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Model for the Diagnosis of Autism Based on Neutrosophic Cognitive Maps

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Abstract. Autism spectrum disorders are diverse conditions characterized by some degree of difficulty in social interaction and communication, atypical patterns of activity and behavior, and unusual reactions to sensations. ASDs do not have a single known cause, scientists do not know the exact causes of their development, and it is believed that they are associated with a combination of several factors. The present study was carried out with 42 cases diagnosed with any of the subclasses of autism established by the DSM-V and included patients between 18 months and four years old, from 4 provinces of Ecuador, to determine the main elements to which they were exposed to establish possible common groups of causal factors of the disease. The experts carried out an analysis and determined three predominant casual factors in the group, and some recommendations derived from the analysis are included.

Keywords: Autism; autism spectrum disorder; ASD; neutrosophic cognitive map; NCM.

1 Introduction

Autism spectrum disorders (ASD) are characterized by severe deficits in socialization, communication, and repetitive or unusual behaviors. It affects information processing in the brain by altering how nerve cells and synapses connect and organize; how this happens is not yet well clarified [1].

The term "autism" is used in psychiatry to mean withdrawn and self-absorbed; it comes from the Greek word "autos," which means "in itself", "own". Defining it is not an easy task, because many years have passed since in 1943 Leo Kanner, an Austrian psychiatrist living in the United States, did it for the first time after describing in detail eleven cases of children who presented peculiar characteristics that differentiated them from the rest of minors with psychopathological alterations [2]. Starting in 1994, as a result of important studies, the Pan American Health Organization began to conceptualize it as: "a generalized developmental disorder, defined by the presence of impaired development (...) that manifests itself before three years of age and a characteristic type of functioning (…) in the three areas of psychopathology: reciprocal social interaction, communication and restricted, stereotyped and repetitive behavior [3]. The World Health Organization estimates that one in 270 people worldwide has an ASD. This estimate represents an average figure because, although the observed prevalence varies considerably between different studies, some well-controlled studies have registered notably higher figures [4][5].

According to the England Institute for Health Measurements and Evaluation, in 2015, the worldwide prevalence of ASD in children under five years of age was 0.12%, with an annual percentage change of 0.037%. In children from 5 to 14 years, the prevalence was 1.34%, with an annual percentage change of 0.029%. In Latin America and the Caribbean, in children under five years of age, in the same year, there was a prevalence of 0.27%, with an annual percentage change of 0.0027%, and in the population aged 5 to 14 years, a prevalence of 1.73%, with an annual percentage change of 0.023% [6].

In Ecuador, as in many Latin American countries, there is no accurate data on the prevalence of ASD [7]; however, according to data provided by [6] in the Ecuadorian population under 5 years of age, the prevalence in 2015 was 0.28% (0.18% - 0.41%) with an annual percentage change of 0.0069% and in the population from 5 to 14 years, the prevalence was 1.7% (1.29 - 2.15%), with an annual percentage change of 0.016%. For 2016, according to data provided by the National Directorate of Disabilities of the Ministry of Public Health, based on its technical report, the existence of 1,266 people diagnosed with ASDs is reported. Out of these, 254 have been registered with a diagnosis of atypical autism; 792 with a diagnosis of childhood autism: 205 with Asperger

syndrome, and 15 registered within Rett syndrome (As of the Fifth Edition of the Diagnostic Statistical Manual of Mental Disorders (DSM-V) Rett Syndrome is no longer listed among the subtypes of autism) (29) [8] [9].

Numerous investigations have published the "causes of autism," although their results have not been generalized because they contradict the conclusions of other studies [10] [11]. Some reports speak of the occurrence of autism due to anatomical alterations, [12] due to neurobiological disorder, or due to neuronal involvement [13] [14]. Others specify that it is a cognitive and neurobiological disorder [15] or caused by mirror neuron dysfunction [16][17], or by genetics [18] [19]. Other studies point to the environmental component [20], eventual consequence of contamination by heavy metals and toxicity [21] [22], or from exposure to pollutants in pregnancy and/or the first year of life, or due to air pollution [2. 3].

Even though the management of ASD is based on an integral, multi-systemic and inter-professional approach focused on the person with ASD, their family and the community, diagnoses of ASD can be difficult to make because there are no conclusive medical tests to diagnose them; it is specially trained physicians and psychologists who rely on specific behaviors to identify autism [24]. Sometimes ASDs can be detected at 18 months of age or even earlier. At 2 years of age, the diagnosis made by an experienced professional can be considered very reliable [25].

