

MATHEMATICAL ACTIVITY IN EPILEPTIC CHILDREN: FROM DIAGNOSIS TO INTERVENTION

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ABSTRACT

This study offers a set of data concerning the exploration of interrelations between neuropsychological aspects and mathematical difficulties presented by epileptic children. These children can be characterized by important neuropsychological functional disturbances in attention, memory and visual perceptual skills, which are related to mathematical impairment related to the proper use of procedural algorithmic tools. Nevertheless, data discussed here show that epileptic children have benefited from the offer of cultural semiotic aids, which highlights the need of considering the neuropsychological foundations of mathematics activity in the context of culture.

Keywords: neuroscience, mathematical impairment, mathematical education, epilepsy.

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INTRODUÇÃO

According to the World Health Organization (WHO), epilepsy is “(...) a chronic non-communicable disorder characterized by recurrent episodes of paroxysmal brain dysfunction due to a sudden, disorderly, and excessive neuronal discharge, (...) being one of the most prevalent neurological disorders that can be effectively prevented and treated at an affordable cost (fifty million sufferers today, 85% from developing countries - 60% to 90% of them receiving no treatment at all)” (WHO, 2006 2009). Research data concerning Brazilian context points out the occurrence of about 11,9 to 21 cases/1000 citizens (Noronha et al., 2007). Epilepsy turns out to be, in Brazil and in other countries, a pervasive problem in the domain of public health, due not only to its rate of incidence in the general population, but also to its social and emotional impact (Quesada, 2007).

The research described here has focused in idiopathic generalized epilepsy with absences, a group of epileptic disorders that are believed to have no correlated anatomical brain abnormalities (idiopathic), being characterized by the presence of a pattern of epileptiform electric discharges in the brain as a whole (generalized), and leading to a state of temporary suspension of consciousness (absences) (Hommet et al., 2005).

Many previous studies have connected epilepsy in children to cognitive alterations and learning difficulties (Hughes, 2009; Costa, Maia Filho, Gomes & Mota, 2009; Mandelbaum, Burak & Bhise, 2009). Nevertheless, these studies show a remarkable diversity of analysis and conclusions, which illustrates how controversial is the topic concerning the relationship between epilepsy and cognitive alterations. For this reason, it is necessary to identify and to understand the very nature of handicaps present in the range of epileptic subtypes (Chaix et. al., 2005). Many studies have suggested a connection between epilepsy and difficulties related to *visual-spatial and visuoconstruction abilities*, this connection being specially evident in idiopathic generalized epilepsy with absences (Caplan et al., 2008; MacAllister & Schaffer, 2007; Seidenberg, Pulsipher & Hermann, 2007). Visual-spatial abilities refer to a neuropsychological function allowing the human individual to place objects in space, taking into account the position of an object in relation to the position of

others and of the individual himself. Visuoconstruction abilities, for their part, allow to assemble pieces in order to build up an unitary object, or to graphically reproduce objects, letters and written words (Zuccolo, Rzezak & Góis, 2010; Mello, 2008; Manning, 2005). Cognitive alteration in these neuropsychological complex functions lead to school difficulties as dysgraphia (difficulty to recall the correct way of writing words and numbers), and also difficulties in solving mathematical problems, specially those requiring mental imagery and ordering numbers in the context of arithmetic algorithms. Many important symptoms due to neuropsychological malfunctions have been associated to difficulties in mathematical activity, and most of these symptoms and difficulties are very frequently related to epilepsy (see Hommet & cols., 2005; Aldenkamp & cols., 2004). This is specially the case for difficulties related to *visual-spatial and visuoconstruction abilities* (e.g., being able to distinguish 6 and 9, \leq and \geq (lesser than /bigger than), “x”(multiplication indicator) and “+”(addition indicator)). These neuropsychological malfunctions are equally related to difficulties in properly ordering digits of compound numbers respecting the places of units, tens, hundreds and so on (Mazeau, 2005), and in dealing with symmetries and mental imagery to represent rotation of solids in space. Finally, idiopathic generalized epilepsy with absences is equally related to difficulties related to *attention*, which makes the management of the superordinated and hierarchic strategies necessary to the use of mathematical algorithms specially hard, leading to difficulties in arithmetic calculations.

