Neutrosophic Sets and Systems, Vol. 82, 2025
University of New Mexico

Estimating the prevalence of delay in comprehensive and expressive language development in preschool children in Pichincha, Ecuador based on Plithogenic Statistics

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Abstract. Language is defined as the exclusive capacity of human beings to communicate through a set of arbitrary linguistic codes materialized in speech, thanks to which cognitive, executive, social, and academic, among other skills are acquired. In the first three years of life, the child goes through the so-called critical period of language acquisition. In this period, the child develops the cognitive, neuromotor, and sensory skills necessary to generate the communicative bases, including intentionality to communicate turns of intervention, encoding, decoding, and interpretation of the message. If something happens at this stage, linguistic development could be severely compromised. This paper aims to carry out a statistical study on the prevalence of language disorders in children between one and three years of age in the Ecuadorian province of Pichincha, in 2024. Language disorders can affect both comprehensive and expressive language and are multicausal. That is why we apply Plithogenic Statistics in the study. Plithogenic Statistics extends Multivariate Statistics where, in addition to randomness, indeterminacy is included. This is the theory we selected to carry out the study because there are indeterminacies and multiple variables in the problem.

Keywords: Language, Language delay, Comprehensive language, Expressive language, Preschool children, Plithogeny, Plithogenic Statistics.

1 Introduction

Language delay is a condition in which a child does not acquire language skills at the same rate or in the same way as other children of his or her age. It can affect either the understanding of language (comprehensive language) the expression of language (expressive language) or both. Furthermore, comprehension and expressive language delay refers to a delay in the development of a child's language skills, where the acquisition of oral language occurs more slowly compared to his or her peers. This phenomenon can manifest itself in both the ability to understand (comprehension) and the ability to express thoughts and needs.

It is characterized by a chronological delay in the development of speech and language, without there being intellectual, sensory or motor deficits that justify it. Often, children with language delay can understand better than express, which means that they can follow simple instructions or recognize words, but they have difficulty formulating complex sentences or using vocabulary appropriate for their age.

Prevalence may be higher in children with other developmental disorders such as autism or learning disorders; factors that influence prevalence include biological factors (hearing problems, neurodevelopmental disorders, prematurity, and low birth weight). Environmental factors include limited exposure to language, lack of early stimulation, and disadvantaged socioeconomic conditions. This is why early detection and timely intervention are essential to improve the prognosis of children with language delay.

In Ecuador, a study was conducted on the prevalence of delay in the development of comprehensive and expressive language in children aged 1 to 3 years 11 months, in the Caritas Alegres, Nueva Esperanza, and Cananvalle Child Development Centers in the Tabacundo parish, Pedro Moncayo canton, Pichincha province, period March-August 2018. The population was 152 children, of which 63 were female and 89 were male. The results observed that the children present a considerable delay in language development; at the comprehensive level 31.4% and expressive 50.4%, no child presented malformations of the peripheral oral mechanism and execution of praxis.

In another study conducted on children aged 1 to 3 years 11 months, at the Urku-Sisa and Quinchucajas Child Development Centers in the Cangahua parish, Cayambe canton, Pichincha province. The study population was 57 children, of which 50.8% were male and 49.1% female. The results showed that the prevalence of language delay in comprehension was 42.11% in the comprehension component and 85.96% in the expressive component.

A third study was carried out at the Child Development Centers Angel of Love, Caritas Felices and Domingo Savio in the Cayambe parish, Cayambe canton, Pichincha province. This study determined that children from 1 to 3 years 11 months have a prevalence of delay in the development of comprehensive language of 27.13% and 45.74% in expressive language.

A fourth study was conducted at the Dos Margaritas, Estrellitas Mágicas, and Cayambe Child Development Centers in the Cayambe parish, Cayambe canton, Pichincha province. The study population was 52% male and 48% female. The results obtained identified that the prevalence of language delay in children aged 1 to 3 years 11 months was 20.31% and expressive language was 50%.

In a fifth study conducted on children aged 3 to 5 years at the Hospital del Callao, it was found that 39.5% of children between 3 and 5 years had delays in expressive language, which is more common in boys (72.25%). Between 7 and 15% of preschool-aged children have some type of language disorder, including delay. Children under 3 years of age are especially vulnerable to presenting language delays, with a prevalence that can reach 22% in comprehensive language and 42% in expressive language.

