Babeş-Bolyai University, Cluj-Napoca

Faculty of Psychology and Sciences of Education

PhD Thesis

Evaluation and stimulation of cognitive processes at elementary students with mathematics learning disabilities

-SUMMARY-

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OWN EXPERIMENTAL STUDIES

Mathematics is part of our daily life: we calculate the time required to perform certain activities, the cost of our shopping and the change we should receive, we approximate the distance from home to school or to other destination and, yet, there are many people who not only that state they do not like mathematics, but they also feel uncomfortable performing mathematical tasks. Because of our lifestyle, which imposes quite often the need of using technical means, there is the demand that mathematics plays an important role in the educational framework (3-4 hours per week for each class of the primary school). By this document, the school organizes student's time spent in a particular stage of schooling by establishing a minimum and maximum of hours allocated during a week to each curriculum area, implicitly for each subject so that the student will acquire the knowledge, skills and the abilities necessary for their vocational development and career training, i.e. for adapting to the current needs of the society, needs that reflect in the working environment (Truță-Surdu, 2010b). Students experience the density and intensity of mathematical activities since the first grade. For many of them this activity is difficult because of the multiple concepts that they have to acquire and because mathematics is abstract and symbolic. Some students have mathematics learning disabilities even since the first grade, difficulties that get more severe during the school years thus leading to learning failure and mathematical anxiety, a feeling that, in turn, negatively affects the mathematical performance.

In Cluj county, the data from the National Institute of Statistics show an alarming increase in the number of students that repeat a school year in the middle compared to the primary school. This fact explains the increase in drop out rates among the middle and high school students, where the number of the students that repeat a school year increased from 215 in 2008/2009, to 883 in 2010/2011.

Based on the data presented above concerning the drop out rate, which is the main cause of school failure, a situation confirmed by the growing number of repeat students, I wanted to bring a contribution in changing this situation by improving the educational performance of the students who have mathematics learning disabilities while most of the children that we referred to above have difficulties related to this discipline. In this work I intended to select the most adequate tools for a dynamic, complex and complete assessment of the primary school children with mathematics learning disabilities in order to identify the cognitive deficits, to develop and implement a program of cognitive intervention meant to reduce these deficits, so that from the overall program the teachers can select individualized intervention plans for improving both cognitive functioning and the mathematical performance. The intervention program is supplemented by strategies proposed to reduce the mathematical and/or testing anxiety as well as by the metacognitive strategies that will also improve the performance of primary school students who have mathematics learning disabilities.

The first part of the research answers questions like: "How is the number represented by our cognitive systems? What are the factors that underlie cognitive development of the mathematical ability? What cognitive deficits are involved in the development of the mathematics learning disabilities? What are the types of mathematics learning disabilities and the empirical models that could be identified?” **The research** consists of a) initial assessment of students from the control group and from the experimental group; in this stage, the deficits involved in the mathematics learning disabilities are identified; b) assessment of the test anxiety and of the mathematical anxiety - these representing factors that may affect the mathematical performance, and proposal of strategies to reduce these factors, in order to eliminate uncontrolled variables; c) development and implementation of the psycho-pedagogical program for reducing the deficits involved in the mathematics learning disabilities, and d) analysis and interpretation of the results.

The early intervention based on a multidisciplinary approach, accomplished through personalized intervention programs, leads to the optimization of scholar activities (Preda, 2010) at children with learning disabilities, thus contributing to the prevention of school failure. Within *the Psychological Intervention Program* elaborated in this research, *for the stimulation of poor cognitive processes involved in the mathematics learning disabilities of the students from primary school*, *I proposed specific strategies for reducing cognitive deficits identified in the initial assessment, but also strategies for reducing mathematical anxiety*, *strategies for developing metacognition and alternative methods of teaching and learning mathematics*, *these also contributing to the improvement of the subjects’ mathematical performance.*

The uniqueness, novelty and importance of this program consists, on the one hand, of integrating in a practical way the theories and models developed by researchers in psychology, neurosciences and education, and, on the other hand, of results that confirm the effectiveness of the proposed intervention. It is a complete program (since it includes activities, strategies, methods of intervention for all cognitive deficits involved in the mathematics learning disabilities and for associated deficits such as mathematical anxiety, low self-esteem), complex (since the theories, models and research findings underlying this program are from the field of psychology, neuroscience and education, and the goal is the cognitive modifiability and transformation of the student from "novice" to "expert") and multifunctional (it could be used both for dynamic assessment and for intervention).

The theories and the explanatory models of the mathematics learning disabilities, as well as *the models of the number processing, of the calculation and of the problem solving* represent **the theoretical basis of the research.**

The neuropsychological explanatory theories (Luria, 1966a, 1966b, 1969a, 1969b, 1970, 1973, 1974, 1976, 1980) consider that the origin of these mathematics learning disabilities is brain damage or dysfunction in various cortical areas, the occipito-parietal region being responsible for simultaneous processing and the left fronto-temporal region being responsible for successive processes. The children with deficits in occipito-parietal areas have difficulties in making spatial relations, thus implicitly affecting the arithmetic calculation by space errors of the mental number line. If the deficits are in the fronto-parietal area, children have difficulties in integrating the stimuli into a specific serial order in the process of solving problems. In their enthusiasm to emphasize the global nature of individual's activities, some contemporary researchers have refused to accept the static features of personality (Magnuson and Torestad, 1993). Morris and Walter (1991) have shown that neuropsychological theories have also weaknesses, in the way that a cognitive modifiability could occur, in the mathematics learning disabilities, by exposing individuals to different learning situations.

The explanatory theories of education (Engelmann and Carnine, 1975) refer to external factors that can lead to mathematics learning disabilities, e.g. educational environment and school requirements in mathematics. These theories have positively resulted in approaching some operant learning techniques of mathematics, but they also have weaknesses in that the operant conditioning is considered as the single mechanism and in that the complex holistic personality of the student is ignored.

The explanatory cognitive theories (Reid and Stone, 1991) assess the child strictly depending on the processes evolving in the school environment, during school learning.

The constructivist theories (Grobecker, 1999) consider that learning should be active and related to real life situations, emphasizing the connections between the important concepts of that subject.

The behavioral theories (Mercer, 1997; Grobecker, 1999) consider modeling as an important element of explicit or direct training techniques (Steele, 2005). Although these approaches have been criticized when used in general education, they have shown promising results in research, particularly for children with mathematics learning disabilities (Mercer, 1997). The decomposition of tasks into small segments, easily to manage in teaching (Grobecker, 1999) is a very useful approach to the students with mathematics learning disabilities who become frustrated when the original material is too complex and they are often discouraged, giving up solving the given tasks (Lerner, 2003).

The metacognitive theories (Desoete et al., 2001) argue that metacognition is involved in solving mathematical problems and prevent the so-called "blind calculation" or the superficial approach, allowing the students to use the acquired knowledge in a flexible and strategic way (Desoete et al., 2001).

The models of number processing and calculation at children and adults include development models, cognitive models and neurocognitive models. The most significant *development models* are those proposed by Carey (2009), assuming that once the child has developed an accurate natural representation of numbers, he will relate those representations with the born approximate, numeric system and the model of Marie-Pascale Noël and Laurence Rousselle (2011) who claim that the first deficit that occurs in the developmental dyscalculia regards the construction of an accurate representation of numerical value due to learning of symbolic numbers.

The cognitive models that this research was based on, are:

- *the conceptual scheme for approaching the mathematics learning disabilities,* a study conducted by Geary and Hoard (2005; Geary, 2005) considering that all conceptual and procedural skills are supported by an array of the cognitive systems,
- *the model of associations' distribution* (Siegler, 1988; Lemaire and Siegler, 1995) describing how to acquire the arithmetic results and explains *the effect of size and errors of operands,*
- *the model of the interference* (Campbell, 1995) assuming that the so-called "nodes" or "connection points" of the problem are activated depending on numbers' activation in that problem,
- *the connectionist model of memory reproduction of the multiplication table* proposed by Verguts and Fias (2005) contains the semantic domain as central component, while the representation of multiplication problems is internally organized according to the size of operands
- *the COMP model of addition* developed by Butterworth and collaborators (2001), based on the hypothesis that the terms of the addition are organized in children's memory as *the maximum + the minimum term* of sum/amount without any other commutative representation.

The neurocognitive models used in this research are:

- *the model of cognitive mechanisms involved in processing numbers and calculations,* model proposed by McCloskey and colleagues (1985), showing that a central semantic system is accessed in all calculation processes, independently of the input format,

- *the triple code model* proposed by Dehaene and Cohen (1995, 1997), assuming the involvement of a *visual Arabic-code*, of an *auditory-verbal code* and of an *analogous size representation code* in order to perform a certain processing task of the number and calculation (Domahs and Delazer, 2005),
- *the hypothesis of the favorite entry code (input)* proposed by Noël and Seron (1993), claiming that some subjects prefer a verbal or visual input,
- *the model of Von Aster and Shalev* (2007) *on the formation and development of the concept of number and of the developmental dyscalculia*, claiming: a) that the results of the current genetic, neurobiological and epidemiological studies concluding that the neuropsychological basis of the developmental dyscalculia are genetically determined disorders in the concept called "number sense", but, at the same time, b) that the affected visual-spatial processing skills, the anxiety, a non-demanding environment and a poor teaching can contribute to the development of these mathematics learning disabilities.

