or absence) were used, including in subscales I (presence of 3 or more puzzles, 10 or more children’s books), II (encouragement for learning) and III (walking with the family every 2 weeks). The HOME Inventory has been used in both international (Jones et al. 2017) and transcultural studies (Bradley 2015), presenting psychometric characteristics investigated in Brazilian preschoolers (Cronbach’s Alpha = 0.84 for the 55 items) (Dias et al. 2017).

Screen time was assessed using an adapted questionnaire to measure preschoolers’ physical activity (PA)—“Outdoor playtime checklist”—(Burrette et al. 2004b). that also includes the description for television exposure in minutes (Burrette et al. 2004a). The instrument was adapted for exposure to other media (smartphone and tablets). This questionnaire was validated for Brazilian preschoolers (Gonzalves et al. 2021). The time the child is exposed to television and other screens (cellular, smartphone, or similar) in the morning, afternoon, and the evening was measured. The application of the questionnaire lasted an average of seven minutes. Each question was used to identify the day of the week and the period of the day (from waking up to noon; from noon to 6 AM; from 6 AM to bedtime) in which the child was exposed to screens (television and tablet/smartphone). The time of exposure to the screens was recorded by the parents considering five possible options (0, 1–15, 16–30, 31–60) or more than 90 min).

Assessment of global cognitive function was performed through the mini-mental state exam (MMC), adapted for children according to Jaine Passi (Jain and Passi 2005) (Brazilian version in Moura and collaborators) (Moura et al. 2017). The MMC consists of 13 items covering five domains of cognitive function (orientation, attention and working memory, episodic memory, language, and constructive praxis) with a maximum score of 37. The Brazilian validation and normalization of MMC presented satisfactory psychometric properties, with 82% specificity and 87% sensitivity. MMC can be applied in the age group from 3 to 14 years old. The MMC application lasts from 5 to 7 min and has been used in several countries, including Brazil (Viegas et al. 2021; Jain and Passi 2005; Moura et al. 2017; Shoji et al. 2002; Rubial-Alvarez et al. 2007; Scarpa et al. 2017; Peviani et al. 2020). Cognitive function was assessed according to the total score. Overall, the MMC is an ideal instrument to track general cognitive function (Viegas et al. 2021).

Verbal Fluency (VF) tests have been used to measure EF, vocabulary and mental processing speed (Heleno 2006; Mitrushina et al. 2005), working memory (Henry and Crawford 2004), inhibitory control (Hirshorn and Thompson-Schill 2006) and cognitive flexibility (Amunts et al. 2021). The score was calculated by the number of words produced and the number of wrong words in 60 s per category (toy, animal, body parts, food and color). For the present study, all categories were also added and the total word production and total word production without errors were created.

Procedures

Recruitment took place at the doors of the schools, with the invitation made to the children’s guardians at the time they left the school. After acceptance and signing of the Informed Consent Form, the subsequent steps were scheduled. The
first stage was carried out in the child’s home by completing survey questionnaires to assess socioeconomic data (ABEP 2019), quality of the home environment (EC-HOME) (Caldwell and Bradley 2003), and data on learning opportunities, screen time, parental education and child medical history. The second stage was carried out at the Centro Integrado de Pesquisa em Saúde (CIPq-Saúde) at the Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM), where the cognitive tests were applied (VF, MMC).

Data analysis

MAUT, known as Multicriteria Decision Support, was used. MAUT is a tool used in the context of the connection and existence of multiple factors in the evaluation process, such as child development, making it possible to identify, characterize and combine different variables (Keeney and Raiffa 1976), also presented in other studies with similar themes (Nobre et al. 2020). The phases of MAUT are as follows:

Phase 1: selection of criteria

First, the selected criteria must faithfully represent what will be evaluated and were selected based on the literature (Adunlin et al. 2015). Thus, for learning opportunities, the selected criteria, based on the literature, were:

Group A “Home Resources”, containing the following items related to the child: (1) to have three or more puzzles; (2) have at least ten children’s books; (3) be encouraged to learn the alphabet; (4) take the family out at least every 2 weeks. Group B “Screens”, containing item (5) is television used judiciously?; (6) total screen time in day/minutes. Group C “Parental Schooling”, containing: (7) maternal and paternal education.