The current study was carried out with a sample of 42 cases diagnosed with any of the subclasses of autism established by the DSM-V. It included boys and girls aged between 18 months and 4 years, of different phenotypes and social strata, natives of the provinces of Guayas, Los Ríos, Manabí, and Santa Elena, to determine the main elements to which the subjects were exposed to establish possible common groups of causal factors of the disease.

The selected team of experts was made up of 9 specialists in Child Psychology, Neuropsychology, and Psychiatry. The study was based on the analysis of the diagnosis through retrospective studies according to the following procedure:

a) Interviews not done with the mother and father separately and then to the parental partner (whenever possible)
b) Very open questions about child development to both parents
c) Elicit anecdotes about the child's development, sometimes triggered by examining photographic materials from the child's early years
d) Review of previous medical records (if any)
e) Tracking over time the symptoms observed in the present

The data obtained were processed by using the Neutrosophic Cognitive Maps (NCM), a very versatile tool in the investigation of causal factors for the treatment of neutralities. Its use enriched the possibilities of analysis, mainly due to the addition of indeterminacy and the possibility of calculating using linguistic terms that are more natural for the selected experts [26].

2 Materials and methods

For a better understanding of data processing with Neutrosophic Cognitive Maps (NCMs), the following is exposed:

Starting from the previous elements, in this particular work, the use of NCM is proposed considering the advantages that this technique offers compared to other soft-computing techniques, in terms of interpretability, scalability, aggregation of knowledge, dynamism, and its ability to represent feedback and indeterminacy relationships [4]. NCMs were introduced by [28] in 2003. MCNs are an integration of the Fuzzy Cognitive Maps (FCMs) introduced by Kosko in 1986 and the Neutrosophic Sets (NSs) introduced by Smarandache in 1995 [29]. This technique overcomes the inability of traditional FCMs to represent indeterminacy. The inclusion of indeterminacy establishes that neutrality and ignorance are also forms of uncertainty. [29] Exposes that FCMs constitute a technique that has received increasing attention due to its possibilities for representing causality. The following is a set of definitions necessary for working with NCMs. Firstly, let formally expose the original definition of neutrosophic logic as it is shown in [30].

Definition 1.

[5] Let $N = \{(T, I, F): T, I, F \in [0,1]\}$ be a *neutrosophic set of evaluation*. v: P□N is a mapping of a group of propositional formulas into N, ie, each sentence p is associated to a value in N, as it is exposed in Equation 1, meaning that p is T% true, I% indeterminate, and F% false.

$$v(p) = (T, I, F) \tag{1}$$

Hence, the neutrosophic logic is a generalization of fuzzy logic, based on the concept of neutrosophy according to [26] [31].

Definition 2. (See [32] [33]) Let K be the ring of real numbers. The ring generated by K∗I is called a *neutrosophic ring* if it involves the indeterminacy factor in it, where I satisfies I2 = I, I + I = 2I and in general, I +

I + ... + I = nI, if k , then kI = kI, 0I = 0. The neutrosophic ring is denoted by K (I), which is generated by K∗I, ie, K (I) = <K∗I>, where <K∗I> denotes the ring generated by K and I.

Definition 3. *A neutrosophic matrix* is a matrix A = [a_{ij}] ij i = 1, 2,…, m and j = 1, 2,…, n; m, nε1, such that each a_{ij} K (I), where K (I) is a neutrosophic ring, see [3. 4]

Let us observe that an element of the matrix can have the form a + bI, where "a" and "b" are real numbers, whereas I is the indeterminacy factor. The usual operations of neutrosophic matrices can be extended from the classical matrix operations.

For example,$(-1\ I\ 5I\ I\ 4\ 7\ )(I\ 9I\ 6\ 0\ I\ 0\ -4\ 7\ 5\ ) = (-21I\ 27I\ -6+25I\ -28+I\ 49+13I\ 35+6I\ )$

Additionally, a *neutrosophic graph* is a graph that has at least one indeterminate edge or one indeterminate node [30] [35]. The *neutrosophic adjacency matrix* is an extension of the adjacency matrix in classical graph theory. aij = 0 means nodes i and j are not connected, a_{ij} = 1 means that these nodes are connected and aij = I, which means the connection is indeterminate (unknown if it is or if not). Fuzzy set theory does not use such notions.