The models obtained in the view of development or experimental approach aimed to investigate the form of acquiring mathematical skills, particularly skills of memory storage and reproduction of arithmetic results (facts) from the memory. The neuropsychological models of calculation focus mainly on the existing relationships between arithmetic operations and the format that results are represented in (as verbal sequences or abstract representations), this fact being yet not clarified by researchers (Domahs and Delazer, 2005).

Based on theories and models of identifying and assessing the mathematics learning disabilities, we could deduct the errors in calculation or problem solving, or the deficits that have led to their production, respectively, and we can achieve individualized intervention programs of cognitive stimulation to reduce the deficits involved in the development of this disorder (Truță-Surdu, 2010a; Truță-Surdu, 2011a).

The multiple theories and models of mathematics learning disabilities, their diverse typologies proof the complexity of mathematics (Geary et al., 1991a; Geary et al., 1991b), which leads to the difficulty that experts face in outlining a single classification of this disorder and of the deficits associated to each type. These considerations determined me to establish **the goal of my research** as identification of all cognitive deficits involved in the mathematics learning disabilities, based on the current research information on "Definition and classification of the mathematics " (Chapter I of research) and "Etiology of the mathematics learning disabilities" (Chapter II), in order to provide an overview, global, complex and complete image of these disorders using "Methods and assessment tools for children with mathematics learning disabilities" (Chapter III of research). *The cognitive program for stimulating the poor cognitive processes involved in mathematics learning disabilities* is a necessity required by the complexity of the disorder and by the fact that, so far, there is not such a complete and complex intervention that may decrease all the difficulties identified in the concept of number and numeracy (Truță-Surdu, 2011b), in calculation and problem solving. Out of the overall program, individualized plans according to cognitive characteristics of the subjects could be developed.

In my research I used the following **methods**: *the observation* -that helped me identify the of third grade students with mathematics learning disabilities, by attending mathematics classes and by filling in the observation sheet, the *conversation* and *the biographical method (history)* - that helped me collect data to identify the subjects with mathematics learning disabilities on the basis of criteria in the Manual of Diagnosis and Statistics of Mental Disorders DSM IV, (Romilă, 2003), on the model based on discrepancy used by Bateman (1965), Mather (1991), Hessler (1993) and McGrew (1994) and on the response to intervention model used by Fuchs (2005). *The psycho-pedagogical experiment* consisted of: a) the establishment of the research methodology by elaborating the general objective and the specific objectives, the general hypothesis and assumptions, the control group and the experimental group of the work procedure, b) initial evaluation of the subjects through standardized tests, c) the progress of the experiment, in this case, the application of the general program in order to reduce the deficits of the mental process, deficits that lead to mathematics learning disabilities and d) organizing, statistical processing of data and drawing the conclusions.

The research includes three studies which outline:

1. The dynamic evaluation of the cognitive phenotype for primary school students with mathematics learning disabilities, aiming as main objective to identify the deficits that occur in the attention/executive functions, memory and learning, language, and visual-spatial sensorimotor fields.

2. Evaluation of mathematical anxiety, of test anxiety and identification of the strategies used for the reduction of these factors at the primary school students.

3. a) Development of a cognitive, complex and comprehensive plan of intervention, intended to reduce the deficits identified in the functioning of the cognitive processes involved in the mathematics learning disabilities at primary school children for an early intervention and prevention of school failure.

b) Implementation of the personalized intervention program to stimulate the poor cognitive processes involved in mathematics learning disabilities in primary school children for an early intervention and prevention of school failure and assessment of the progress made in their performance based on a quantitative and qualitative analysis of the results obtained by the subjects in the experimental group.

The main objective of this research is to assess and stimulate the cognitive processes at the students from primary school who have mathematics learning disabilities by developing a cognitive, general educational program in order to reduce the identified cognitive deficits that are involved in the development of this disorder.

The specific objectives are:

1. Assessment of the cognitive processes in the fields of attention/executive functions, language, sensorimotor, visual-spatial and memory/learning for students with mathematics learning disabilities in primary school, and identifying the cognitive deficits involved in this disorder.

2. Evaluation of mathematical anxiety of the students from primary school and proposing strategies to reduce this anxiety, and improve the performance at mathematics.

3. Development of a general educational cognitive program for stimulating the poor cognitive processes to reduce the difficulties in acquiring number, the difficulties in calculation and in problem solving.

4. Implementation of a general educational cognitive program and analysis of its effectiveness in reducing the difficulties in acquiring number, the difficulties in calculation and problem-solving, this program includes personalized intervention plans.

The general hypothesis assumes that the delay in developing executive functions - implicitly of the working memory, attention, phonological processing and understanding of the instructions, the visual-spatial processing - correlates with poor performance in mathematics, possibly leading to mathematics learning disabilities.

The specific hypotheses assumed in this research are:

1. The third grade students with mathematics learning disabilities acquire poorer performance at tests that assessed mathematical skills (the neurocognitive test for learning the number and calculation entitled *the Numerical* and *the Reasoning Test* proposed by André Rey) than third grade students without learning disabilities and their results at tests from *NEPSY Battery* - that assess phonological processing and understanding of instructions, visual-spatial processing, attention and executive functions, including working memory, are generally below the expected level.
2. Mathematics anxiety and test anxiety correlates inverse proportionally with the poor math performance of the students from primary school, requiring the use of specific strategies for reducing the mathematical anxiety.
3. The educational cognitive program reduces the deficits of the executive functions, including working memory, attention deficits, phonological processing and understanding the instructions, visual-spatial processing deficits, all being involved in the mathematics learning disabilities of third grade students.

4. Stimulation of the poor cognitive processes in fields like *attention/executive functions, language, senzoriomotor, visual-spatial and memory/learning* through the *Educational cognitive program* improves the performance at tests on mathematics learning disabilities (the neurocognitive test for learning Number and calculation entitled *the Numerical* and the *Reasoning Test* proposed by André Rey) of third grade students with mathematics learning disabilities, thus contributing to the achievement of the objectives in the overall curriculum.

The psychological and neuropsychological instruments used in this research are: *Raven's Coloured Progressive Matrices* (Raven, 1962; Kulcsar, 1975, Raven et al., 2005; Dobrean et al., 2006), *The Numerical* – a neurocognitive test for learning the number and calculation (Gaillard and Willadino-Braga, 2001), *the Reasoning Verbal and Numerical Test - André Rey* (Rey, 1967), *the Tests for basic evaluation from NEPSY battery* (Korkman et al., 2007), *Additional tests of selective evaluation for calculation disorders from NEPSY battery* (Korkman et al., 2007), *the Test for mathematical anxiety* (Freedman, 2006a), and *Evaluation of test anxiety* (Strawderman, 2006, test based on the research of Zbornik, 2001).

Research design:

The psycho-pedagogical experiment consists of developing and implementing an intervention program to reduce the cognitive deficits involved in the mathematics learning disabilities in primary school, thus contributing to the achievement of the objectives targeted in the curriculum.

The experimental design proposed is a basic experimental design with a single factor, therefore I will have only this single independent variable to handle within the experiment.

The independent variable is the customized intervention program developed on a quantitative and qualitative analysis of the statistical data and on the observations obtained from the initial assessment of the students from the control group and from the experimental group, observations on the attention and executive functions, including working memory, phonological processing and understanding the instructions, and the visual-spatial processing involved in the difficulties of calculation and problem solving, analysis that represents the objective of the first study. *The pedagogical intervention program* implies developing and solving tasks based on specific methods and strategies in order to stimulate the mental processes involved in the mathematics learning disabilities.

The dependent variable refers to the results obtained after the psycho-pedagogical intervention, which consists of developing mental processes involved in the mathematics learning disabilities at the subjects from the experimental group and implicit, of the mathematical abilities/skills by acquiring declarative and procedural knowledge, by developing adequate learning strategies, and by developing effective strategies of solving problems.

Along with independent and dependent variables, other **uncontrolled variables** could also operate, and may affect, in one way or another, the results of the experiment, i.e. the individual characteristics (social and family environment non-demanding for the development of language and mathematical skills/abilities, for learning in general, the generalized anxiety, the test anxiety and/or mathematical anxiety, the emotional problems caused by family problems including divorce, the abandonment of a parent or parents who went to work in another country, the educational deficiencies at children with permissive parents, ADHD), peculiarities of age, the personality of the teacher that is carrying out the experiment. The influence of these factors is neutralized a) by various procedures such as proposing and implementing effective strategies to reduce test anxiety and/or mathematical anxiety, to decrease the general anxiety and emotional problems by creating a calm atmosphere that ensures the safe, adequate climate to the individual and age particularities of the subjects, and b) by proposing and implementing metacognitive strategies that develop self-esteem and contribute to an increase in mathematical performance.

The selection of the subjects for the control group and for the experimental group was not achieved by simple randomization ("to draw lots"), but I planned to have pair samples, so that each student in the sample has a correspondent in the other sample with the same average age and gender. The intention was to neutralize different age or individual peculiarities by selecting the students of the same mean age and the same number of girls and boys in each sample. Among the third grade students from two schools in Cluj-Napoca, 29 subjects with mathematics learning disabilities were selected (experimental group) based on *the criteria of DSM IV* (Romilă, 2003), *on the Model of discrepancy* (Bateman, 1965; Mather (1991), Hessler (1993) and McGrew (1994) and *on the Response to intervention model* used by Fuchs (2005), 14 of which were girls and 15 boys. Then, 29 subjects of almost the same age, without mathematics learning disabilities (group control) were selected, and the composition of the sample was again 14 girls and 15 boys. According to the anamnesis record, these students have not manifested school failure or such a risk during their school years.