Phase 2: establishment of a utility scale for scoring each criterion

After selecting the criteria, the subsequent phase aims to place the scores of the selected criteria on the same ordinal scale. In MAUT, it may happen that some selected criteria have different measurement units quantified through attributes (Adunlin et al. 2015). In this study, the selected criteria have answers quantified by attributes described in the fourth column of Table 1. In this phase, the answers were converted into numerical variables using an ordinal scale. For each answer, a positive value was attributed when the practice was considered favorable and null if the criterion does not characterize facilitating opportunities for learning.

In Group A, “Resources of the house”, the first criterion scores 0.25 for the child who has three or more puzzles (Christensen et al. 2014; Caldwell and Bradley 2003; Pereira et al. 2021); the second criterion scores 0.25 for the child who has at least ten children’s books (Christensen et al. 2014; Caldwell and Bradley 2003; Pereira et al. 2021); the second criterion scores 0.25 for the child who has at least ten children’s books (Christensen et al. 2014; Caldwell and Bradley 2003; Pereira et al. 2021).
Dickson et al. 2016), or more) (Andrade et al. 2005; Vernon-Feagans et al. 2020; Christensen et al.. 2013). Finally, and Christakis 2016; Heller 2021; Tremblay et al. 2017; Nobre et al. 2020; Caldwell and Bradley 2003; Bradley 2015). The total sum of the criteria in this group makes a total of 1 point.

In Group B, “Screens”, the fifth criterion scores 0.25 for the child whose use of television is done judiciously, and in the sixth criterion (Nobre et al. 2020; Caldwell and Bradley 2003; Bradley 2015), scores 0.75 for the child that screen time approaches 90 min (Council on Communications Media. Media and young minds 2016; Eisenstein et al. 2019; Radesky and Christakis 2016; Heller 2021; Tremblay et al. 2017; Academy and of Pediatrics. Children et al.. 2014; Caldwell and Bradley 2003; Bradley 2015), scores 0.25 for the child who walks with the family at least every 2 weeks (Britto et al. 2017; Bradley 2015); is encouraged to learn the alphabet (Christensen et al. 2014; Pereira et al. 2021; Defilippo et al. 2012); 10 children’s books or more (Christensen et al. 2014; Caldwell and Bradley 2003; Bradley 2015); is encouraged to learn the alphabet, goes out with the family at least every 2 weeks (Britto et al. 2017; Christensen et al. 2014; Caldwell and Bradley 2003; Bradley 2015). In addition, this child uses television judiciously (Nobre et al. 2020; Caldwell and Bradley 2003), and the time of use of all media (tablets, smartphones, and television making up the screen time) approaches 90 min (Council on Communications Media. Media and young minds 2016; Radesky and Christakis 2016; Heller 2021; Tremblay et al. 2017; Academy and of Pediatrics. Children et al.. 2013). Finally, his father or mother are highly educated (higher education or more) (Andrade et al. 2005; Vernon-Feagans et al. 2020; Dickson et al. 2016).

Phase 3: determination of weight for each multicriteria

The numerical measure that measures the importance of each criterion is the weight. It is possible to assign different weights if the decision-maker understands that there is a different relevance between the criteria (supported in the literature or in the opinion of experts on the subject) (Adunlin et al. 2015). For the research, equal weights were used for the different criteria, assuming that each selected factor has the same degree of relevance for children’s cognitive learning.

Phase 4: calculation of the multicriteria index

In the present study, the weights considered for each criterion were the same as described in phase 3, and, for multicriteria index calculation, an average of the evaluations of all criteria was made for each participating child. The multicriteria index represented the weighted sum of the evaluations of the different evaluated criteria. Equation 1 shows how this calculation was performed (n = number of evaluated criteria):

\[
\text{Multicriteria index child } i = \text{Evaluation criterion 1 child } i \times \text{weight criterion 1} + \cdots + \text{Evaluation criterion } n \times \text{weight criterion } n
\]

Phase 5: validation of results

At this moment, it is verified whether the performed multicriteria analysis meets the objective (Henry and Crawford 2004; Adunlin et al. 2015). In this study, it was intended to verify if a higher multicriteria index was related to the better performance of the VF and global cognitive function (MMC) tests. Therefore, a correlation analysis between the multicriteria index and the variables of the mentioned tests (VF and MMC) was performed.