As can be seen from these studies, the number of cases of language delay in children between one and four years old in Ecuador is not small. These disorders are not the same in comprehensive language and expressive language. On the other hand, the causes are different, which is why a statistical study on the subject requires multivariate statistics.

The purpose of this article is to understand the prevalence of comprehensive and expressive language disorders in preschool children from 1 to 3 years of age who attended 23 public institutions located in various areas of the Ecuadorian province of Pichincha, in 2024. These data were part of the graduation works of the students of the Speech Therapy program at the Central University of Ecuador, which are in the institutional repository.

For the calculations, we use Plithogenic Statistics [1, 2]. This is a theory based on F. Smarandache's Plithogeny, which deals with the dynamics between multiple concepts or variables and their interactions between the concepts or their opposites or their neutrals (which is neither the concept nor its opposite) [3-13]. The way they interact produces results that cannot be described with classical dialectics.

Plithogenic Statistics, in particular, generalizes Multivariate Statistics, where the uncertainty and indeterminacy that exists between the variables involved, in addition to randomness, are incorporated [14-16]. It also generalizes Neutrosophic Statistics, where the latter uses the methods of Classical Statistics applied to data or parameters in interval form, or when the size of the sample or population is not exactly known [17].

This article is divided into a Preliminaries section, where we explain the basic concepts of Plithogenic Statistics. In the Results section, we explain the methods used in the study and the results. We conclude the article with the conclusions.

2 Preliminaries

The Plithogenic Probability of an event's occurrence is composed of the probabilities of the event occurring for all the random variables or parameters that constitute it [1]. The Plithogenic Probability based on the Plithogenic Variate Analysis, is multi-dimensional. It could be said that it is a probability of sub-probabilities, where each sub-probability refers to the behavior of a variable assuming that the event is produced by one or more variables. Each variable is represented by a Probability Distribution (Density) Function (PDF).

According to F. Smarandache's classification, the Subclasses of Plithogenic Probability are the following:

(1) Classical MultiVariate Probability: Whether all PDFs are classical.

(2) Plithogenic Neutrosophic Probability is defined when the PDF is expressed in the form of $(\mathrm{T}, \mathrm{I}, \mathrm{F})$, where T is the probability that the event occurs, I is the indeterminacy probability that the event occurs and F is the probability that the event does not occur. Such that the following is fulfilled: $\mathrm{T}, \mathrm{I}, \mathrm{F} \in [0,1]$, $0 \leq \mathrm{T}+\mathrm{I}+\mathrm{F} \leq 3$.

(3) Plithogenic Indeterminate Probability: When all PDFs have indeterminate data or arguments.

(4) Plithogenic Intuitionistic Fuzzy Probability: When PDFs have the form (T, F) where $\mathrm{T}, \mathrm{F} \in [0,1]$, $0 \leq \mathrm{T}+\mathrm{F} \leq 1$.

(5) Plithogenic Picture Fuzzy Probability: When PDFs have the form $(\mathrm{T}, \mathrm{N}, \mathrm{F})$. $\mathrm{T}, \mathrm{N}, \mathrm{F} \in [0,1]$, $0 \leq \mathrm{T}+\mathrm{N}+\mathrm{F} \leq 1$; where T is the probability that the event occurs, N is the neutral probability of the event occurring or not occurring, and F is the probability that the event does not occur.

(6) Plithogenic Spherical Fuzzy Probability: When PDFs have the form $(\mathrm{T}, \mathrm{H}, \mathrm{F})$. $\mathrm{T}, \mathrm{H}, \mathrm{F} \in [0,1]$, $0 \leq \mathrm{T}^2+$

$H^2 + F^2 \leq 1$; where T is the probability that the event occurs, H is the neutral probability of it occurring or not, and F is the probability that the event does not occur.

(7) Plithogenic (fuzzy-extension) Probability: when we have that all PDFs are in the (fuzzy-extension set) style.

(8) Plithogenic Hybrid Probability: when some PDFs are in one of the above styles and others are in other styles.