We conducted an **initial assessment (pretest)** of the students from the two samples to measure the general intelligence - by applying *the Raven's Coloured Progressive Matrices*, and the math performance skills – by applying *the Reasoning Test conducted by André Rey* and *The Numerical neurocognitive test* in which the items were constructed so as to meet the criteria of the general curriculum. The subjects from the experimental sample were also assessed with *the Tests for basic and extended evaluation of calculation difficulties from NEPSY battery* to assess the mental processes involved in the mathematics learning disabilities and to identify the gaps that have to be improved.

After statistical processing and interpreting the quantitative and qualitative results of the two groups, **I verified if the first specific hypothesis is confirmed,** i.e. if the third grade students with mathematics learning disabilities acquire poorer performance at the tests assessing mathematical skills (The specific neurocognitive test entitled *the Numerical* for learning the number and calculation and *the Reasoning Test* proposed by André Rey) compared to that of the ones in the third grade without mathematics learning disabilities, and their results at *the tests from NEPSY battery* (that assess the phonological processing and understanding of instructions, the visual-spatial processing and fields like executive functions, including working memory, attention) are generally below the expected level.

In order to check if **the second specific hypothesis** is confirmed, i.e. if the mathematical and test anxiety are inversely correlated to the mathematical performance of the students from primary school, thus requiring the use of specific strategies for reducing mathematical anxiety, I applied *the Mathematical anxiety test* (Freedman, 2006) and *the Evaluation of test anxiety* (Strawderman, 2006) - which is based on the research of Zbornik (2001) initially on 30 students from Class II to IV, from a school located in Cluj-Napoca, chosen at random, to notice if the students from primary school manifest anxiety. After data analysis and interpretation I proposed several adequate strategies elaborated by Lupu (2001) and Freedman (2006b) to reduce the mathematical anxiety.

The third specific hypothesis assumes that *the educational cognitive program* reduces the deficits of the executive functions, including working memory, attention deficits, phonological processing and understanding the instructions, visual-spatial processing deficits that are involved in the mathematics learning disabilities of third grade students. To verify this specific hypothesis **I applied the psycho-pedagogical intervention program** on a sample of 29 students from the experimental group. From the general cognitive program I develop *educational personalized programs* of cognitive stimulation focused on three major axes: 1) the concept of number, 2) arithmetic operations (addition, subtraction, multiplication and division) and 3) solving problems.

The post-intervention (post-test) **evaluation** of the students from the experimental lot consisted of applying *The Reasoning Test performed by André Rey* and *the neurocognitive test entitled The Numerical* - to assess the performance of the mathematical skills, and *the tests for evaluating the basic and extended evaluation of calculation disorders through the NEPSY battery* + in order to assess the level of development of the targeted mental processes to be improved by the specific program developed and implemented in the experimental stage and to see if there is a reduction of the mathematics learning disabilities at students from the experimental group after the intervention. The significant differences between the results obtained for the subjects in the experimental group achieved at the initial and the final assessment, i.e. the increased performance at the post-test assessment proved that **the fourth specific hypothesis** was confirmed, namely the stimulation of the specific deficient cognitive processes from fields such as attention/executive functions, language, senzoriomotor, visual-spatial and memory/learning using *the Educational cognitive program* improves the performance at the tests on mathematics learning disabilities (the neurocognitive test for learning the number and calculation entitled *the Numerical* and the *Reasoning Test* proposed by de André Rey) of third grade students with mathematics learning disabilities, thus contributing to the achievement of objectives in the overall curriculum.

The post-test assessment results were statistically processed with the SPSS 16.0 program and **were analyzed both quantitatively and qualitatively.** They were compared to the initial assessment using SPSS 16.0, to observe if the cognitive program **significantly** reduced the mathematics learning disabilities at students in the experimental sample.

I will present the conclusions and recommendations derived from this experiment, the limitations and relevance of my research, the novel elements as well as the opportunities or proposals for future research in the final section of this thesis.

THE FIRST STUDY: Identification of the cognitive deficits involved in the poor performance of the third grade students with mathematics learning disabilities at tests on calculation abilities and reasoning

The first study of my research comprises the dynamic evaluation of the cognitive phenotype for primary school students who have learning disabilities in mathematics in order to identify the deficiencies that occur in the fields of attention/executive functions, memory and learning, language, visual-spatial and senzoriomotor.

Methodology:

The specific objective: To assess the cognitive processes in the fields of attention/executive functions, language, senzoriomotor, visual-spatial and memory/learning for students with learning disabilities in mathematics in primary school and to identify the cognitive deficits involved in this disorder.

The specific hypothesis: The third grade students with mathematics learning disabilities acquire poorer performance at tests designed to evaluate the *mathematical skills* (the neurocognitive test entitled *the Numerical* - for learning the number and calculation, and *the Reasoning test* proposed by André Rey) than the third grade students without mathematics learning disabilities, and their performance at the NEPSY battery tests assessing the phonological processing and understanding of instructions, the visual-spatial processing, and attention and the executive functions, including working memory, are generally below the expected level.

Working procedure and description of the lot of subjects:

To neutralize the uncontrolled variables such as age and individual differences, I selected the two pair samples so as that the students from the control and experimental group have about the same age and that the number of girls and boys in each sample is equal. I chose 58 subjects, 29 of them without mathematics learning disabilities (control group) and 29 with mathematics learning disabilities (experimental group) that were diagnosed according to the criteria of DSM IV (Romilă, 2003), but also according to *the Model based on discrepancy* used by Mather (1991), Hessler (1993) and McGrew (1994) and to *the Response to intervention model* used by Fuchs (2005).

The subjects were selected out of the third grade students, in two schools of Cluj-Napoca.

The control group consisted of 14 girls and 15 boys; average age was 9 years and 2 months.

The experimental group consisted of 14 girls and 15 boys, just like the control group; the average age was 9 years and 4 months.

To check if **the first specific hypothesis** is confirmed, I performed **an initial assessment (pre-test)** of the students from the two groups. The general intelligence was assessed with *the Raven's Coloured Progressive Matrices*, and the mathematical skills were assessed with *the Reasoning test conducted by André Rey* and the neurocognitive test, *the Numerical*, the items I constructed were in agreement with the general curriculum for the third grade. To assess the level of development of the mental processes involved in the mathematics learning disabilities and to identify specific deficits that have to be reduced, the students from the experimental group were assessed also by using *the tests for basic and extended evaluation of the calculation disorder, tests from the NEPSY battery*.

The results of the two groups were statistically processed with SPSS 16.0 and interpreted quantitatively and qualitatively in the formulation of the conclusions.

The psychological and neuropsychological instruments used in this research are: *Raven's Coloured Progressive Matrices* (Raven, 1962; Kulcsar, 1975, Raven et al., 2005; Dobrean et al., 2006), *the Numerical - a neurocognitive test for number and calculation learning* of Gaillard and Willadino-Braga (2001), (model that could also be considered an essay for checking curriculum-based knowledge, since the items I built-up were intended to fulfil the general criteria of the curriculum for the third grade), the verbal and numerical Reasoning test - André Rey (Rey, 1967), *the tests for basic evaluating from the NEPSY battery* (Korkman et al., 2007), *Additional tests from selective evaluation of calculation difficulties, from the NEPSY battery* (Korkman et al., 2007).

Outline of the results

According to the diagnostic criteria for mathematics learning disabilities in DSM IV (Romilă, 2003), I assessed the general intelligence by applying **Raven's Coloured Progressive Matrices** (Raven, 1962; Kulcsar, 1975, Raven et al., 2005; Dobrean et al., 2006) to the students in the experimental group. The results indicated that all subjects had normal intelligence, so the poor arithmetical skills were not due to a general mental retardation.

The Mathematical ability has to be evaluated by standardized tests of mathematical calculation or reasoning, as required by the DSM IV criteria, and for this reason I applied ***the Numerical*** - *a neurocognitive test for number learning and calculation* (Gaillard and Willadino-Braga, 2001) and ***the Verbal and numerical Reasoning test*** *developed by André Rey* (Rey, 1967) to the control and experimental group.

Quantitative results of the initial assessment or pre-test of the control and experimental group ***at the Numerical test*** showed that the average of the control group is 23.50 and the average of the experimental group is 11.63, the average difference of the two groups show a level of significance lower than 0.0005, therefore it is highly significant at the threshold significance of $p<0,001$. The average of the experimental group was 11.6 points out of 27 possible, this clearly indicating the mathematics learning disabilities of these students, who solved less than 50% of the proposed tasks.

By comparing the results obtained by the subjects of the control and experimental groups at the items of the Numerical test, pre-test phase, by using t test for pair samples (with SPSS 16 program) I observed that for all of the items, the average score is higher in the control than in the experimental group. Non-significant differences at the threshold $p=0.05$ were observed only at the items number 2 (comparison of numbers written in numerical code), 22 (reading in numerical code), 10 (dictation for writing some numbers in numerical code), 14 (oral rehearsals), 16 (alphabetical reading), 17 (the probe of the wrong recorded number which supposes the rehearsal of the numbers heard in every statement while part of the number is annihilated by noise) and 18 (the counting of the points from different figures), these items being easy to solve for the students in both groups. For the other items of the test, the differences are significant or strongly significant between the results obtained by the subjects in the control group and in the experimental group.

For **the qualitative analysis** of the results for the experimental group at the initial evaluation test entitled ***the Numerical***, a neurocognitive test for number learning and calculations (Gaillard and Willadino-Braga, 2001) I calculated the average for each item of the test so as to identify and assess the deficits involved in mathematics learning disabilities.