First, the Excel Program (version-2010) was used to formulate the multicriteria model; then, for the validation step, the data were transferred to the Statistical Package for the Social Sciences (version-22.0). The normality test was obtained using the Shapiro–Wilk test. Subsequently, Pearson’s correlation with the dependent variable (Multicriteria Index) and cognitive tests were performed. With the independent variables that presented a value of \( p < 0.05 \) in the correlation analysis, simple linear regression was performed with the dependent variable “Multicriteria Index” to verify how much the created index could explain the results in the MMC and VF tests. The variable age was adjusted in the model.

Results

Fifty-one preschoolers from public schools in a small town in southeastern Brazil participated in this study. More than half children were boys (52.9%), with a mean age of 5 years; children’s mothers had a mean age of 31 years (± 6), and fathers had a mean age of 45 (± 25). Most children’s families belonged to stratum C of the economic
classification, which means lower middle class. Of note, children’s parental education was characterized by higher levels of school education; 82.3% of the mothers and 52% of the fathers had 12 years of school education. In addition, most children belonged to the middle quartiles of the EC_HOME scores, which characterizes medium stimulation environments. More than half of children had high screen time exposure (64.7%), and the average exposure time to screen was 133.23 min/day (± 69.75). Table 2 presents the participant’s characteristics and the correlation of the variables with the de multicriteria index.

Table 3 presents the correlation between the multicriteria index and the cognitive tests. The multicriteria index was correlated with the MMC test total score (p = 0.002). The multicriteria index also showed a positive correlation with the VF test in the subcategories toy (r = 0.333; p = 0.017), animals (r = 0.347; p = 0.013) and body parts (r = 0.325; p = 0.020), word production (p = 0.001) and word production without errors (p = 0.001) (Table 3).

Figure 1 shows the correlation between the multicriteria index and the cognitive test variables (VF and MMC score). High scores in the index of cognitive stimulation opportunities correlated positively with high scores in the VF tests (for both word production with and without errors). High scores in the multicriteria index also meant high scores in the cognitive test (Fig. 1).

Table 4 presents the simple linear regression between the variables of the cognitive tests and the multicriteria index (p < 0.05).

A high multicriteria index was linked to improved performance in both VF tests (production of total words and production of words without errors; p = 0.001). Of note, children who presented greater facilitating opportunities for learning (better results in the multicriteria index) also

### Table 2 Participant’s characteristics (n = 51)

| Variable                              | Mean (standard deviation) | N(%)  |
|---------------------------------------|---------------------------|-------|
| Age                                   | 4.60 (± 0.60)             |       |
| Gender                                |                           |       |
| Male                                  | 27 (52.9)                 |       |
| Female                                | 24 (47.1)                 |       |
| Maternal education                    |                           |       |
| Elementary school                     | 9 (16.6)                  |       |
| High school                           | 30 (58.8)                 |       |
| University education                  | 12 (23.5)                 |       |
| Paternal education                    |                           |       |
| Elementary school                     | 14 (27.5)                 |       |
| High school                           | 19 (37.3)                 |       |
| University education                  | 7 (13.7)                  |       |
| Economic status                       |                           |       |
| Class B                               | 13 (25.4)                 |       |
| Class C                               | 33 (61.1)                 |       |
| Class D and E                         | 5 (9.8)                   |       |
| Quality of the home environment       | 38.84 (± 5.77)            |       |
| 1. Middle half                        | 42 (82.4)                 |       |
| 2. Upper fourth                       | 9 (17.6)                  |       |
| Exposure time to screen               | 133.23 (± 69.75)          |       |
| Up to 90 min/day                      | 18 (35.3)                 |       |
| More than 90 min/day                  | 33 (64.7)                 |       |

### Table 3 Correlation between Learning Opportunities Index and cognitive tests

| Test                                           | Mean (standard deviation) | p value |
|------------------------------------------------|---------------------------|---------|
| MMC (score)                                    | 23.78 (± 3.81)            | 0.002 * |
| Verbal fluency                                  |                           |         |
| Number of words—toy category                   | 5.04 (± 2.55)             | 0.017 * |
| Number of words—animal category                 | 8.25 (± 3.18)             | 0.013 * |
| Number of words—body parts category            | 9.96 (± 4.02)             | 0.020 * |
| Number of words—food category                  | 6.98 (± 2.50)             | 0.170 * |
| Number of word—color category                  | 8.69 (± 2.15)             | 0.088 * |
| VF total word production                        | 42.66 (± 10.68)           | 0.001 * |
| VF total word production (without errors)       | 41.50 (± 10.38)           | 0.001 * |

*Pearson’s correlation. Verbal fluency (VF). Mini-mental state exam (MMC)
achieved higher scores in the cognitive test \( (p = 0.006) \). In addition, a high multicriteria index explained 18% of VF (total word production), 19% of VF (total word production without errors) and 17% of improved performance in global cognitive function (Table 3).