Plithogenic Statistics (PS) comprises the analysis and observations of the events studied by Plithogenic Probability.

Plithogenic Statistics generalizes classical MultiVariate Statistics, and in turn allows an analysis of many output variables that are neutrosophic or indeterminate. It is also a multi-indeterminate statistic.

Various Subclasses of Plithogenic Statistics are as follows:

- Multivariate Statistics,
- Plithogenic Neutrosophic Statistics,
- Plithogenic Indeterminate Statistics,
- Plithogenic Intuitionistic Fuzzy Statistics,
- Plithogenic Picture Fuzzy Statistics,
- Plithogenic Spherical Fuzzy Statistics,
- and in general: Plithogenic (fuzzy-extension) Statistics,
- and Plithogenic Hybrid Statistics.

On the other hand, Plithogenic Refined Statistics is the most general form of statistics that studies the analysis and observations of the events described by Plithogenic Refined Probability.

In classical inference statistics, the population's average of the variable is estimated from the sample's average.

When we have a classical random variable, the exact size of the sample is known and all elements of the sample belong 100% to the population. However, this does not reflect the dynamics of a population such as the student population, which is the example illustrated by F. Smarandache, where there is fluctuation of students within courses, in addition to the fact that the membership of each student varies depending on whether he or she is studying a course full-time, part-time or over-time.

In a Neutrosophic Population, each element has a triple probability of membership equal to (T_j, I_j, F_j) such that $0 \leq T_j + I_j + F_j \leq 3$.

If we assume we have the dataset (T_j, I_j, F_j) for $j = 1, 2, \ldots, n$, where n is the sample size, then the average probability for all data in the sample is calculated by Equation 1.

$$\frac{1}{n}\sum_{j=1}^{n}(T_j, I_j, F_j) = \left(\frac{\sum_{j=1}^{n} T_j}{n}, \frac{\sum_{j=1}^{n} I_j}{n}, \frac{\sum_{j=1}^{n} F_j}{n}\right) \quad (1)$$

3 Results

This research evaluated a population of 3,374 boys and girls who attended 23 public institutions located in various areas of the Ecuadorian province of Pichincha in 2024. These data were part of the graduation works of the students of the Speech Therapy program at the Central University of Ecuador.

A random sample was selected using stratified random sampling, the size of which was calculated based on Equation 2:

$$n = \frac{Z^2 Npq}{e^2(N-1) + Z^2 pq} \quad (2)$$

Where,

n = Sample size,

N = Population size (3374),

Z = deviation for the desired confidence level (1.96),

e = Maximum allowed error margin (0.05),

p = proportion that we expect to find (p= 0.5).

Thus, $n = 344.9828700401366 \approx 345$ children. This is the sample size.

23 specialists were hired, one for each institution, who had to study an average of 15 students per institution.

The aspects to be measured are the following:

First, there are the dimensions of comprehensive language and expressive language. Each of them is evaluated according to the following sub-aspects as shown in Table 1:

Language	Aspect to be measured	Definition
Expressive Language	Babbling	The quantity and variety of sounds the child produces.
	First words	The age at which the child says his or her first words and the number of words he or she knows.
	Use of phrases	The ability to combine words to form simple sentences.
	Vocabulary	The variety and quantity of words the child uses regularly.
	Clarity of speech	The ease with which the child can be understood by others.
Comprehensive Language	Response to commands	The child's ability to follow simple instructions
	Understanding questions	The ability to understand and answer simple questions.
	Recognition of words and objects	The ability to recognize and relate words to the objects they represent.
	Joint attention	The ability to maintain gaze and attention during a conversation or activity.
	Social interaction	The ability to communicate and play with other children and adults.

Table 1: Type of language and aspects to be measured and their definitions.

It is important to remember that each child is unique and can develop at his or her own pace. This is why the specialist cannot be able to determine a single probability value as occurs in classical probabilities. It may be necessary to evaluate with the support of more than one probabilistic value on the probability of occurrence, the indeterminacy of occurrence and the probability of non-occurrence.