Deficits identified at the items that recorded poor results are:

- errors in identifying the number of the digits for each number written in alphabetical code (item 24)

- difficulties in rounding or approximation of the results for the written calculation involving addition and subtraction with numbers in the range 0-1000 (item 9) or in estimating quantities in a context (item 27)
- difficulties in proposals of oral calculation where students had to state orally a large series of numbers, a difficult calculation, an addition, a subtraction and a multiplication (item 20) these difficulties becoming more serious when the proposed calculations had to be written and solved (item 26)
- deficits in solving problems that require multiple steps, that need to plan the stages, keeping in mind these stages and their application during the problem solving by using working memory, deficits identified in the difficulties (from item 23) to handwrite increasing numbers from the given table according to the requirements (the lowest number, the numbers less than 300, the numbers less than 100, the highest number, the numbers between 100 and 300, the numbers greater than 1000)
- deficits in storage and/or updating declarative and procedural knowledge concerning the arithmetic knowledge such as the number of months in a year, the number of days in a week, the approximate number of weeks in a month, the number of hours in a day and the number of minutes in an hour (item 13)
- difficulties in alphabetical separations (item 11) where the subjects made many errors in decomposing by vertical bars the numbers written together in the alphabetical code (e.g. "twenty four" that had to be decomposed by vertical bars as follows: "twenty/and/four" was separated as "two/ten/and/four"), these kind of difficulties being found also when they write after dictation numbers in the alphabetical code (item 12)
- deficits in the visual-spatial processing, arranging inappropriate the series of numbers as required (numbers were arranged in a line even if it was required to be arranged in a column, or some of them did not start the counting from the top down or from the bottom up as required), some have written the first and the last number in the string even if the requirement was to count ”from... to...„ and not to write numbers "in the range..." of the given numbers (item 1). This fact reveals a confusion between arithmetic knowledge; difficulties in the oral calculation (item 21), since the students made errors in addition, subtraction, division of numbers, but also in finding the half, the quarter or the third part of those numbers, fact that reveals, once again, deficits in the declarative and procedural arithmetic knowledge; deficits found also in the written calculation (item 5); deficits in counting (item 15), since the subjects failed to count correctly in an ascent, and descent manner, from 10 to 10 or from 3 to 3 from one

given number to another; difficulties in properly placing the given numbers on a vertical axis –this also indicating deficits in comparing and arranging numbers according to the requests – fact that proves, once again, the visual-spatial deficits (item 8). Other deficits identified were: the deficit in number comparison (item 3, item 19) and in transcoding (item 4, item 6).

The quantitative results of the initial assessment or pre-test of the control and experimental group with ***the Verbal and numerical Reasoning test*** (Rey, 1967) indicates that the average of control group is 12.34 and the average of the experimental group is 5.17, so the average difference of the two groups was highly significant at the threshold $p<0.001$.

The average of 5.17, obtained by the experimental group, indicates a raw score at this essay, situated in the range of 10-20 percentile of the 100 possible, thus indicating that the students in the sample have mathematics learning disabilities.

Based on **the qualitative analysis of the results for the initial evaluation** of the experimental group assessed with ***the Numerical and verbal Reasoning test*** (Rey, 1967) it was found that the subjects had poor results at the ***arithmetic signs test***, since they used immature or ineffective solving strategies (some students chose strategies of "testing -error" losing precious time, while the test was time limited; the multiplication is properly understood by some students as repeated addition, but if the right product for the pair of factors is not found in the memory and multiple addition is used instead, time is wasted and the strategy is ineffective in this case; the strategy of using fingers in the arithmetic calculation may be helpful, just that in the case of addition, some students used the procedure of "counting all" instead of "counting from the larger one" - which is more efficient), the written arithmetic calculation is deficient (the students use fingers to solve addition because the arithmetic facts are not known and therefore the arithmetic solving speed decreases, resulting in a lower score at the test; the results of the multiplication and division table are not known at all or were incorrectly stored/reproduced in/from the memory; some students were confused about the meaning of the signs "+" and "x" and thus, misused them).

At ***the numerical equality test*** the results were worse than at the arithmetic signs test because students made calculation errors, and the numbers that they completed the exercise, so that the result from the right side to be equal to the one in the right side were wrong, some students even filled the gaps with numbers without any reasoning. At this test a logical error was also found because some subjects filled in gaps with the result from the right side without taking into account that they should modify it as required in the left side, e.g. for the first equality "2 + 0 + 0 + 0 = 1 +..." instead of filling the gap with "1" –since the result in the left side of the equality is 2 and in order to have an equal result in the right side, they should have filled in 2, i.e., in this case the correct reasoning should be "How much should we add to 1 to have 2?", the right answer being "1", most students filled in the gap with the answer "2" - the result of the calculation in the left side of the equation.

After applying *the tests for basic evaluation of the NEPSY battery* (*Attention/executive functions field:* the Tower, the Auditory Attention and the Response Set, the Visual Attention; ***Language field***: Phonological Processing, Rapid Naming, Understanding Instructions; ***Senzoriomotor field***: Finger Tapping, Imitating Hand Positions, Visio-motor Accuracy; ***the Visual-spatial processing field****:* the Copy of the Drawing, Arrows; ***the Memory and learning field***: the Face Memory, the Names Memory, Narrative Memory) **and *the Additional tests from selective evaluation for calculation difficulties of NEPSY battery* (Attention/executive functions field**: Fluency drawings, and the Knock and the tap; **Language field**: verbal fluency; **Senzoriomotor field**: the finger discrimination; **Visual-spatial processing field**: the construction of cubes, Finding the road, **Memory and learning field**: the repetition of the sentences, Learning List) (Korkman et al., 2007) **the results of the initial assessment or pre-test** for the experimental group were as follows: the average scores of **the main filed Attention/executive Functions** of the experimental group calculated by SPSS 16.0 was 76.03, which means that the primary domain score ranges between 5.6 and 6.9 - thus ranking this score in the range of 3-10 percentile, according to the directions regarding qualitative interpretation of the scaled scores in the main fields listed in the NEPSY Battery Manual (Korkman et al., 2007) - indicating a result less than expected; the average score of the ***Language field*** is 75.44 percentile ranging between 5.5 and 6.1, i.e. in the same range of 3-10 percentile thus indicating that the score is below the one expected; the average score of the **main Senzoriomotor Functions field** is 81.31, ranging between 11.0 and 13.9 percentiles, i.e. in the classification range of 11-25 percentiles, thus indicating a borderline score; the average score of the **Visual-main Spatial Processing field** is 75.96 which lies between percentiles 4.8 and 7.9, i.e. in the classification range of 3-10 percentile - a result below the one expected; the average score for **the main Memory and Learning field** is 75.27, between 4.4 and 6.2 percentiles, in the range of 3-10 classification interval – thus showing that the subjects' score is below the one expected.

The quantitative analysis of the results in the main fields facilitated the identification of the cognitive functioning deficits, that may be specific (only one or two functions are affected) or general (occurring in all fields) (Korkman et al., 2007). The results obtained for the NEPSY battery tests previously presented indicate deficits in attention/executive function, language, visual-spatial processing, memory and learning fields, the scores being lower than expected, and the result obtained in the senzoriomotor functions field is close to the threshold, while the deficits were more significant in the other fields.

The qualitative interpretation of the results obtained by the experimental group at the main and selective NEPSY Battery tests facilitate the analysis of the subjects' difficulties, the identification of the deficit's source, an analysis that is imperatively necessary in the case of complex function disorders e.g. the arithmetic calculation disorders (Korkman et al., 2007). The primary and secondary deficits (derived from the primary ones) could be identified after such an analysis. I will describe the deficits identified in the initial assessment of the subjects from the experimental group, while a detailed analysis on the tests and subtests, of the performance obtained by the subjects from the control and experimental group is detailed in the PhD thesis, in the section "Results":

- **In the Attention/Executive Functions field**: the deficits of the motor persistence in the ability of inhibiting the impulsive responses, in the visual attention and the auditory selective attention, the deficits in planning, monitoring, self-regulation and problem solving, the deficits in the ability of adopting, supporting and changing the cognitive sets, the deficits of the selective and sustained attention, working memory deficits. These deficits have been identified by assessing the students with tests from the basic evaluation and with additional tests from selective evaluation of the NEPSY battery for calculation disorders in the field: Attention/executive Functions. The poor performance obtained at these tests, as it was presented and analyzed in the section "Results" correlates with the poor performance recorded at **the Numerical Test** (the subjects manifested, also at this test, deficits in solving multistep problems that require planning, storage and implementation of these steps, the working memory deficits revealed by the poor results in solving the oral or written calculation) and at **the Verbal and Numerical Reasoning Test** (the students manifested deficits in planning, or applied immature, ineffective strategies in solving problems, as well as deficits in attention, self-control and self-monitoring of the performance identified especially in the second part of the test when they completed incorrectly gaps with numbers representing the partial result of the equality, or manifested working memory deficits by failing to provide the proper operation signs in the first part of the sample due to the difficulties in calculating and memory reproduction of the arithmetic facts);
- **In the Language field**: deficits of the phonological processing (Anca, 2002; Hațegan, 2011), monitoring, planning verbal sequences, difficulties in understanding more complex receptive language, difficulties in producing and accessing words out of the memory from specific categories (difficulties based on working memory deficits); These deficits - identified by applying basic and selective evaluation tests for calculation disorders in the *Language field* of NEPSY battery - are present also in **the Numerical Test** (the students had difficulties related to the items that contain alphabetical separations and writing the numbers in the alphabetic code, difficulties in solving items that involve a more complex receptive language, deficits of working memory manifested by errors when transcoding from the Arabic to numeric code or from numeric code to Arabic Code, deficits in organizing fluent verbal sequences manifested by

difficulties in recalling "a complex calculation" or difficulties in maintaining the order formulated in the requirement) and to **the Verbal and Numerical Reasoning Test** (language underlies the development of thinking and reasoning, so the poor performance obtained at tests from the *Language field* could explain the problems of logic occurring in this essay when students wrote the results from the left side of the equality or a partial result in the gaps from the right side instead of calculating the correct answer; some of them explained that they did not use any reasoning so that they filled in the gaps with numbers chosen at random, disregarding all rules of the solving algorithm).