On the other hand, if the indetermination is introduced in a cognitive map as it is referred to in [36], then this cognitive map is called a neutrosophic cognitive map, which is especially useful in the representation of causal knowledge [26] [37]. It is formally defined in Definition 4.

Definition 4. A Neutrosophic Cognitive Map (NCM) is a neutrosophic directed graph with concepts like policies, events, among others, as nodes and causalities or indeterminacy as edges. It represents the causal relationship between concepts.

The measures described below are used in the proposed model; they are based on the absolute values of the adjacency matrix [36]:

- Outdegree (vi) is the sum of the row elements in the neutrosophic adjacency matrix. It reflects the strength of the outgoing relationships (cij) of the variable:

$$od(v_i) = \sum_{i=1}^{n} \quad c_{ij} \tag{2}$$

- Indegree (v_i) is the sum of the column elements. It reflects the strength of relations (cij) outgoing from the variable.

$$id(v_i) = \sum_{i=1}^{n} \quad c_{ji} \tag{3}$$

- Total centrality (total degree td (vi)), is the sum of the indegree and the outdegree of the variable.

$$td(v_i) = od(v_i) + id(v_i) \tag{4}$$

The variables are classified according to the following criteria, see [6]:

a) *Transmitting variables* are those with od (vj)> 0 and id (vi) = 0.
b) *Receiving variables* are those with od (vj) = 0 and id (vi)> 0.
c) *Ordinary variables* satisfy both od (vj) ≠ 0 and id (vi) ≠ 0.

The static analysis is applied using the adjacency matrix, taking into consideration the absolute value of the weights [35]. Static analysis in Neutrosophic Cognitive Maps (NCM), see [37], initially contains the neutrosophic number of the form (a + bI), where I = indetermination [38]. Then, it requires a process of de-neutrosophication as proposed in [36], where I ∈ [0, 1] and it is replaced by their values maximum and minimum.

Finally, we work with the average of the extreme values, calculated using Equation 5, which is useful to obtain a single value as it is referred to in [39]. This value contributes to the identification of the characteristics to be attended, according to the factors obtained, for our case study.

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \tag{5}$$

Then,

$$A \succ B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2} \tag{6}$$

3 Results

By the interviews carried out with the parents of the children diagnosed and the clinical review of each case, the experts consulted used brainstorming to propose a universe of possible causal factors in the study sample. After the use of expert methods and taking into account the statistical results of the sample, a smaller set was selected, which, in their opinion, are the most relevant for the fulfillment of the study objectives:

1. Premature birth: studies have found that preterm and low birth weight newborns are more likely to suffer from neurological diseases than other babies [40] [41]. In this group, patients born between 30 and 37 weeks of gestation are considered.
2. Cesarean birth/traumatic delivery: Despite the lack of conclusive evidence, numerous correlations have been found between cesarean birth and ASD. Recent studies suggest that children undergoing cesarean are more likely to develop the disease than other children [42].
3. Use of children's medications during the first 3 years of life: Children exposed to medication for the treatment of chronic diseases or non-chronic diseases that required treatment and specialized medication are considered.
4. Exposure to electronic devices with blue light: The accelerated development of technology has made cell phones, TV screens, monitors, among others, totally diffused objects. This group refers to patients who had an exposure greater than the 2 hours a day recommended by the American Academy of Pediatrics.
5. Social interaction of family members with the child refers to the level of personal interrelation between any close member of the family and the patient under study. It is known that among the cases studied, 7% come from dysfunctional families or from families that have antisocial members.
6. Advanced age of the parents: Children who have been the result of geriatric pregnancies and/or in which the paternal age is greater than 45 years are considered. Of the sample under study, 7.1% are in this category. One of the cases studied includes the advanced age of both the mother and the father.
7. Family history of autism: Several studies have identified a series of genetic changes or mutations associated with autism, confirming that genetics is one of the most important risk factors for ASD. Patients with relatives up to the fourth generation who have presented autism are considered.
8. Family history of mental illness: Children are considered to be related to some extent with close relatives or undiagnosed with some kind of mental illness [43]. In the selected sample, about 5% are within this category.
9. Family history of neurological diseases: Children are considered related to some extent with close relatives diagnosed with some neurological disease.
10. Family history of chronic diseases: This subgroup includes a family history of chronic non-neuronal diseases. In the study group, about 30% are linked in some way to relatives associated with rheumatic, cardiovascular, endocrine, and oncological diseases.
11. Use of medications during pregnancy/lactation: the cases are considered in which the mother was exposed during pregnancy or breastfeeding to the intake of anxiolytic, antidepressant, an opioid analgesic, barbiturate, antispasmodic or anticonvulsant medications. In this case, about 20% of pregnant or lactating mothers fall into this category.
12. Use/abuse of drugs, alcohol and/or cigarettes of one of the parents during the period of fertilization, pregnancy, and lactation (in the case of the mother): About 26% of the cases studied were exposed before birth and during the first years of life for the purposes included in this category.