To facilitate the assessment, a linguistic scale was associated with a numerical scale between 0 and 1 for each of the probabilities of event fulfillment T, indeterminacy I, and non-fulfillment of the event F. Therefore, for each aspect to be measured, each specialist evaluates each child in terms of the aspect with a triple of (T, I, F) probability values. The proposed scale is shown in Table 2.

Linguistic value	Numeric value
Very low	0.2
Low	0.3
More or less low	0.4
Neither low nor high	0.5
More or less high	0.6
High	0.7
Very high	0.8

Table 2: Scale of linguistic and numerical values corresponding to the probabilities of occurrence, non-occurrence, or indeterminacy of events.

The utility of the scale shown in Table 2 is that the surveyed expert can more easily determine the triple values that he or she proposes. For example, if the specialist determines that an attribute is satisfied with a "Very high" probability with a "Low" indeterminacy and a "Very low" probability of non-satisfaction, then the triple obtained is $(0.8, 0.3, 0.2)$.

Next, we will establish the procedure that we follow for the evaluations,

It is based on the set of experts as $E = \{e_1, e_2, \dots, e_{23}\}$, the children evaluated correspond to the set $U = \{u_1, u_2, \dots, u_{345}\}$.

The following aspects need to be evaluated:
A_1: Expressive Language,
A_2: Comprehensive Language.
The following sub-attributes to A_1 be evaluated are:
A_{11}: Babbling,
A_{12}: First words,
A_{13}: Use of phrases,
A_{14}: Vocabulary,
A_{15}: Clarity of speech.
The following sub-attributes to A_2 be evaluated are:
A_{21}: Response to commands,
A_{22}: Understanding questions,

A_{23}: Recognition of words and objects,
A_{24}: Joint attention,
A_{25}: Social interaction.
The study uses the Plithogenic Refined Probability (PRP) as follows:

$$PRP_1(u_i/e_j) = \left(\left(p_{A_1ij}, p_{A_2ij}\right), \left(indp_{A_1ij}, indp_{A_2ij}\right), \left(np_{A_1ij}, np_{A_2ij}\right)\right) \quad (3)$$

Where:

u_i: This is the ith child to be investigated ($i = 1, 2, \ldots, 345$),
e_j: This is the jth expert who conducts the investigation ($j = 1, 2, \ldots, 23$),

p_{A_1ij}: It is the probability assigned to the ith child by the jth expert that he or she has a disorder in expressive language.

p_{A_2ij}: It is the probability assigned to the ith child by the jth expert that he or she has a disorder in comprehensive language.

$indp_{A_1ij}$: It is the probability assigned to the ith child by the jth expert such that there is indeterminacy in establishing whether he or she has an expressive language disorder.

$indp_{A_2ij}$: It is the probability assigned to the ith child by the jth expert such that there is indeterminacy in establishing whether he or she has a disorder in comprehensive language.

np_{A_1ij}: It is the probability assigned to the ith child by the jth expert such that he or she does not have a disorder in expressive language.

np_{A_2ij}: It is the probability assigned to the ith child by the jth expert such that he or she does not have a disorder in comprehensive language.

Equation 3 can be broken down into further detail by substituting the probabilities with respect to the attributes into the probabilities with respect to the sub-attributes, as follows, see Equation 4:

$$PRP_2(u_i/e_j) = \begin{pmatrix} \left(p_{A_{11}ij}, p_{A_{12}ij}, p_{A_{13}ij}, p_{A_{14}ij}, p_{A_{15}ij}, p_{A_{21}ij}, p_{A_{22}ij}, p_{A_{23}ij}, p_{A_{24}ij}, p_{A_{25}ij}\right) \\ \left(indp_{A_{11}ij}, indp_{A_{12}ij}, indp_{A_{13}ij}, indp_{A_{14}ij}, indp_{A_{15}ij}, indp_{A_{21}ij}, indp_{A_{22}ij}, indp_{A_{23}ij}, indp_{A_{24}ij}, indp_{A_{25}ij}\right), \\ \left(np_{A_{11}ij}, np_{A_{12}ij}, np_{A_{13}ij}, np_{A_{14}ij}, np_{A_{15}ij}, np_{A_{21}ij}, np_{A_{22}ij}, np_{A_{23}ij}, np_{A_{24}ij}, np_{A_{25}ij}\right) \end{pmatrix} \quad (4)$$

Where:

$p_{A_{1k}ij}$: It is the sub-probability of p_{A_1ij} to A_{1k} ($k = 1, 2, \ldots, 5$).