- **In the Senzoriomotor field**: little difficulties in performing correct and rapid motor tasks regarding the coordination of the hands and fingers, as well as in generating new and rhythmic movements were identified, using tests of basic and selective evaluation for calculation difficulties from *the Senzoriomotor field* of NEPSY battery. These difficulties have not been observed using the Numerical test.
- **In the Visual-Spatial field**: deficits identified with the basic and selective evaluation tests for calculation difficulties from *the visual-spatial area* of NEPSY battery are found in the assessing of the correct perception of direction, in the ability of locating the item by using the directional and spatial relationships from a short schematic sequence, deficits in the coordination of the spatial information with motor performance, in the ability to reproduce three-dimensional shapes according to a two-dimensional model. The poor performance at these subtests - indicating difficulties in the visual-spatial aspects that don't involve motor coordination - correlates with poor performance at the items regarding number comparison, where students reversed the mathematical symbols from *the neurocognitive test* entitled ***the Numerical test***, the above difficulties in spatial perception implying repercussions on the mathematical ability to understand and visually represent the place value of the digit in numbers, deficits found at items of *the **Numerical** test* that identifies the number of digits for each number written in alphabetical code (item 24), deficits in the visual-spatial processing at item 1 where the students did not arrange the series of numbers as required, or they arranged incorrectly the numbers in ascending order, according to certain requirements (item 23), difficulties in properly placing on a straight vertical line of the given numbers show deficits both in number comparison, and in their arrangement as required, which shows, once again, the visual-spatial deficits (item 8), that lead to difficulties in processing more complex mathematical skills necessary in geometry, and in arithmetic calculation where the mental spatial number line is necessary to use.
- **In the Memory and Learning field**: by applying the basic and selective evaluation tests for difficulties in calculation from the Memory and Learning field of the NEPSY battery, verbal and nonverbal memory deficits were identified, manifested in memory encoding and updating

of information (revealed in the difficulties of oral or written calculation in *the **Numerical** test* and in ***the Verbal and Numerical Reasoning test***, but also in the poor performance at the items that aimed arithmetic declarative and procedural knowledge of the ***Numerical** test*, students manifesting difficulties in recalling and applying the rules for filling the gaps in the given equations in ***the Verbal and Numerical Reasoning test***). The poor performance recorded in the field correlated also with the difficulties in solving more complex, multistep problems, difficulties that involved poor working memory.

Other difficulties that were identified by applying the NEPSY Battery, *the Numerical* and *the Verbal and Numerical Reasoning tests* would be the slow speed of information processing in case of some subjects (that achieved poor performances because the tests of NEPSY Battery are time-limited) while in case of others, the deficits in inhibition leaded to impulsiveness in answers (the students were quick, but imprecise in the execution of the tasks).

A single case was identified as having deficits in the concept of number sense, as it was found in the literature (Butterworth, 1999, 2001, 2003, 2005, Mazzocco and Myers, 2003), while the deficits in counting were found at most students, the subjects from the experimental group manifesting difficulties at the items of *the Numerical test* that involve counting according to given requirements (e.g. "from 3 to 3", "increasing number", "decreasing number" and so on).

Another deficits observed in solving the NEPSY battery tasks, in *the Numerical* and *in the Verbal and Numerical Reasoning Test* were the use of immature, ineffective or inappropriate strategies because the subjects used counting fingers in arithmetic calculation, thus losing precious time (strategy inadequate for the task that is time-limited such as *the Reasoning Test*), but the counting starts at 1, so they used the immature strategy "counting all" instead of "counting from the biggest operand". The lack of a strategy, of reasoning in solving problems (identified in all tests applied to items that the students answered randomly) indicates deficits in planning, in working memory, but also in declarative and procedural knowledge.

Conclusions:

The results of the initial assessment, their analysis and interpretation converge to the conclusion that the students with mathematics learning disabilities in primary school manifest deficits particularly in fields like: *Attention/Executive Functions, Language, Visual-spatial, Memory and Learning,* **results that correlate with the ones in the literature,** as follows:

1. Deficits in *Attention/executive Functions Field* identified in the initial complex evaluation, deficits presented also in the analysis of research findings: difficulties in the ability of inhibiting impulsive responses (Baddeley, 1986, 1998, Lezak, 1995; Anderson, 2002, 2008; Geary 2005, Geary and Hoard, 2005; Feifer, 2007, von Aster and Shalev, 2007), deficits in the selective and sustained attention (Baddeley, 1986, 1998, Keller and Sutton, 1991; Zelazo et al., 1997; Muresan,

2003; von Aster and Shalev, 2007, Feifer, 2007), deficits in the visual attention and selective auditive attention (Keller and Sutton, 1991; Muresan, 2003), deficits in planning (Zelazo et al., 1997, Anderson, 2002, 2008, Feifer, 2007; von Aster and Shalev, 2007), deficits in monitoring (Zelazo et al., 1997, Anderson, 2002, 2008, Feifer, 2007, von Aster and Shalev, 2007), in self-regulation (Zelazo et al., 1997, Anderson, 2002, 2008; Feifer, 2007, von Aster and Shalev, 2007) and of problem solving (Zelazo et al., 1997, Anderson, 2002, 2008, Feifer, 2007, von Aster and Shalev, 2007), deficits in the ability to adopt, support and change cognitive sets (Zelazo et al., 1997), deficits in the working memory (Baddeley, 1986, 1998, Butterworth et al., 2001 Geary, 2005; Geary and Hoard, 2005; Feifer, 2007, Von Aster and Shalev, 2007);

2. Deficits in the *Language Field* - that can be found in the results of the evaluation and have been identified by research in the field: deficits of phonological processing (McCloskey, Caramazza and Basili, 1985; Sharma, 1986; Baddeley, 1986, 1998, Keller and Sutton, 1991; Noël and Serono, 1993; Kosc, 1994, Dehaene, 1995, Dehaene and Cohen, 1997; Rosselli and Ardila, 1997; Muresan, 2003 Geary, 2005; Geary and Hoard, 2005; Feifer, 2007, von Aster and Shalev, 2007), of the semantic processing (Verguts and Fias, 2005), of monitoring, of planning verbal sequences and difficulties in understanding the more complex receptive language (McCloskey, Caramazza and Basili, 1985; Sharma, 1986; Baddeley, 1986, 1998, Keller and Sutton, 1991; Kosc, 1994, Dehaene, 1995, Dehaene and Cohen, 1997; Rosselli and Ardila, 1997; Muresan, 2003 Geary, 2005; Geary and Hoard, 2005; Feifer, 2007, Von Aster and Shalev, 2007), difficulties in producing and accessing words of the memory, from specific categories (Sharma, 1986 - argues that this deficit leads to difficulties in the inductive and deductive reasoning, in the estimation and recognition of the pattern);

3. Deficits in *The Visual-Spatial Area* revealed by the results of the evaluation that are also present in the studies available in the field: deficits in assessing the correct perception of direction or in the ability to locate an item using the spatial relations coordinated with motor performance (McCloskey et al., 1985; Sharma, 1986; Baddeley, 1986, 1998, Kosc, 1994, Rosselli and Ardila, 1997; Geary, 2005; Geary and Hoard, 2005; Feifer, 2007, von Aster and Shalev, 2007), this possibly leading to difficulties in spatially representing the numbers ("number blindness") (Butterworth, 1999, Butterworth et al., 2001, Butterworth et al., 2003, Butterworth, 2005).

4. Deficits in *Memory and Learning field* were identified in this study and found in the available literature: deficits of verbal and nonverbal memory - based on difficulties in encoding and in updating the information from the memory (McCloskey et al, 1985; Sharma, 1986, Baddeley, 1986, 1998, Keller and Sutton, 1991; Kosc, 1994, Rosselli and Ardila, 1997, Butterworth et al., 2001; Muresan, 2003 Geary, 2005; Geary and Hoard, 2005; Feifer, 2007, Von Aster and Shalev, 2007), thus leading to difficulties in learning the arithmetic facts and the sequences, the mechanical

procedures, the automatisms (Butterworth, 1999, Butterworth et al., 2001, Butterworth et al., 2003, Butterworth, 2005).

The students with mathematical learning disabilities have the skills of processing simple numbers (consisting only of units) preserved, but they have difficulties in the abilities of representing and processing the large numbers, as well as in the ability of mentally forming the spatial number line, fact observed also by Geary and Hoard (2005). A single case was identified with difficulties in the concept of number sense (involved in the non-symbolic representation of the numbers), other deficits being encountered in making connections between the non-symbolic and symbolic representation of the numbers, deficits in the symbolic verbal representation - also present in the research results of Mazzocco and Myers (2003).

