Logical-mathematical notions in children with perinatal encephalopathy

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ABSTRACT

Objective: *To describe the characteristics of the logical and mathematical concepts in preschool and school children with a history of perinatal encephalopathy.*

Setting: *National Institute of Pediatrics (INP) in Mexico City.*

Study design: *Cross-sectional study.*

Participants: *28 children, 10 male (36%) and 18 female (64%), all of them diagnosed with perinatal encephalopathy.*

Methods: *To evaluate the logical-mathematical notions the Monterrey test was used. Gender, birth, perinatal encephalopathy (hypoxic-ischemic, hyperbilirubinemia, or mixed).*

Results: *In logical-mathematical notions 16 children (57%) were found at the right level and 12 (43 %) with a lower level answers than expected for their age. Statistically significant association of the logic-mathematical notions with age ($p < 0.0001$), encephalopathy ($p < 0.04$) IQ ($p < 0.04$) and classification ($p < 0.02$) was observed, and socioeconomic status ($p = 0.03$).*

Conclusions: *The acquisition of the natural number concept can be disrupted by early developmental disorders such as perinatal encephalopathy, since 43 % of the children tested had arrived at lower levels than expected for their age.*

Keywords: mathematics, perinatal, encephalopathy, classification, seriation, conservation.

1. Introduction

The basis for the development of logical-mathematical notions are established since early stages in the childhood, based on the acquisition of practical concepts that children learn in interaction with the objects around him. Piaget (1992) describes that in the initial stages of development, children exercise patterns of action on the objects, which are all movements or probable, elementary, and repetitive perceptions, representing behaviors, such as sucking, see, grab, hit or throw objects that the children can apply to new situations. Concept development begins at approximately 2 years and continues throughout life; starts through the physical interaction with objects and then reaches levels of abstraction that are separated from concrete situations.

The relationships between objects comparison promotes the construction of numerical concepts, which are learned in the same way that other concepts of non-numeric category where features are attributed to an object such as its color, shape, texture, etc. (Mix, 2008).

The child will add different attributes to the object and he will be able to include all these attributes in one object. For example, he will say, “I have two large blue circles”, or he can even use the label two when facing different objects such as candies and balls; “here there are two sweets, there are two balls”. However, the development of enumeration concepts does not depend on the possession of numeric words (Gelman & Butterworth, 2005; Butterworth, Reeve, Reynolds, & Lloyd, 2008).

Through sets of actions the handling of reversibility is achieve by children, that will be able to perform inverse operations that later will apply to conventional basic arithmetic operations such as addition and subtraction. The construction and understanding of the inversion has been considered as an important concept and a milestone of reasoning. (Ginsburg, 2006; Gilmore, 2006; Gilmore & Spelke, 2008).

Some research has shown that children aged 5 and 6 years, who have not had the experience of formal education at school, are able to perform inversion operations, as they understand subtraction and addition operations a result of experience their interaction with their parents (Gilmore & Spelke, 2008). Before children receive formal teaching about algorithms to be applied in arithmetic tasks, they build various strategies of addition, subtraction and even multiplication and division as a result of their interaction with the physical and social world where they develop (Rodríguez et al., 2008; Laski & Yu, 2014).

When the child learns the specific meanings of spoken and written numerals, he learns their ordinal meaning, and he is able to synthesize equivalence relations corresponding to the classification and relations of order corresponding to serialization (Serrano & Pons, 2008).

Children with difficulties in the acquisition of arithmetic skills have been linked to neurological problems, specifically in the parieto-temporal areas of both hemispheres (Shalev & Gross-Tsur, 2001; Gracia-Bafalluy & Escolano-Pérez, 2014). This pathology has shown abnormal recruitment of neural sources using functional Magnetic Resonance Imaging studies (fMRI) in children that were calculating arithmetic tasks of approximation and exact quantities (Kucian et al., 2006).

In this research we aim to describe the characteristics of the logical and mathematical concepts in preschool and school children with a history of perinatal encephalopathy.