Epilepsy and children’s neuropsychological impairments in general motivate the proposition of a complete program of intervention, in order to help these children to bypass, recover or compensate those functional troubles. Such a program demands a rigorous previous evaluation procedure, taking into account the dynamic character of neurodevelopment. A complete evaluation should then start from rigorous methods of psychological diagnosis, making an important distinction between functional, diseased and even superfunctional cognitive abilities. A rigorous evaluation procedure is a necessary requirement in order to build up a plan of rehabilitation of the impaired child not only in terms of his/her individual bodily health, but also in terms of the quality of his/her entire social life (Tranel, 2005). These theoretical and methodological guidelines are largely based on Alexandr Romanovich

Luria's (1902-1977) neuropsychological evaluation model, which encompasses bodily maturational processes together with social, cultural, historical processes, all these aspects being necessarily present in order to address complex superior psychological functions (Luria, 1992; Vygotsky, 1991).

EPILEPSY AND MATHEMATICAL ACTIVITY

We would like to conclude these preliminary remarks by stressing some central points that are in line with theoretical ideas above. The authors of the present paper adopt the theoretical assumption that mathematical knowledge emerges as an *embodied* functional product of a human brain *embedded in a socio-cultural context* (Lakoff & Núñez, 2000). Mathematical activity is seen here as a product of a *material mind* (Vygotski, 2003) subsumed in a specific social, cultural and historical context, depending interconnectedly of individual logical reasoning and cultural semiotic tools (Da Rocha Falcão, 2001; Da Rocha Falcão & Clot, 2011)). Finally, it is important to take into account the *perspective* of mathematical activity which is adopted as reference. Mathematical activity cannot be reduced to its algorithmic aspects, even though these aspects are important to school performance. Considering this approach of mathematical activity, research on mathematical impairment of epileptic children should go beyond traditional psychometric evaluations and neuropsychological correlational clinical studies. This is the theoretical and methodological effort of the present research.

METHOD

As pointed out above, this research offers data about mathematical impairment among epileptic children, trying to show *who* these children are and *what* they can and cannot do in terms of mathematical performance. Contributions from neuropsychology and psychology of mathematics education were combined in a five-points exploratory procedure, based on the neuropsychological evaluation approach proposed by A.R. Luria. This procedure encompasses the qualitative analysis of

investigated symptoms, taking into account both primary and secondary alterations. Primary alterations are directly connected to neurophysiological level, while secondary ones refer to the organization of superior mental functions (Glozman, 2007; Luria, 1981; Christensen, 1974). This analytical model considers each task of evaluation in terms of both a comprehensive theory of cognitive functioning and a conceptual nervous system (Haase et. Al, 2008). It is an idiographic diverse approach when referred to nomothetic-nomologic perspective in which individual performance is compared to a general average populational reference. Clinical biographic individual data are combined to data issued from neuropsychological tests, as described below.

The present study had two stages:

Stage A: A.1.) Survey study in the neuro-pediatric ambulatorial service of a children's hospital in Recife (Brazil), aimed to form a group of four epileptic children with idiopathic generalized epilepsy/childhood absence epilepsy (CAE)-cf. DSM-4), age of 9 (girl, private school), 10 (girl, private school) and 11 years (two children, a boy and a girl, both from public school), with the same pattern of drug prescription (valproic acid). A.2.) Formation of four reference groups of non-epileptic children (one group of five children for each epileptic child, with similar profile for age, sex, type of school (public or private) and socio-economic level).