Once the causal factors that, in the opinion of the experts, have the greatest incidence in the study group have been screened, the data is processed using the NCM. See adjacency matrix below:

$$A(x)=\begin{vmatrix} 1 & 0.7 & 0 & 1 & 1 & 1 & 0.2 & 1 & 0.5 & 1 & 0.4 & 1 \\ 1 & 0 & 0 & 0 & 0.4 & 0.5 & 1 & 1 & I & 0 & 0 & 1 \\ 0.5 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0.2 & 0 & 1 \\ 0 & 0.2 & 0.5 & 1 & 0.2 & 1 & 1 & 1 & 0.8 & 0.5 & I & 0 \\ 1 & 1 & 0 & 0 & 0 & 0.5 & I & 0.6 & 0.4 & 0 & 0 & 1 \\ 1 & 0.8 & 0 & 1 & 1 & 0 & 1 & 0.5 & 0.4 & 1 & 1 & 0 \\ 1 & 0.1 & 1 & 0.5 & 1 & 1 & 1 & 0.1 & 0.5 & 1 & 0 & 0 \\ 0 & 0 & 0.5 & 0.3 & 0.6 & 0 & 1 & 0 & 0.5 & 0.5 & 0.4 & 0.5 \\ 0.5 & 0 & 0.5 & 1 & 0.4 & 0.6 & I & 1 & 0 & 1 & 0 & 0.2 \\ 0.2 & 0.2 & 0.2 & 0.2 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0.5 & 0 & 0 & 0 & 0.2 & 0.2 & 0.2 & 0 & 0 & 0.5 & 0 & 1 \\ 1 & 1 & 0 & 1 & 1 & 0.5 & 0 & 1 & 0.2 & 0.5 & 0 & 1 \end{vmatrix}$$

Figure 1: Neutrosophic adjacency matrix.

The causal analysis resulting from the data processing indicates that within the group studied, the factors with the greatest influence are the premature birth of the patients and the family history of autism. Other factors such as cesarean birth and traumatic deliveries, and prolonged exposure to electronic blue light devices are considered lesser.

Factors	id	od	td
Premature birth	0.88	1.00	**1.88**
Family history of autism	0.95	0.82	**1.77**
Cesarean birth/traumatic delivery	0.76	0.82	**1.58**
Exposure to electronic devices in blue light	0.80	0.76	**1.56**
Parents' advanced age	0.60	0.88	**1.48**
Social interaction of family members with the child	0.77	0.57	**1.34**
Family history of mental illness	0.70	0.49	**1.19**
Family history of neurological diseases	0.55	0.65	**1.19**
Use/abuse of drugs/alcohol/cigarettes by either parent during the period of fertilization, gestation, and lactation (in the case of the mother)	0.45	0.61	**1.07**
Family history of chronic diseases	0.70	0.32	**1.02**
Use of children's medications during the first 3 years of life	0.31	0.53	**0.84**
Medication use during pregnancy/lactation	0.26	0.30	**0.56**

Table 1: Static analysis of the adjacency matrix by perspectives according to the order of influence

The experts found consensus on the three main causal factors detected for this sample. In the first place, the relationship between exposure to adverse prenatal situations and the prevalence of ASD symptoms is known. In recent years, the international community has increased screening studies investigating possible risk factors for ASD in preterm newborns. Out of the study sample, almost 20% had a birth between 30 and 37 weeks of pregnancy. From the debate with the experts, it was known that babies born prematurely or with low weight are more likely to develop the disease than babies born on term and with adequate weight. At this point, the experts agree with the existing opinion and this factor is validated as a possible causal factor of ASD in the group under study.