2. Method

2.1. Participants

A cross-sectional study that included 28 children, 10 male (36 %) and 18 female (64 %) between 4 and 8 years of age was performed.

Based on the hospital records of the National Institute of Pediatrics (INP) in Mexico City, the following data from the clinical history of the participants were recorded: 1) condition at birth (weeks of gestation at birth), term or preterm; the presence of perinatal encephalopathy (brain injury caused by acute pathology in the perinatal period), hypoxic-ischemic, hyperbilirubinemia, or mixed (a situation in which the two conditions, hypoxia-ischemia and coexisting hyperbilirubinemia) (Table 1).

The Intellectual Quotient (IQ) was assessed with the Terman Merrill test, based on the scales of Stanford-Binet Intelligence, in which the IQ is assessed from 2 years of age. According to the score obtained children were classified as follow: Mentally deficient (MD) with an IQ of 69 or less; borderline (B) with an IQ of 70 to 79, normal (N) with an IQ of 80 to 119; and superior (S) with an IQ of 120 or above.

Neuropsychological Sequel was scored according to Campistol (1997) as mild or non-disabling, moderate or severe. The criteria for considering mild neurological sequel were: mild developmental quotient of 71 to 84, mild language impairment, soft neurological signs, minor sensory disturbances, such as decreased vision or unilateral hearing loss, and mild conduct disorder. In moderate neurological sequel were considered: that the child had a developmental quotient of 50 to 70; hemiplegia, diplegia or quadriplegia with possibility of mobility; partial sensory deficit and bilateral hearing loss or decreased vision; deafness or unilateral blindness. Subjects were classified with serious neurological sequel if they have: an IQ of less than 50; motor disorder without the possibility of running; total sensory deficit; refractory epilepsy; and severe behavioral disorder such as psychosis or autism.

The study was conducted in accordance with the Helsinki Declaration of the World Medical Assembly (2013).

2.2. Materials and procedures

With the Monterrey Test, a psychogenetic one (Gómez et al., 1984), we evaluated the acquisition processes of logical-mathematical concepts from 4 years of age. The answers given by the child were registered about aspects of classification, serialization and conservation of quantity. For classification, logic plastic blocks were presented in the form of triangles, squares and circles that were characterized by color (blue-red); size (big-small); and thickness (thin-thick). The children were told had to describe and classify the items by putting "together what looked like" or "together what belongs together". Afterward the children needed to describe the reason why he ordered the items in such way and characteristics he used. In serialization, each child was given 10 wooden rulers from 17 to 8 cm high, with a difference of 1 cm between each and asked to describe the rulers. After the children were told to order the rulers from "the biggest to the smallest". For conservation 30 round plastic chips (15 green and 15 yellow) were given to each child, and from they were asked to choose a color and put the chips in front of a row of 7 chips already made by the examiner and being told to put the chips "as mine, neither more nor less".

The logical-mathematical concepts evaluated were logical classification, serialization and conservation of a discontinuous quantity. The answers were linked to three stages of development: figural, preoperative and operative (Table 1).

Table 1:
Logical mathematical notions. Test Monterrey.

Notions	**Levels**		
	Figurative	**Preoperative**	**Operative**
Classification	*Figurative Collection* a) alignments in one dimension b) collective objects with 2 or 3 dimensions c) complex objects	*Non Figurative Collection* a) only small collections without a single criteria b) encompassing collections with a single criteria c) encompassing collections and sub collections	Operative classification Class inclusion
Seriation	*Global Comparison* a) elements in a series without own order. b) series in pairs or set of three uncoordinated together. c) series of 4 or 5 ladder-shaped elements at the top without caring for the bottom.	*Progressive and intuitive seriation* Sorting by trial and error	*Immediate and operative seriation* Transitive ordering of the differences between the strips.
Conservation	*Lack of conservation* a) without initial correspondence b) with initial correspondence	*Correspondence from term to term* Establish correspondence. Notice that the length and positions of the rows determine the amount	*Operative conservation* Correspondence achieved regardless of the length or position of the elements.