This study presented a power of 0.95, with an effect size of 0.20, 0.50, and 0.80 to interpret observed effect sizes as small, medium, or large, respectively (Cohen 2013).

**Discussion**

In summary, the multicriteria index showed the potential to synthesize environmental opportunities that facilitate learning in preschoolers since it correlated positively with the MMC tests and VF in three categories. Similar
to MMC test, this multicriteria index was accurate for screening global cognitive function (Viegas et al. 2021; Peviani et al. 2020). Therefore, children with high scores in the multicriteria index also had high scores in the MMC test. In addition, we also verified if the index could predict cognitive development. Child development is influenced by multifactorial aspects, including the child’s reciprocal relationships with the environment (Black et al. 2017; Daelmans et al. 2017). Our index sought to address the sphere of the home environment (Bronfenbrenner 2005), which exerts the greatest influence on a child’s cognitive development (Morais et al. 2021). In the present study, we considered for the analyses the house resources (Morais et al. 2021; Christensen et al. 2014; Caldwell and Bradley 2003), screen time exposure (Nobre et al. 2020; Heller 2021) and parental education (Andrade et al. 2005; Vernon-Feagans et al. 2020; Dickson et al. 2016; Hamadani et al. 2014).

Our results corroborate recent findings showing a direct influence of the home environment on children’s cognitive development (Morais et al. 2021). Overall, improvements in children’s learning opportunities through home stimulation can be essential for promoting early learning (McCoy et al. 2018; Caldwell and Bradley 2003; Bradley 2015), favoring child cognitive development (Britto et al. 2017; Christensen et al. 2014). In a longitudinal study with Bangladeshi children, home environment, child growth, and parental education mediated 86% of the effects of poverty on child cognition in the first 5 years of age (Hamadani et al. 2014); thus, simple environmental interventions at home can positively impact children’s cognitive development (Jeong et al. 2018; Yang et al. 2021).

The healthy use of interactive media as a learning resource has been discussed in the literature (Nobre et al. 2020). Previous studies pointed out that the use of interactive media can positively contribute to child development (Price et al. 2015; Radesky et al. 2015; Russo-Johnson et al. 2017; Anderson and Subrahmanyam 2017; Skaug et al. 2018; Souto et al. 2020) if used sparingly (Nobre et al. 2020). Accordingly, a recent study showed positive results of using interactive media for domains of child development, especially language and fine motor coordination (Souto et al. 2020) in early childhood children (Nobre et al. 2020); thus, if used with caution, tablets and smartphones may improve preschoolers’ knowledge (numbers, alphabets and colors learning). Moreover, animated e-books (e.g., with voice and interactive pictures) can awaken children’s interest in reading and creating. Then, parents with high scholarly education may offer their children the use of media as a learning resource (Nobre et al. 2020).

Recent studies have shown that high parental education (Vernon-Feagans et al. 2020) was positively associated with children’s brain’s temporal cortical area development, which is related to reading ability (Assari 2020). According to previous studies (McCoy et al. 2018), access to material resources and home stimulation may have contributed to the positive association between parental education and reading ability. Then, the variables mentioned above were crucial in constructing the multicriteria index of this study (see Table 1). Children with the highest scores on the index also achieved the highest scores on the VF test in three categories and, consequently, on the total production of words with and without errors. Among these, the subcategory animals ($r = 0.347$, $p = 0.013$), toys ($r = 0.333$; $p = 0.017$) and body parts ($r = 0.325$; $p = 0.020$).

We highlight that the VF test (or task) assesses language (lexical knowledge) and executive functions (Becker et al. 2019). Li and colleagues (Lin et al. 2017), investigated brain activation in adults using VF tests; they emphasized the predictive potential of VF tests which might be employed for executive function screening. These characteristics are related to the components of volition/choice, flexibility, and inhibition of executive functions (Anderson 2002). In addition, we believe that these characteristics are expanded by access to the repertoire of resources that encourage verbal communication and challenges when thinking (Pereira et al. 2021; Jeong et al. 2018; Bornstein and Putnick 2012), facilitating, for example, literacy (Bornstein and Putnick 2012), an essential component for cognitive processes (Jeong et al. 2019), academic learning (Rodriguez and Tamis-LeMonda 2011) and language amplifying (Bornstein and Putnick 2012).