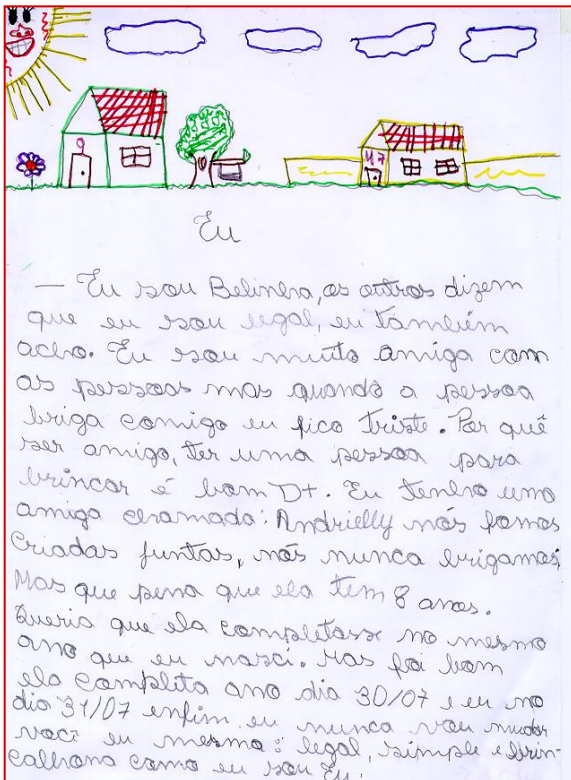
Stage B: B.1.) Diagnosis I: This stage consisted of an anamnesis interview with the parents of participant children, followed by the application of the Story-Drawing Technique (Trinca, 2002). This technique consisted of giving a certain theme to participant-children and to ask them to create a story illustrated by a drawing. Four theme were proposed to the children: Me, Mathematics, Me and Mathematics and how do I feel havin epilepsy. Transcripts of drawings and stories are reproduced below:

1. Me

"My name is _____. People say that I am cool, and I agree. I'm very friendly with people in general, but when someone argues with me I get sad. That's because being a friend of someone and having someone to play with is very good.

(...)

I'll never change, I'll always be like I am: cool, easy and gay.”



C. 11 years

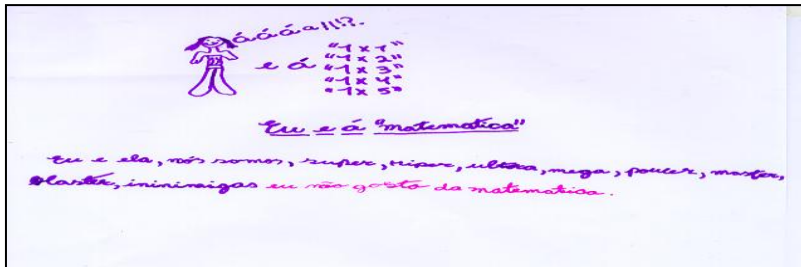
Mathematics

“Mathematics is easy for me, but for some people it is difficult. (...) Mathematics is a subject that is present every where: Portuguese, sciences, etc. We need maths when we go to the bank, bakers, etc. Mathematics is cool.”

M. 10 years

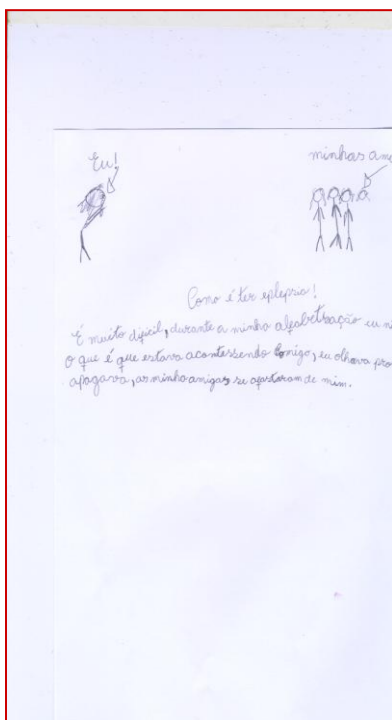
Me and mathematics

“Mathematics and I we are super, hiper, ultra, mega, power, master, blaster enemies, I don't like mathematics!”