$p_{A_{2k}ij}$: It is the sub-probability of p_{A_2ij} to A_{2k} ($k = 1, 2, \ldots, 5$).

$indp_{A_{1k}ij}$: It is the sub-probability of $indp_{A_1ij}$ to A_{1k} ($k = 1, 2, \ldots, 5$).

$indp_{A_{2k}ij}$: It is the sub-probability of $indp_{A_2ij}$ to A_{2k} ($k = 1, 2, \ldots, 5$).

$np_{A_{1k}ij}$: It is the sub-probability of np_{A_1ij} to A_{1k} ($k = 1, 2, \ldots, 5$).

$np_{A_{2k}ij}$: It is the sub-probability of np_{A_2ij} to A_{2k} ($k = 1, 2, \ldots, 5$).

Equation 4 is simplified by Equation 5:

$$\overline{PRP}_2(u_i) = \begin{pmatrix} \left(\bar{p}_{A_{11}i}, \bar{p}_{A_{12}i}, \bar{p}_{A_{13}i}, \bar{p}_{A_{14}i}, \bar{p}_{A_{15}i}, \bar{p}_{A_{21}i}, \bar{p}_{A_{22}i}, \bar{p}_{A_{23}i}, \bar{p}_{A_{24}i}, \bar{p}_{A_{25}i}\right) \\ \left(\overline{indp}_{A_{11}i}, \overline{indp}_{A_{12}i}, \overline{indp}_{A_{13}i}, \overline{indp}_{A_{14}i}, \overline{indp}_{A_{15}i}, \overline{indp}_{A_{21}i}, \overline{indp}_{A_{22}i}, \overline{indp}_{A_{23}i}, \overline{indp}_{A_{24}i}, \overline{indp}_{A_{25}i}\right), \\ \overline{np}_{A_{11}i}, \overline{np}_{A_{12}i}, \overline{np}_{A_{13}i}, \overline{np}_{A_{14}i}, \overline{np}_{A_{15}i}, \overline{np}_{A_{21}i}, \overline{np}_{A_{22}i}, \overline{np}_{A_{23}i}, \overline{np}_{A_{24}i}, \overline{np}_{A_{25}i}\big) \end{pmatrix} \quad (5)$$

Where:

$\bar{p}_{A_{1k}i} = \frac{\sum_{j=1}^{23} p_{A_{1k}ij}}{23}$,

$\bar{p}_{A_{2k}i} = \frac{\sum_{j=1}^{23} p_{A_{2k}ij}}{23}$,

$$\overline{indp}_{A_{1k}i} = \frac{\sum_{j=1}^{23} indp_{A_{1k}ij}}{23},$$

$$\overline{indp}_{A_{2k}i} = \frac{\sum_{j=1}^{23} indp_{A_{2k}ij}}{23},$$

$$\overline{np}_{A_{1k}i} = \frac{\sum_{j=1}^{23} np_{A_{1k}ij}}{23},$$

$$\overline{np}_{A_{2k}i} = \frac{\sum_{j=1}^{23} np_{A_{2k}ij}}{23}.$$

Equation 5 is further reduced to obtain Equation 6 which corresponds to all children studied:
This formula represents the probability that any given child will meet them.