Our data also reinforce the importance of environmental opportunities facilitating joint and simultaneous learning for academic performance (Rodriguez and Tamis-LeMonda 2011); once the multicriteria index explained 18% of the total word production, 19% of the total word production with no errors, and 17% of the highest global cognitive function score. The impact of the children’s home environment was enhanced by the facilitating learning opportunities provided in their early years of age (Munoz-Chereau et al. 2021). Considering the evidence that academic difficulties can be accurately tracked in the preschool years and last throughout life (Camara-Costa et al. 2015), some of these contextual factors probably represent environmental characteristics that can be changed in early life through adequate support to families (McCoy et al. 2018; Camara-Costa et al. 2015) and through efforts to build holistic learning opportunities in developing countries (Camara-Costa et al. 2015).

Our study has some limitations. First, despite being utilized in research with Brazilian preschoolers aged 3–6 years, the MMC test has not been validated for use with children under the age of. (Viegas et al. 2021). Second, screen time exposure was calculated by adding up the use of interactive media and television; therefore, no questionnaire was used to assess cautious use (Nobre et al. 2020). However,
the criteria for time exposure to television were measured using a validated instrument subscale (Caldwell and Bradley 2003) as well as current guidelines (Council on Communications Media. Media and young minds 2016; Radesky et al. 2015) and flexibilities according to emerging studies (Heller 2021). To our knowledge, this is the first study to consider multiple factors in the home environment (including interactive media as a resource) to create an index that synthesizes environmental learning opportunities in preschoolers from a Brazilian urban area. In addition, we used MAUT, a robust methodology that considers multiple factors, used in similar studies in the area of health (Nobre et al. 2022), cognitive development, and language (Nobre et al. 2020).

Conclusion

The present multicriteria index has potential application as it synthesizes the preschooler’s environmental learning opportunities and predicts domains of child cognitive development. A positive and significant relationship was found between the high multicriteria index means better performance in both VF tests and better performance in global cognitive function.

Our data point out the importance of family-based interventions to improve preschoolers’ academic performance. Children who have access to books and puzzles, are stimulated to learn the alphabet, take family outings, are encouraged to watch screens sparingly respecting usage criteria and exposure time and have parents with high schooling, probably have a greater global cognitive function and VF.

Summary

Child development is a product of the child’s reciprocal relationships and environment so that access to environmental opportunities can favor learning and cognitive development. The objectives is to establish an index that synthesize the environmental learning opportunities considering relevant factors of the domestic environment and verify how the index can facilitate domains of child cognitive development. Quantitative, cross-sectional, exploratory study with 51 preschoolers with a multi-attribute utility theory (MAUT). The criteria used for drawing up the index were supported by the literature and subdivided in Group A “Resources from the house” including: (1) to have three or more puzzles; (2) have at least ten children’s books; (3) be encouraged to learn the alphabet; (4) take the family out at least every 2 weeks. Group B “Screens” (5) caution with using television; (6) total screen time in day/minutes. Group C “Parental Schooling” (7) maternal and paternal education. Pearson correlation analyzes to verify the relationship between the established index and cognitive tests and univariate linear regression. The index correlated with the total score of the mini-mental state exam (MMC), verbal fluency test (VF) in the category of total word production and word production without errors. High multicriteria index explained 18% of the VF (total word production), 19% of the VF (total production of words without errors) and 17% of the MMC. The multicriteria index developed has the potential to be used. The positive and significant associations between the environmental opportunities facilitating cognitive development and best test FV and MMC.

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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest We declare no competing interests.

Ethical approval All the protocols were carried out in accordance with relevant guidelines and regulations. This study was approved by the Research Ethics Committee of the Universidade Federal dos Vales do Jequitinhonha e Mucuri (Protocol: 2.773.418), authorized by the Municipal Education Secretariat of Diamantina (MG), Brazil.

Consent to participate We declare that all the parents of the children or legal guardians signed the informed consent form in writing, authorizing participation in the study.

Consent for publication Not applicable.

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