A. 11 years

Eu e a matemática



A. 11 years

“ It is very difficult. During the time I was learning to read I could not understand what was happening to me, I used to look at the sky and fall down, my friends began to give me up.”

B.2.Diagnosis II - Application of a neuropsychological set of evaluation tests for the epileptic group and for the four reference (non-epileptic) groups in order to

establish a profile of children, adopting a set of psychometric tools largely employed and well-ranked in neuropsychological research (see Lezak, 2004). Tests and respective psychological aspects considered are summarized in table 2 below:

Tests	Psychological aspects
▪ Wechsler Intelligence Scale for Children-III (WISC-III)	Intelligence (total IQ, verbal IQ, executive/ manipulative IQ).
▪ Rey Auditory-Verbal Learning Test (RAVLT)	Memory
▪ Test de la Figure Complexe de Rey-Osterrieth	Visual and spatial abilities (organization and planning)
▪ Trail Making Test (parts A and B) ▪ Stroop Test ▪ Teste AC (Cabraia, 2003)	Attention and executive functions
▪ Teste de Desempenho Escolar (Stein, 1994)	General school performance

Table 1: Neuropsychological set of tests with respective psychological focus.

B.3.) Diagnosis III: Evaluation of mathematical school performance for epileptic children and reference groups using Evaluation Instrument DII. The main goal of using this instrument was to establish a trustworthy school mathematics profile of all children. This instrument consisted of a modified version of a set of 20 questions conceived for evaluating mathematical school performance at the end of the first level of fundamental teaching for Brazilian children (1st to 4th primary school level, 6-8 to 9-11 years of age). It was built in order to cover five sets of mathematical school domains, as described and exemplified below:

- Algorithmic abilities and comprehension of numerical decimal system: “Write a number formed by 2 hundreds, 7 tens and 5 units”, “Do the following operation: $847 + 5 + 98$ ”
- Additive structures: “A friend and I like stickers very much. Yesterday my friend came to my home to visit me, and I gave him four stickers and he gave me six; at the end I had fifteen stickers. How many stickers did I have before my friend’s visit?”
- Multiplicative structures: “We are going to have a birthday party, and we want to give two balloons to each invited child. How many children will we be able to invite if we have eighteen balloons?”

- Mental imagery of geometrical properties of solids: look at the object below and choose among the options (A to D) which would be its best representation when it is seen from above”.

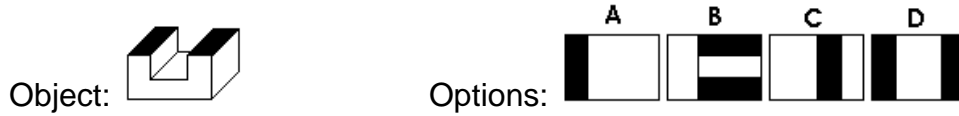


Figure 1: Mental imagery task

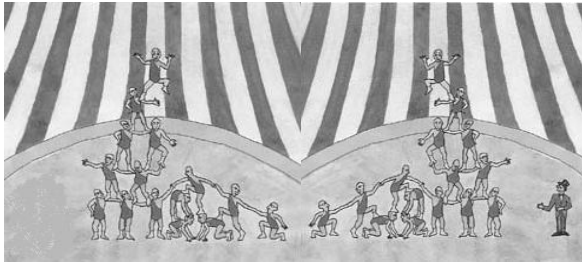
- Comprehension of cultural measures (e.g., time): “I wake up at 6:30 a.m., take a shower and go to school; my classes begin at 7 o’clock a.m.. I leave school at 12:30 p.m. and come back home to have lunch. In the afternoon I do my homework, and I go to bed at 8 o’clock p.m. Complete the clocks below, drawing the pointers of hours and minutes accordingly to the moments of the day mentioned:”