The NEPSY battery is based on Luria's research findings on the identification of cognitive deficits, findings that correlate with the ones obtained at the initial assessment, the subjects from the control group manifesting: logic and spatial organization deficits, (e.g. the NEPSY battery test “the circle under the square” where the subjects from the experimental group had scores lower than expected) and deficits in writing the numbers in a correct sequence (order), deficits in planning that lead to deficits in the development of the strategies for solving problems and in understanding the mathematical language (speech, language introspection), the use of inefficient counting and addition strategies, the subjects manifesting also perseverance or inflexibility in implementation (for example, they continue to use a strategy that was adequate, but they do not change it with other adaptive strategies) and the disability of performing simple calculations, difficulties in learning the multiplication table (Luria, 1966, 1966b, 1969a, 1969b, 1970, 1973, 1974, 1976, 1980). The subjects from the experimental group use immature or ineffective (inadequate) procedures to solve arithmetic problems, they commit frequent procedural errors, these deficits being observed also in the research of McCloskey et al., (1985), Sharma (1986), Kosc (1994), Rosselli and Ardila (1997), Geary (2004), Geary and Hoard (2005), Feifer (2007), von Aster and Shalev, 2007).

The principles of counting are not well controlled because the frequency of the errors in “the mad" counting or in the ascendant and descendant tasks of the Numerical test was significant.

Therefore, the results of the initial evaluation presented above, their analysis and interpretation, ***confirm the first specific hypothesis of the research i.e. that third grade students with mathematics learning disabilities acquire poorer performance at the tests designed for mathematical skills (the neurocognitive test for number learning and calculation entitled the Numerical and the Reasoning test proposed by André Rey) and at tests of NEPSY battery assessing the phonological processing and understanding instructions, the visual-spatial processing, attention and executive functions, including working memory, and their results are generally below the expected level.***

There were identified several cases with symptoms of anxiety in testing and/or math anxiety (anxiety was considered by the researchers von Aster and Shalev, 2007, an important factor in mathematical performance), particularly because the samples were time limited, and some students reported that they were nervous, trembling, afraid that they would not get good results, this also indicating a low level of self-esteem. Taking all these into consideration, I wanted to perform an assessment of the test anxiety and/or mathematical anxiety with specific instruments**, in Study 2**, where I proposed effective strategies to reduce them, strategies that I subsequently used in the individualized intervention program along with metacognitive strategies and implicitly, with cognitive, neurocognitive and educational specific strategies, to increase the mathematical performance by reducing the cognitive deficits involved in the mathematics learning disabilities.

Practical applications of the study: In the diagnosis of the mathematics learning disabilities, it is imperative that the specific deficits involved in this disorder are identified at each subject, for the establishment of the correct and complete personalized intervention program that implicitly leads to the stimulation of poor cognitive processes involved in this disability. The results of this dynamic assessment show what the student is able do (Preda, 2000) and, based on this information, to find out what needs to be improves so that to change him, as stated by Mih (2010), from a "novice student" to an "expert student ".

THE 2nd STUDY: ***Direction of research aiming to bring into focus the issue of mathematical anxiety and the test anxiety***

The second study of my research targets the evaluation of mathematical anxiety and test anxiety and the identification of the strategies that could be used for their reduction at students in the primary school, so that the cognitive functioning and by default, their mathematical performance were not affected.

The mathematical anxiety can affect the performance and it could be caused by mathematical disabilities, possibly reaching a level that affects in an adverse way the ability to solve even simple mathematical operations. "Many children with severe mathematics learning disabilities are anxious" (Emerson and Babtie, 2010, p 9).

The test anxiety is most often defined as a feature of anxiety in a specific situation, having as major components emotional and anxiety disorders (Zbornik, 2001). In the terminology of DSM-IV (Romilă, 2003), test anxiety is a specific phobia, of situational type, assuming the existence of a test.

The mathematical anxiety was defined by Richardson and Suinn (1972) as a feeling of tension and anxiety that interferes with handling of the numbers and solving mathematical problems in a variety of situations, in everyday life or in academic situations.

Miller and Bichsel (2004) conducted a study that tested predictions about the working memory subsystems associated both to mathematical anxiety and mathematical performance. The results of the first study in my research highlighted that the language field of working memory, and also the visual-spatial field are significant factors of mathematics performance, but the study findings reported by Miller and Bichsel (2004) indicated that mathematical anxiety is, also, a strong predictor of mathematical performance.

Methodology:

The specific objective was to assess mathematical anxiety at the students from primary school and to propose strategies to reduce this anxiety, in order to improve the performance in mathematics.

The specific hypothesis assumes that mathematical anxiety and test anxiety are inversely correlated to the poor mathematics performance of the students from primary school, requiring the use of specific strategies for reducing these anxieties.

Procedure*:* To investigate if the students in the primary school manifested test anxiety and/or mathematical anxiety, I applied *The Math Anxiety Test* (Freedman, 2006) and *The Evaluation of Anxiety Test* (Strawderman, 2006) on 30 students from classes II-IV, chosen at random. Afterwards, I analysed the data on the assessments of test anxiety and mathematical anxiety, drawing the conclusions of the study, and I proposed proper strategies to reduce these disorders.

Participants: I randomly selected a number of 30 students from grades II-IV, primary school, in Cluj-Napoca, by lot-casting, out of which 15 were girls and 15 boys, and the average age of the sample was 9 years and 6 months.

Instruments:

In this study I used *The Evaluation of the Test Anxiety* (Strawderman, 2006) and *The Mathematical Anxiety Test* (Freedman, 2006a) for the evaluation process.

Results:

The results obtained at *The Mathematical Anxiety Test* performed by Freedman (2006a) showed that 40% of the students manifest severe mathematical anxiety, 27% have moderate mathematical anxiety and 23% a possible anxiety, this meaning that more than half of the students manifest mathematical anxiety.

The results from *The Evaluation of Test Anxiety* (Strawderman, 2006), a test based on Zbornik's research (2001) correlated with those obtained from the Mathematical Anxiety Test, performed by Freedman (2006a), in the sense that at 8 out of the 14 items, over 50% of the students showed symptoms of test anxiety (items 1, 3, 5, 6, 8, 10, 11, 13). Item 5 indicates a high level of test anxiety, since 23 students answered that they were able to study during the night before an exam (when they were asked if they studied only that night, before the exam, this suggesting a poor time management, they answered that the reason for that study was to review, and update the knowledge since they were "afraid" not to forget something, even if they started to learn for the respective exam in advance).

Data analysis and interpretation:

The study findings show that the test anxiety is manifested particularly in a situation of mathematical testing, because the students are less anxious in case of other disciplines (Zbornik, 2001).

The *Evaluation of Test Anxiety* (Strawderman, 2006) provides more likely a qualitative rather than a quantitative interpretation of the major components of mathematical anxiety. The following qualitative information could be derived from the subjects' answers: the level of flurry changes or not during the test (item 7) depending on the student's success or failure in solving the tasks - this leading to the conclusion that a constant and efficient training at this subject reduces the flurry during the test (as evidenced from the responses at item 9) even if the students were anxious at the beginning of the testing, thus proving a higher efficiency in solving; the students think (before, during and after evaluation) of the grade they will get, as illustrated by items 13 and 14, this representing a factor that affects the self-image, not only the level of their performance at the respective subject (in his own perception or in the colleagues' perception: "I feel good when I am applauded for being the only one in the class that got FB at the mathematical test ").

The **strategies I used to reduce mathematical anxiety** were "Ten manners to reduce mathematical anxiety" (Freedman, 2006b) and the strategies proposed by Lupu (2001).

Limitations of the study: Because the marks at mathematics, of the 30 students randomly selected from the primary school (second, third and fourth grade) indicate the fact that 17 students, more than half of the control group, acquired a poor performance at this subject, the results of the tests on mathematical anxiety and/or test anxiety confirm the data in the anamnesis record, i.e. the mathematics anxiety and the test anxiety are inversely correlated to the mathematics performance at students in the primary school, implying some specific strategies necessary for their reduction. The conclusion of the study which supposes that more than half of the participating students manifest testing anxiety or/and mathematical anxiety is supported by the poor mathematical performance of these students, performance that is inversely correlated to the scores obtained at the tests for mathematical anxiety and test anxiety. Due to the fact that the randomly selected students belong to a school where many students are at risk of school failure or dropout, it is possible that the investigated group was not selected from the "ordinary" population which has a normal distribution of scores, i.e. 66% of the population have "average" scores (in the range m-σ and m+σ), and the rest is equally distributed between "low" and "high" scores.

The necessity of the research: The need of investigating the causes of test and mathematical anxiety as well as of proposal of new strategies for their reduction was based on the request of parents and of teachers that were interested in the improvement of their children's performance in mathematics and in the prevention of school failure.

Conclusions:

The mathematical anxiety, manifested and/or in the case of the test anxiety affects both the emotional shape and the cognitive and the behavioural conduct of the students. The emotional shape is manifested through somatic disorders (headaches, stomach aches) or other symptoms (sweating, shivering, tachycardia, and dry mouth). The cognitive aspect focuses on a catastrophic thinking and expectations of failure, this inducing low self-esteem ("I think I won't finish, I'll get a bad grade, I'll have mistakes, I will be repeater, I would not be able to solve the test, I'm thinking of accidents"). The behavioural aspect is manifested through motor restlessness.