3. Results

The general characteristics of the study subjects are shown in Table 2. The age groups were evenly distributed except for the group of 8 who had 4 cases (0.14). In the condition at birth predominated term infants (0.54), and with normal trophic (0.53). Regarding perinatal encephalopathy seven children (0.25) presented hypoxia-ischemia, eight (0.29) hyperbilirubinemia, and thirteen (0.46) both conditions. Regarding the presence of sequelae predominant patients with mild consequences (0.75). With respect to IQ the highest number of cases were 19 children with normal level of intelligence (0.67). Finally we observed that in socioeconomic status children predominated cases in the average level (0.51).

In the development of logical-mathematical notions 16 children (0.57) were found at the right level and 12 (0.43) with lower answers than expected for their age. No gender differences were observed.

Significant differences were found when comparing age with the level of development of logical-mathematical notions ($p < 0.0001$) (Figure 1). These differences encompassed specific tasks such as classification ($p < 0.0001$), seriation ($p < 0.0001$) and conservation ($p < 0.003$). 7 and 8 years old children had moderate intellectual disability and presented severe delays in the acquisition of the mathematical notions (Figure 1).

By associating encephalopathy with logical-mathematical notions significant differences ($p < 0.04$) were found, confirming the difference in notions of seriation ($p < 0.05$) and conservation ($p < 0.01$). Children with mixed encephalopathy showed a delay in the acquisition of the evaluated concepts (Figure 2).

While comparing IQ with logical-mathematical notions as a whole showed no significant differences, differences were be observed when IQ was compared with seriation ($p < 0.04$), and classification ($p < 0.02$). In children with intellectual disability and in the borderline moderate and severe delays were observed in the acquisition of logical-mathematical notions mentioned above.

Finally, a strong association was shown between the socioeconomic status of children and logical-mathematical notions. Children with low socioeconomic status showed moderate to severe delays in the acquisition of these notions, as it is reflected in the concept of seriation ($p < 0.03$).

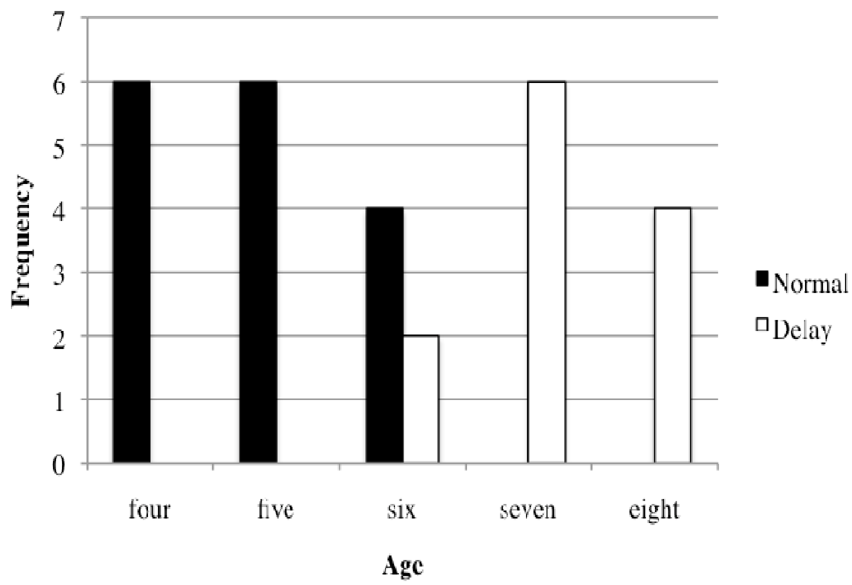

Figure 1. Acquisition of logic-mathematical notions. Children with a normal performance and with intellectual disability are compared side-by-side in each age group.