Figure 2: Comprehension of cultural measures task

Stage C: Diagnosis IV: Evaluation of mathematical performance of epileptic and four non-epileptic children, (each non-epileptic children taken at random from each of the reference groups), using another evaluation instrument (Evaluation Instrument DIII), conceived in order to highlight situations where procedural-algorithmic and conceptual aspects of mathematical activity could be distinguished. This stage, therefore, was crucial for the purposes of the present study, since we presumed that mathematical impairment of epileptic children had an important component represented by difficulties in the spatial representational execution of algorithms. In other words, mathematical impairment of epileptic children would be *procedural* rather than *conceptual*. Evaluation Instrument 2 consisted of a set of questions aimed to explore aspects connected to analytical visual spatial reasoning, covering the following aspects:

- Ability to identify, analyze and complete mirror-like complex images. This ability is considered here as a psychological precursor for the geometrical concept of symmetry.



“Is there anything lacking in the big picture? Where must the small picture of the man be placed in the bigger picture?”

[Illustration adapted from the game “Mirror”, Freudenthal Institute, 2005].



Figure 3: Identify, analyze and complete mirror-like complex images.

Ability to manage visual imagery of solids. In this task subjects were firstly asked to establish the quantity of elements composing each of the four sets based only in visual imagery and visual spatial reasoning (item 1 below). Afterwards, the same subjects were asked to build similar sets of elements using brick layers (Lego™ bricks) (item 2). 1. “How many blocks are there in each set?” 2. “Build similar sets using Lego bricks”. [Illustrations from the game “Build Free”, Freudenthal Institute, 2005]

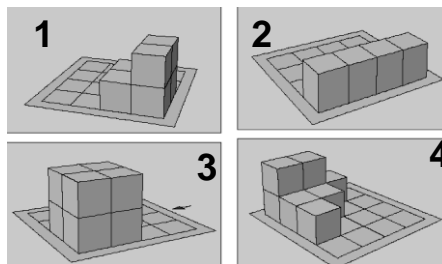
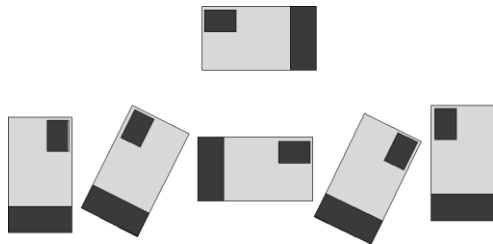


Figure 4: visual image of solids

- Spatial orientation 1: ability to manage imagery of solids rotation and translation in space:



“Look at the figure at the top; you have five other figures below it, in different positions.

To which of the figures at the bottom does the figure at the top correspond when it is rotated”?

[Reproduced from the Space Thinking Test (flags), Lezak, 2004].

Figure 5: Spatial orientation

- Spatial orientation 2: ability to adequately represent and operate algorithms of addition with the aid of colors to distinguish units, tens and hundreds:

“Operate the following addition: **847 + 5 + 98**”

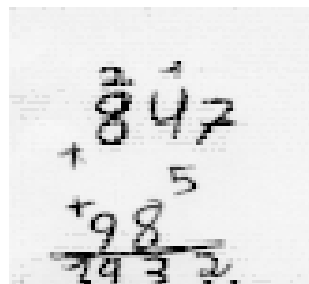
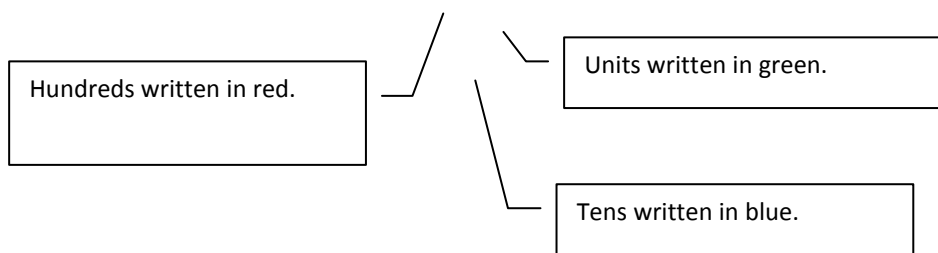