The quantitative analysis of the answers to item 12 - where students were asked to indicate if there is a difference in what they feel while they have a mathematical test compared to what they feel when they have a test at other subjects, shows that 21 of the 30 students responded positively. For a qualitative interpretation of the answers, following a previous quantitative analysis, a supplementary question was introduced, i.e. to explain the way their emotional shape would change if the testing was in mathematics. All 21 students responded that at this subject "the test is more difficult" and they are afraid they would fail. This fact indicated that the test anxiety is manifested on the emotional, cognitive and behavioural plan, particularly in mathematics, and therefore their mathematical performance was negatively affected. **This confirms the second specific hypothesis of the research, i.e. mathematical anxiety and test anxiety are inversely correlated to the poor mathematical performance of the students from primary school, requiring the use of specific strategies to reduce mathematical anxiety.** The strategies for reducing mathematical anxiety (reflected in test situations and particularly when students are evaluated at this subject) will be included also in the psycho-pedagogical intervention program developed and presented in **Study 3** (possibly being considered as **practical applications** of the second study) so that the students from the experimental group manifesting mathematical anxiety could have a maximum efficiency during the intervention, the performance not being influenced by this variable.

THE 3rd STUDY: ***The impact of the psychopedagogical intervention program - elaborated for the stimulation of poor cognitive processes- on the mathematics learning disabilities of the third grade students with mathematics learning disabilities***

The third study was divided in two major studies which continue logically and cursively the first two studies. The first part was the implementation of a general, complex and complete intervention program which aimed at stimulating the cognitive processes involved in mathematics learning disabilities in primary school students, for early intervention and prevention of school failure. This program integrated a) the personalized intervention plans for all cognitive deficits identified in **the first study**, deficits that lead to mathematics learning disabilities and b) strategies proposed in **the second study** to reduce mathematical anxiety and test anxiety - that could affect mathematical performance. The second part of the study includes the presentation and the analysis of the results after the implementation of the program that reduces the cognitive deficits involved in the mathematics learning disabilities of primary school students, the results obtained after the final evaluation (post-test) being relevant in this respect, i.e. the better performance at tests from the NEPSY Battery correlated with the performance in tests like *The Reasoning Test* and *the Numerical* - designed to evaluate mathematical skills.

Methodology:

The specific objectives proposed for this study are:

a) Development of a general educational cognitive program to stimulate the poor cognitive processes in order to reduce the difficulties in learning numbers, in calculation and in problem solving.

b) Implementation of the general educational cognitive program and analysis of its effectiveness in the reduction of difficulties in acquiring number, in calculation and in problem solving, a program that includes personalized intervention programs.

Specific hypotheses:

- *The Educational cognitive program* reduces the deficits of executive functions, including working memory, deficits of attention, of phonological processing and understanding the instructions, of visual-spatial processing, deficits involved in the mathematics learning disabilities of third grade students.

- The stimulation of the poor cognitive processes in fields like *attention/executive functions, language, sensorimotor, visual-spatial and memory/learning*, by *the Educational cognitive program* improves the performance at tests on mathematics abilities (the neurocognitive test for learning number and calculation, entitled *the Numerical* and *the Reasoning test* proposed by André Rey) of third grade students with mathematics learning disabilities, contributing to the achievement of the objectives in the overall curriculum.

Working procedure:

In the first part of the study I elaborated *the Psychopedagocical intervention program for stimulating poor cognitive process at students from primary school with mathematics learning disabilities,* based on the findings from Study I and Study II, on the current theories and models on cognitive modifiability and on valid strategies that aim to reduce the deficits involved in this disorder.

In the second part of Study III, I performed the intervention based on *the Educational cognitive program for stimulating the cognitive processes at third grade students with mathematics learning disabilities* - developed in the first part of this study, and subsequently, I presented the final evaluation results, of post-test, and I analysed and interpreted the data pursuing the program's effectiveness in improving a) the performance of the targeted cognitive processes and b) the mathematical skills (especially calculation and problem solving).

The description of the subjects' lot:

The participants were the 29 subjects from the experimental group in **Study 1**, who manifested mathematics learning disabilities, third grade students, from two schools of Cluj-Napoca.

The experimental group consisted, as specified in **Study 1**, of 14 girls and 15 boys, the average age being 9 years and 4 months.

The instruments used were: ***The Numerical*** - *a neurocognitive test for learning numbers and calculation*, proposed by Gaillard and Willadino-Braga (2001), (a test that could be considered as knowledge-based curriculum since the items were constructed on the criteria of general curriculum for grade III), ***the Verbal and Numerical Reasoning test*** (Rey, 1967) and ***the tests for basic and selective evaluation for calculation difficulties, of the NEPSY Battery*** (Korkman et al., 2007).

Conducting the psycho-pedagogical experiment:

In **Study I**, I evaluated the students in the experimental group with ***tests of the basic and selective evaluation for calculation difficulties of the NEPSY Battery*** (Korkman et al., 2007), with ***the Numerical*** *- a neurocognitive test for learning numbers and calculation* (Gaillard and Willadino-Braga, 2001) and with ***the Verbal and Numerical Reasoning tes***t (Rey, 1967) in order to identify the cognitive process involved in mathematics learning disabilities at the primary school and their deficits. The poor cognitive processes were identified in all cognitive domains, particularly in the Attention/executive Functions, Language, Visual-spatial processing, Memory and Learning fields, as specified in study I of the research. Based on the results obtained, on the analysis and interpretation of data from **the first two studies**, I developed and implemented *the Psychopedagogical intervention program for stimulating poor cognitive processes at students with mathematics learning disabilities in primary school* in **the third study**. Then, I correlated the results of the initial evaluation with the performance obtained at the final evaluation, post intervention, in order to highlight the effectiveness of this program in reducing the cognitive deficits involved in this disorder and in the increase of mathematical performance.

The first part of this study, **PART A,** aims to achieve the third objective of the research, i.e. to develop a general educational cognitive program for stimulating the poor cognitive processes in order to reduce the difficulties in acquiring number, in calculation and in solving problems.

The program developed in my research was based on the researchers' findings in the field of mathematics learning disabilities: Fuchs (Fuchs et al., 2004, Fuchs et al.., 2008b; Fuchs et al., 2009), Geary (Geary, 2004; Geary and Hoard, 2005), Emerson (Emerson and Babtie, 2010), Gherguț (Gherguț, 2011) and Feuerstein (2002), and PASS Model proposed by Naglieri and Das (1997), model developed from the core concepts of Luria's theory on cognitive functioning (McCrea, 2009).

The program (Appendix 1) includes 6 stages unreeling over 16 weeks, including sequences with duration of one hour, with a frequency of three times a week (Fuchs et al., 2008b; Fuchs et al., 2009).

The overall objective of the program **was to reduce the difficulties in acquiring number, in calculation and solving problems by stimulating the poor cognitive processes involved in mathematics learning disabilities at students from primary school.**

The results expected at the end of the intervention were: *on the cognitive level,* ***an improvement in the functioning of cognitive processes*** at students from the experimental group will be observed, *on the behavioural plan* the student is more open-minded, confident, relaxed, and the mathematical anxiety is considerably reduced, and *on the educational plan*, an increase of the academic performance in mathematics will be observed.

The intervention involves the use of some mathematical computer games and media projects.

Students with behavioural disorders had an individualized behavioural intervention program.

The duration of the intervention program was 16 weeks, a total of 48 sequences (Fuchs et al., 2004; Fuchs et al., 2008b; Fuchs et al., 2009), the ***frequency*** being 3 times a week in sequences of 1 hour.

The **sequences** had 6 intervals of 10 minutes each (The 10 minutes Rule):

1. ***Quick mental calculation***, *Flashcards* (checking prior knowledge) (Fuchs et al., 2008b; Fuchs et al., 2009) - in pairs.

2. Conceptual and strategic instruction (reviewing or acquiring new knowledge, introducing new concepts and strategies) - small group (2-4 students).

3. Exercises Specific to the Lesson with Flashcards (Glover et al., 2010) - individually.

4. Optimizing knowledge by computer exercises (educational software "Wrecked on the Calculations' Island" purchased from Cognitrom) – individual, at the computer.

5. Review/systematization - paper-pencil (individually)

6. Evaluation (individually).

The second part of the study, **Part B**, consisted *in implementing* ***the overall educational cognitive program*** *and the analysis of its effectiveness in order to reduce difficulties in number acquiring, in calculation and in solving problems, a program from which the personalized intervention programs could be derived* - the fourth specific objective of the research.

The analysis and interpretation of the final evaluation results, of the post intervention led to the confirmation of the third specific hypothesis, i.e. *the educational cognitive program reduces the deficits of the executive functions, including working memory, deficits in attention, phonological processing and understanding the instructions, deficits in visual-spatial processing involved in mathematics learning disabilities of third grade students* and to the confirmation of the last specific hypothesis i.e. that *stimulation of the poor cognitive process in fields like attention/executive functions, language, senzoriomotor, visual-spatial and memory/learning by* ***the Educational cognitive program*** *improves the performance at tests on mathematics learning disabilities (the neurocognitive test for learning Number and calculation entitled the Numerical and the Reasoning Test proposed by André Rey) of third grade students with mathematics learning disabilities, thus contributing to the achievement of the objectives in the overall curriculum.*

Presentation of the results

Due to the fact that mathematics learning disabilities do not have a single central deficit (Geary, 1993; Mazzocco and Myers, 2003), as evidenced also by the results of my **first study**

research, the cognitive program designed to stimulate all the poor cognitive processes involved in the development of this disorder -as described in **Part A** of this study- was implemented.