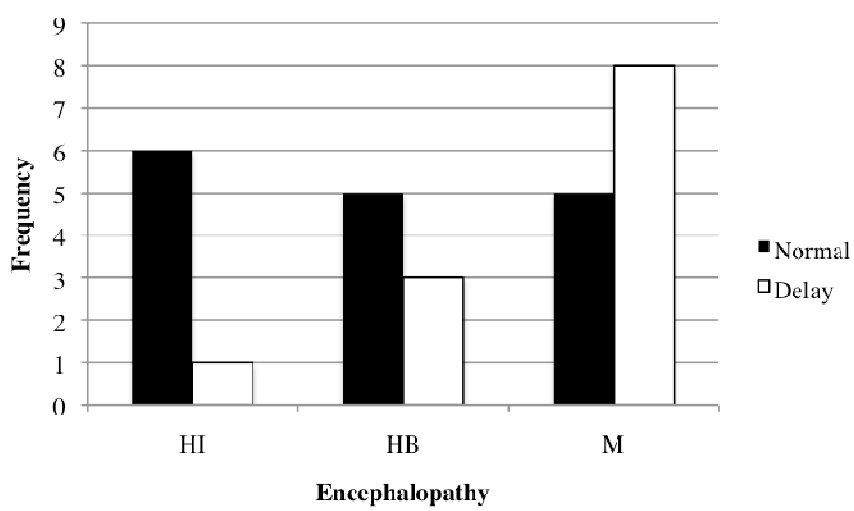

Figure 2. Logic-mathematical notions and perinatal encephalopathy. Comparison between the type of encephalopathy that children presented: hypoxic-ischemic encephalopathy (HI), Hyperbilirrubinemic (HB) and mixed (M); and their level of acquisition of logic-mathematical notions.

Table 2
Characteristics of 28 children with perinatal encephalopathy.

	Frequency	Proportion
Age (years old)		
4	6	(.21)
5	6	(.21)
6	6	(.21)
7	6	(.21)
8	4	(.14)
Gender		
Male	10	(.36)
Female	18	(.64)
Condition at birth		
Preterm	13	(.46)
Term	15	(.54)
Birth weight		
Low	12	(0.43)
Normal	15	(0.53)
High	1	(0.04)
Perinatal encephalopathy		
Hypoxic-ischemic	7	(0.25)
Hyperbilirubinemia	8	(0.29)
Mixed	13	(0.46)
Socioeconomic status		
Low	10	(0.35)
Middle	14	(0.51)
High	4	(0.14)
Sequel		
Mild	21	(0.75)
Moderate	6	(0.21)
Severe	1	(0.04)
Intellectual Quotient		
Intellectual disability	1	(0.04)
Borderline	7	(0.25)
Normal	19	(0.67)
Superior	1	(0.03)

4. Discussion

This work focuses on exploring the psychogenesis of natural numbers in children, in order to understand how the child grasps numbers, and how this process is affected by variations in the development of a child, such as perinatal damage. We know that mathematical concepts are part of the daily life of children. In all cultures these mathematical concepts are necessary for children to understand the world around them and are the result of analysis and generalization from practical experience (Serrano, 2008).

Without mastering logical-mathematical notions, children are adversely affected not only in their school performance but also in everyday activities such as counting, exchange, asset value allocation and the purchase of items. Mathematical concepts acquire meaning for children through their use in everyday situations and in problem solving (Vergnaud, 1990; Laski & Yu, 2014). When children learn mathematical concepts they also learn their applications and show mastery of the mathematical concepts through their management of conventional symbols and operations and the proper application of their knowledge to practical problems. The handling of mathematical concepts involves understanding the reasons for carrying out some actions, achieving a goal through the expertise, knowing how to solve a problematic situation and how to apply operative schemes such as association or distribution during their assimilation of mathematical knowledge (Serrano, 2008).