$$\overline{\overline{PRP}}_2(\mathrm{u}) = \begin{pmatrix} \left(\bar{\bar{p}}_{A_{11}}, \bar{\bar{p}}_{A_{12}}, \bar{\bar{p}}_{A_{13}}, \bar{\bar{p}}_{A_{14}}, \bar{\bar{p}}_{A_{15}}, \bar{\bar{p}}_{A_{21}}, \bar{\bar{p}}_{A_{22}}, \bar{\bar{p}}_{A_{23}}, \bar{\bar{p}}_{A_{24}}, \bar{\bar{p}}_{A_{25}}\right) \\ \left(\overline{\overline{indp}}_{A_{11}}, \overline{\overline{indp}}_{A_{12}}, \overline{\overline{indp}}_{A_{13}}, \overline{\overline{indp}}_{A_{14}}, \overline{\overline{indp}}_{A_{15}}, \overline{\overline{indp}}_{A_{21}}, \overline{\overline{indp}}_{A_{22}}, \overline{\overline{indp}}_{A_{23}}, \overline{\overline{indp}}_{A_{24}}, \overline{\overline{indp}}_{A_{25}}\right), \\ \overline{\overline{np}}_{A_{11}}, \overline{\overline{np}}_{A_{12}}, \overline{\overline{np}}_{A_{13}}, \overline{\overline{np}}_{A_{14}}, \overline{\overline{np}}_{A_{15}}, \overline{\overline{np}}_{A_{21}}, \overline{\overline{np}}_{A_{22}}, \overline{\overline{np}}_{A_{23}}, \overline{\overline{np}}_{A_{24}}, \overline{\overline{np}}_{A_{25}} \end{pmatrix} \quad (6)$$

Where:

$$\bar{\bar{p}}_{A_{1k}} = \frac{\sum_{j=1}^{345} \bar{p}_{A_{1k}i}}{345},$$

$$\bar{\bar{p}}_{A_{2k}} = \frac{\sum_{j=1}^{345} \bar{p}_{A_{2k}i}}{345},$$

$$\overline{\overline{indp}}_{A_{1k}} = \frac{\sum_{j=1}^{345} \overline{indp}_{A_{1k}i}}{345},$$

$$\overline{\overline{indp}}_{A_{2k}} = \frac{\sum_{j=1}^{345} \overline{indp}_{A_{2k}i}}{345},$$

$$\overline{\overline{np}}_{A_{1k}} = \frac{\sum_{j=1}^{345} \overline{np}_{A_{1k}i}}{345},$$

$$\overline{\overline{np}}_{A_{2k}} = \frac{\sum_{j=1}^{345} \overline{np}_{A_{2k}i}}{345}.$$

What relates formula 6 to an aggregation formula is calculated with Equation 7:

$$\overline{\overline{PRP}}_1(\mathrm{u}) = \left(\left(min_k p_{A_{1k}}, min_k p_{A_{2k}}\right), \left(max_k indp_{A_{1k}}, max_k indp_{A_{2k}}\right), \left(max_k np_{A_{1k}}, max_k np_{A_{2k}}\right)\right) \quad (7)$$

After applying the calculations on the formulas above, i.e. Equations 3-7, the following results were obtained:

$$\overline{\overline{PRP}}_1(\mathrm{u}) = \left((0.487,0.267), (0.273,0.374), (0.681,0.776)\right).$$

This means that the plithogenic neutrosophic probability is $PNP_{A_1} = (0.487,0.273,0.681)$ for having an alteration in expressive language, whereas $PNP_{A_2} = (0.267,0.374,0.776)$ is the probability that there will be an alteration in comprehensive language.

These values can be reduced to a single numerical value, with Equation 8 called the score function [18,19,20]:

$$\mathcal{S}\left((T,I,F)\right) = \frac{2+T-I-F}{3} \quad (8)$$

Therefore, we have $\mathcal{S}\left(PNP_{A_1}\right) = 0.511$ and $\mathcal{S}\left(PNP_{A_2}\right) = 0.372$. These values are classified, according to the distance to the values shown in Table 1, as "neither low nor high" probability of suffering from expressive language disorder and "more or less low" probability of suffering from comprehensive language disorder.

Conclusion

The age between 1 and 3 years is critical for language development in children. Delays and alterations in the proper use of language may occur in children of that age than would be expected. In this article, we presented a study carried out on a random sample of 345 children from a population of 3374, who are associated with childcare institutions in the province of Pichincha in Ecuador, 2024. For the calculations, we based ourselves on Plithogenic Statistics, because each of the alterations has probabilities and sub-probabilities related to the attributes and sub-attributes being studied. As attributes, the alteration of expressive language and the alteration of comprehensive language were evaluated. Each of them was evaluated according to five sub-attributes. The results were that the probability of suffering from alterations in expressive language in this region is "neither low nor high" and the probability of suffering from alterations in comprehensive language is "more or less low".

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Received: Oct 20, 2024. Accepted: March 16, 2025