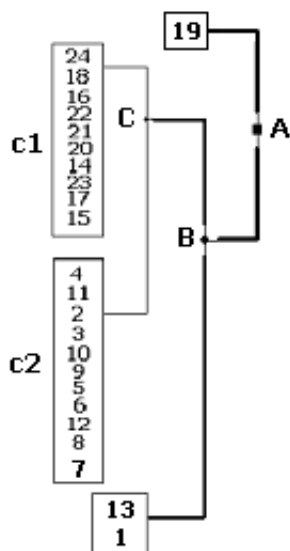
Figure 6: Reproduction of a child’s effort to represent and operate the addition algorithm.

Epileptic children with particular difficulty in organizing properly the algorithmic procedure to operate addition (see figure 1 on the left) were expected to get around this difficulty with the representational aid of using colors associated to the place-value system of numeric decimal system.

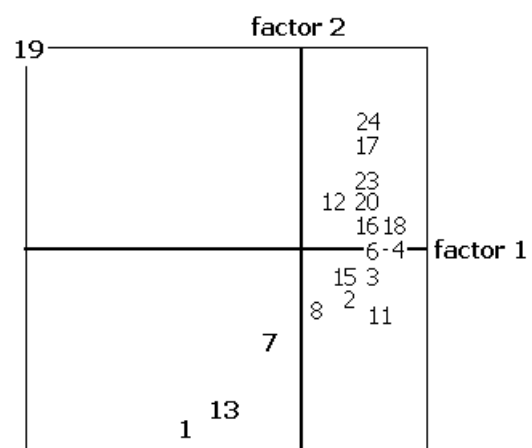
RESULTS

Data from stage B mentioned above were categorized and encoded for treatment by descriptive multidimensional analysis, combining hierarchical cluster

analysis (figure 2) and factor analysis (figure 3). Both analyses show a clear separation of epileptic children (subjects 13, 1, 7 and 19) from the rest of the group. Hierarchical cluster analysis (figure 2) produced a first partition (A) opposing the epileptic child 19 to the rest of the group; the second partition (B) opposes epileptic children 13 and 1 to groups c1 and c2. The first (and more important) factor from factor analysis opposes epileptic children (1, 13, 7 and 19, having projections over the left side of the factor) to the others (right side of the factor); the second factor opposes subjects 1, 13, 7 (bottom to subject 19 (top), which will help us to explain the isolation of subject 19. Data from a complementary factor analysis based on modalities of variables from stage B, crossed with clinical analysis of data from stage C allow us to go further in the interpretation of partitions and separations in the factorial plan: the most important contributions for the left side of the first factor (the “epileptic” side) were, in decreasing order of importance concerning their respective contributions: 1. Difficulties in operating algorithms for addition (being able to put hundreds under hundreds, tens under tens and units under units (see fragment of protocol reproduced in figure 1 above); on the other hand, it is important to mention that these epileptic children have benefited from operating with numbers displaying hundreds, tens and units written in different colors, according to data from Stage C; with this kind of representational-chromatic aid, epileptic children could organize (and operate) properly the algorithm of addition, as expected by us.



Hierarchical cluster representation 1



Factorial plan (factor analysis from nominal data), factors 1 by 2.