The fact that children show that they know how to count properly does not mean they understand the implication of their actions. It shows only that children's memory skills have been strengthened by frequent repetition on the part of adults or themselves. These skills are coordinated plans of action or actions likely to be repeated, just as are sorting objects into groups, comparison, and assigning numeric labels to singular items or groups (Piaget, 1990).

Psychogenetic assessments such as the Monterrey test analyze the process that children follow from an early stage in their acquisition of mathematical concepts and detect what the child can do at the moment of the test, because problematic situations that may arise must be solved at the moment, and showing up the necessary actions and verbal expressions to justify their answers. This methodology was used to understand the sources of knowledge in children between 3 to 5 years old, allowing the analysis of their answers to specific tasks (Robinson, Haigh and Nurmsoo, 2008), and the confirmation of the non dissociation between cardinal and ordinal numbers established by Piaget (Serrano and Pons, 2008), arriving to the conclusion that Piaget's proposal is a macrogenetic response in the psychogenesis of the number in the child. At the same times it showed the necessity of deeper studies in the inter-stage microgenesis in order to understand the changes in children that go from a low to a high stage of complexity.

The behavioral changes that children undergo between the developmental stages of the number will be more understandable in longitudinal studies describing the processes taking place within and between individuals. From our study, as observed in Serrano (2008), we observe the macrogenetic approximation of the apprehension of the natural number in a specific population. Our data confirm that the acquisition of the natural number concept can be disrupted by early developmental disorders such as perinatal encephalopathy, since 43% of the children tested had arrived at lower levels than expected for their age. 57% of the children gave answers expected for their age, a result that coincides with the data from Isaacs et al. (2001) which showed that premature infants with low birth weight gave adequate calculation answers at school age. In our group we must consider that these differences can be attributed to the effect of the early stimulation they received. It should be necessary to establish if the application of suggested strategies for handling these children was applied as often in all of them to measure the impact of such intervention and establish its connection with the acquisition of mathematical concepts among other learning skills.

In the evaluated cases of children between 4 and 6 years old the expected responses were found, while in the cases of 7 and 8 year-olds responses were observed with severe and moderate delays. However, it is not possible to predict whether the children in the group of 4 year-olds will not later present difficulties as they get older, since they were giving only initial responses in the process of acquiring logical-mathematical notions. To test it, it would be necessary to have a longitudinal follow-up of cases from pre-school stages to school stages, where the children already had to operate with symbols, and to do a microgenetic analysis as suggested by Serrano (2008).

In the model of perinatal encephalopathy it was evident that the greater the number of indicator variables of nervous system dysfunction, such as the presence of perinatal damage, and the structuring of the sequel at the age of assessment, coupled with adverse social conditions such as low socioeconomic status, the more severe the difficulties to be encountered in the process of learning logical-mathematical notions.

It has been reported that children with attention deficiencies and hyperactivity had difficulties in mathematics and literacy (Capano, Minden, Chen, Schachar & Ickowicz, 2008). Probably these groups of children had neurological risk factors at an early stage that posed difficulties in their learning process.

We observed that children with IQ between borderline levels and intellectual disability gave delayed answers in classification and seriation skills. These data are consistent with the relationship found by Granados and Alcaraz (2006) in children with perinatal encephalopathy, where children with high ratios were able to express most concepts while children with low ratios showed less antithetical concepts.

Difficulties in the acquisition of logical-mathematical notions in seriation were observed in children from families with low socioeconomic status. In studies of Mexican pre-school and primary education, it has been observed that socioeconomic status, associated with variables of gender and educational level, is reflected in performance scores on language, concepts and mathematics, with the lowest scores for low socioeconomic levels (Anderson, 2000; Merino & Muñoz, 2007). At early school stages, considered critical to cognitive development, the contribution of environmental variables has been highlighted, since at lower socioeconomic levels there is a high rate of malnutrition that is detrimental to the development of children (Ghuman et al., 2006).

As we have shown in our study, it is important to understand the process of acquiring numeric concepts at early developmental stages, especially in populations at risk, in order to establish appropriate teaching strategies.

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