On the other hand, although it is very difficult to determine exactly to what extent genes determine the prevalence of ASD, researchers agree that autism has an important hereditary component since the disorder tends to run in families, which is why several studies have validated that genetic inheritance plays an important role in the development of the disease. In the sample studied, 14.7% of the children have a genetic relationship to a greater or lesser degree with a case previously diagnosed with autism, so the experts agree that the genetic relationship is a significant causal factor that is prevalent in the group of study.

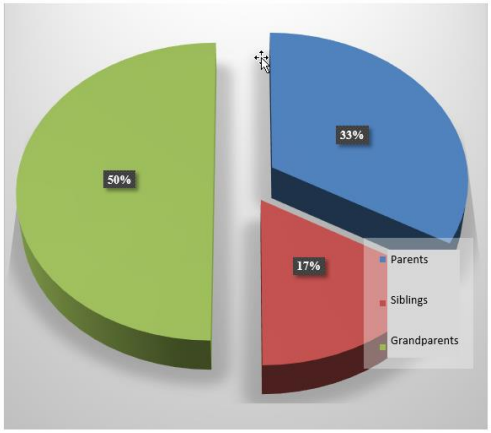

Figure 2: Family history diagnosed with ASD of the study subjects.

Although to a lesser degree than the first two, cesarean birth has also been associated as a possible causal factor for ASD. It is well known that the time of delivery is one of the most biologically complex in mammals. Many neurological disorders have their origin in incorrect brain development, and recent studies reveal that children born by cesarean section or problematic deliveries are more likely to be diagnosed with autism, so experts agree with the inclusion of this factor as a causal factor in the sample studied. Out of the total sample, about 12% were delivered by cesarean method, while 7% of the total were born due to deliveries that had some kind of neonatal complication and suffered some obstetric injury.

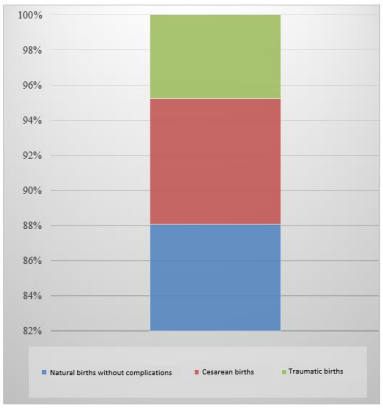

Figure 3: Percentage ratio of natural deliveries, cesarean deliveries, and traumatic deliveries of the total sample.

It is important to note that, although it is not among one of the top three causative agents of the disease in the group, experts position exposure to blue light electronic devices above others approved by the international scientific community. Currently, there is no doubt that exposure to these devices is increasing. Mothers and fathers turn to them as an infallible means of entertainment for children, many times without considering that their needs for human interaction at an early age are vital for the proper development of psychosocial functions.

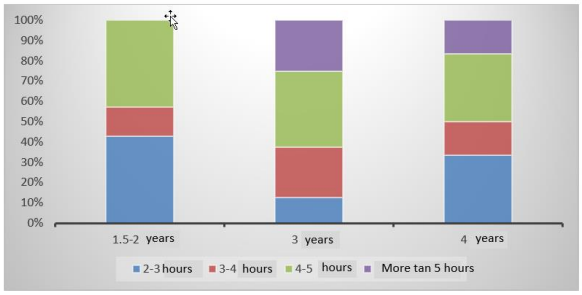

Figure 4: Summary of the time of exposure to blue light devices according to age groups.

In the sample analyzed, almost half of the children were exposed to blue light devices for a longer time than recommended by the American Academy of Pediatrics. Children from 18 months to 2 years have a large representation of exposure for times more significant than 4 hours; 3-year-old children are prevalent in 4 to 5-hour exposure, as are 4-year-old patients. It should also be noted that the most affected group of those studied is the 3-year-old since they have the largest number of children exposed to this factor for more than 5 hours. In this sense, it would be pertinent for this same group to develop other studies that could analyze in-depth the real impact of blue light devices and patients' medium and long-term behavior when eliminating this exposure.

Conclusions

The number of cases diagnosed with some kind of autism has been increasing over the years. The causes of ASD are still unknown to science; however, experts on the subject have concluded that there are factors of various kinds that lead to the appearance of the disease with greater probability in some individuals than in others. The sample studied determined that the most important causal factors were premature birth and a family history of autism. To a lesser extent, other factors such as cesarean delivery and traumatic deliveries and prolonged exposure to electronic blue light devices are considered. It is recommended to study the behavior of the symptoms and signs of the disease before the elimination of the exposure to blue light devices.

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