Even more important: these children could properly justify the role and interest of colors use, pointing out that different colors were representing different place-values (hundreds, tens and units). This clinical aspect allows us to discard the interpretation of epileptic children's improvement only as a result of strictly and simple perceptual combinations: blues under blues, greens under greens and so on. In fact, the semiotic aid represented by color-use allowed these children to show a mathematical conceptual knowledge that they could not mobilize under usual conditions. 2. Difficulties in distinguishing numbers like 6 and 9. 3. Normal memory-span at RAVL-Test, with difficulties in progressing along repeated essays. 4. Percentiles 25 (under the reference mean for the age group) in Rey-Osterrieth Complex Figure for copy and also for memory reproduction. 5. Low performance (inferior to the expected mean for the age group) in concentrated-attention tests (AC Test). The only relevant contribution to the right-side of the factor 1 (the "non-epileptic" side) was a normal (mean) performance in concentrated-attention tasks (AC Test). This difference in contributions between these two sides is normal in this case, since the non-epileptic group is more heterogeneous and numerous than the epileptic group. Factor 1, then, operates a partition between epileptic and non-epileptic children in terms of visual spatial organization (data from Rey-Osterrieth Complex Figure for copy and memory), and processes of attention. These results can be completed by clear differences observed in two of the tasks from Stage C: i) epileptic children consistently failed in the first item of the tasks aimed to evaluate ability to manage visual imagery of solids (to say the number of blocks in the sets), while all non-epileptic children have produced a right answer for this task. Nevertheless, it is important to mention that all epileptic children have corrected themselves when they were answering part 2 of the task (to build similar pieces as showed in the illustration, using Lego brick layers); ii) epileptic children have once again consistently failed in the task Spatial orientation 1, related to managing imagery of solids rotation and translation in space (no right answers at all), while non-epileptic children have consistently produced right answers for this task.

The present analysis must finally take into account information given by the second factor in importance, factor 2. Only epileptic children have relevant contributions (i.e., equal or superior to the mean of contributions) to this factor, which

explains the opposition of epileptic subjects 19 (top) and 1, 13 and 7 (bottom). Shortly, subject 19 presents a deeper degree of impairment of cognitive processes related to verbal memory (difficulties in progressing across repeated essays in Rey Auditory-Verbal Learning Test) and visual perceptual skills (as shown by the mixing-up of numbers like 6 and 9).

FINAL REMARKS

Epileptic children have clearly shown difficulties in mathematical activity, in processes related to attention, memory and visual perceptual skills, the latter being the most salient and unifying aspect of the group. Such data are in line with other research initiatives (Schubert, 2005). Visual perception refers to the process of organization and interpretation of visual information, covering abilities such as visual discrimination, visual memory and visual spatial organization. As shown by data presented here, these abilities are directly related to *procedural* aspects of mathematical activity, like digit discrimination, spatial organization of written numbers and imagery and resolution of geometrical problems. Nevertheless, it is important to highlight that this peculiar kind of impairment of mathematical activity shown by epileptic children does not necessarily imply in conceptual mathematical insufficiency, since even the most compromised epileptic subject (19) has benefited from the offer of representational-chromatic aid (hundreds, tens and units represented by different colors); all epileptic children could explain what the different colors were representing (red for hundreds, blue for tens and green for units), showing that they were aware of the logic of the place-value in decimal system. On the other hand, data from Evaluation Instrument DII have not allowed the establishment of significant mathematical conceptual gap between epileptic and non-epileptic children. The use of the chromatic aid mentioned above, and also the possibility of manipulating brick layers to build equivalent sets of solids represented bi-dimensionally in a written illustration, allowed the bypass of a specific difficulty related to visual spatial organization. These clinical data call attention to two important aspects: first, mathematical activity covers both procedural and conceptual aspects; it is particularly important to keep this in mind and look attentively to the

difficulties shown by mathematics learners. Accordingly, diagnosis of mathematical impairment should go beyond isolated scores of psychometric and mathematical evaluation tools. Second, as very well expressed by Vygotsky, semiotic tools from culture can change negative aspects of deficiency into positive aspects of compensation (Vygotsky, 1993). Keeping this in mind is important to understand and help not only difficulties of epileptic children, but also of children in general.

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