In **the final evaluation**, the same **tests for basic and selective evaluation for difficulties in calculation, of NEPSY Battery** (Korkman et al., 2007) were used in order to assess the development of the cognitive processes that have been stimulated by the evolved program.

The results of the final evaluation (or post-test) of the experimental group were: the average score of **Attention/executive Functions Core Domain** calculated by SPSS 16.0 was 90.79 this meaning that score of this main domain is between 26.0 and 29.2 thus belonging to the range 26-75 percentiles, indicating the expected results, according to the indications for qualitative interpretation of scaled scores in the basic domains of the NEPSY Manual Battery (Korkman et al., 2007), the result indicating an expected level; the average score in **the Language Core Domain** was 86.65 ranging between 16.8 and 22.9 percentiles and being classified in the range of 11-25 percentiles thus showing that the result is at the threshold; the average score in **Senzoriomotor Functions Core Domain** was 88.79 ranging between 20.8 and 26.5 percentiles, i.e. between the classification intervals 11-25 percentiles, this indicating a result at threshold, and the 26-75 percentiles – indicating an expected result; the average score of the **Visual-Spatial Processing Core Domain** was 89.10 ranging between 23.2 and 30.9, i.e. between the classification intervals 11-25 percentiles, this indicating a result at threshold and 26-75 percentiles this showing a result in the expected level; the average score of the **Memory and Learning Domain** was 89.41 ranging between 24.7 and 28.1, percentiles between the classification intervals of 11-25 -indicating a threshold result and 26-75 percentiles - showing an expected score.

The quantitative analysis of the results in the core domains of NEPSY battery shows that the score of subjects in all fields was at threshold or at the expected level, while in the case of initial assessment the scores of the core domains attention/executive function, language, visual-spatial, learning and memory obtained by the students in the experimental group were below the expected level, except the senzoriomotor area where the result was at threshold, these indicating an improvement in the cognitive process intended to be stimulated by the program developed in **Part A** of the Study III. To observe whether there is a significant difference or improvement, I correlated the results that the students obtained at the initial evaluation with the ones at the final evaluation in the **Field of Attention/executive Functions, Language, Senzoriomotor, Visual-Spatial, Memory and Learning**.

The differences between the average scores of the initial and final evaluation in all domains of the NEPSY Battery *(Attention/executive Functions, Language, Senzoriomotor, Visual-spatial, Memory and Learning)* ***are highly significant at the threshold of $p<0.001$***, this suggesting that null hypothesis should be rejected and that we should ***accept instead the specific hypothesis***

stating that the educational cognitive program reduces the deficits of the executive functions, including working memory, the deficits of attention, phonological processing and understanding the instructions, as well as deficits of visual-spatial processing involved in mathematics learning disabilities of third grade students.

The qualitative interpretation of the final evaluation results obtained by the experimental group at the basic and selective tests of NEPSY Battery indicates that the deficits identified in the initial assessment performed in Study I were reduced by the program of cognitive stimulation so that the subjects from the experimental group showed an increase in their performance in:

- **the Attention/Executive Functions Field,** in working memory, in the ability to inhibit impulsive responses, in selective visual and auditory attention, in sustained attention, in the flexibility of attention, in planning, monitoring, self-regulation, self-control and problem solving, in the ability to adopt, maintain and change cognitive sets in the development of strategies and ideas;
- **the Language Field**, the performance increased in the ability to produce and access the memory words from phonemic categories, in the comprehension of the more complex receptive language, in phonological processing, in the rate/speed of processing and in organizing fluent verbal sequences, in processing and responding to verbal instructions with increased syntactic complexity, in the understanding of negation, of temporal, sequential or spatial concepts;
- **the Senzoriomotor Functions Core Domain,** in movements that require coordination of hands and fingers and hand-eye to generate new, rhythmic movements,
- **the Visual-spatial processing Domain,** in assessing the accurate perception of direction, in the ability to locate the item using the directional and spatial relationships from a short schematic sequence, in the coordination of spatial information with motor performance, in the ability to reproduce three-dimensional patterns based on the bi-dimensional or three-dimensional model (Korkman et al., 2007), in the integration of visual-spatial skills in coordinated motor activity, in the ability to visualize spatial relationships, in the ability to understand visual-spatial relationships, guidance and direction, as well as in the ability to transfer visual-spatial knowledge, orientation and direction to simple and complex schematic maps, in the ability of positioning objects in the space, and in the representational thinking that helps becoming aware that the map represents real spatial relations (Korkman et al., 2007);
- **the Memory and Learning Core Domain**, in the ability of verbal/nonverbal, immediate/delayed memory, in the ability of solving problems with several steps (students memorize and update from the memory the algorithm steps), in the initial encoding (learning),

maintenance and reproduction of arithmetic facts from the memory, of declarative knowledge and of procedural knowledge, in selecting the adequate strategies, in working memory.

In **the final evaluation**, the mathematical ability of the 29 subjects from the experimental group was assessed by the same calculation or mathematical reasoning, standardized tests used in the initial assessment: ***The Numerical*** and ***The Verbal and Numerical Reasoning test*** (Rey, 1967).

The quantitative results of the final evaluation (or post-test) for the experimental group of **the Numerical** test showed that the average is 22.6 (of the maximum 27 points), this meaning that students did not manifest mathematics learning disabilities any longer. The different average scores of the two evaluations suggest a level of significance less than 0.0005, being therefore highly significant to the threshold of $p<0.001$.

For **the qualitative analysis** of the results for the experimental group at the final evaluation of ***the Numerical*** test (Gaillard and Willadino-Braga, 2001), I calculated the averages of each item of the test to observe if the mathematical performance at the investigated skills increased or not. At the final evaluation the students solved 50% or over 50% of each item, their performance showing significant improvement (since the index of significance was at the threshold $p= 0.00$) at the following items:

- item 1: writing a series of numbers in numerical code in column or line, from top-down and bottom-up;
- item 3: alphabetical comparison
- item 4: transcoding from digital code (Arabic code) into alphabetical code
- item 5: calculation written conventionally
- item 6: transcoding of the numbers from alphabetical into numerical code (Arabic)
- item 8: correct placement of the given numbers on a vertical axis
- item 9: wrote rounded calculation or the approximation of calculation results
- item 11: alphabetical separation
- item 12: writing the dictated numbers in the alphabetical code
- Item 13: precise numerical knowledge
- item 15: counting tasks according to given requirements
- item 20: proposals of oral calculation
- item 21: assessment of oral calculation
- item 23: selecting from a given table of the handwritten numbers that have to meet certain requirements and that should be written in ascending order
- item 24: identification of the number of digits for each number written in alphabetical code

– item 25: assessment of the capacity of measuring speed
– item 26: assumptions of written calculations
– item 27: estimating the quantities in the context.

A highly significant difference at the p=0.01 threshold was also observed for the performance of the subjects at item 19 - that involves oral comparison of the given numbers. Less significant correlations were observed for item 7 -that involves correct spelling by underlining the number pronounced by the examiner from a string of six given numbers (0.006). Insignificant correlations were obtained for item 2 - that compares numbers written in numerical code (0.041), for item 10 - that involves writing some numbers from dictation in numerical code (0.112), for items 14 involving oral rehearsal and 17 -assessing the extent to which a number is incorrectly registered (0.326), for item 18 - that which involves counting the points from given figures (0.850) and a correlation not at all significant was observed for item 16 - that measures the alphabetical reading and for item 22 – that evaluates reading in numerical code (1.00).

The data shown above suggest that the subjects from the experimental group no longer present any deficits in the concept of number, calculation or problem solving, that they have acquired arithmetic facts as well as declarative and procedural knowledge by accessing them more quickly and more accurately from the memory.

The quantitative results of the final (or post-test) evaluation of the experimental group at **the Verbal and Numerical Reasoning Test** (Rey, 1967) indicated that the average is 13.96, a raw score situated in the centile 95-100, this proving that the students from the experimental group no longer have mathematics learning disabilities.

The correlation of the scores obtained at the initial and final evaluation with **the Verbal and Numerical Reasoning test** developed by André Rey (1967) for the experimental group revealed a significant difference at the threshold $p<0,001$.

From the **qualitative analysis of the final evaluation results** of the experimental group at ***the Verbal and Numerical Reasoning Test*** (Rey, 1967) it was concluded that subjects achieved good results both at ***the test of arithmetical signs*** where they used mature and adequate solving strategies (they accessed more quickly and accurately the arithmetic facts from the memory, without appealing to counting strategy), their arithmetical calculation was correct, since the mathematical signs were properly perceived and understood, and also at ***the test of numerical equality***, where the students proved a good planning, self-monitoring, self-evaluation and self-control, that correlated with a good functioning of working memory, led to a reasoning in solving the items and there were no longer logical errors or lack of planning, therefore the students completed the gaps of the equalities in a satisfactory way.

The results above showed that the subjects from the experimental group improved their mathematical performance through the program for stimulation of the cognitive processes involved in the mathematics learning disabilities, this leading to the assimilation of the concept of number, to the development of calculation skills and of solving problems. Therefore, the null hypothesis was invalidated and ***the last specific hypothesis of the research was accepted,*** i.e. ***the stimulation of the cognitive processes with deficits in domains like attention/executive functions, language, senzoriomotor, visual-spatial and memory/learning through the educational cognitive program improves the performance at tests on mathematics learning disabilities (the neurocognitive test for learning Number and calculation entitled the Numerical and the Reasoning Test proposed by André Rey) of third grade students with mathematics learning disabilities, thus contributing to the achievement of the objectives in the overall curriculum.***

Data analysis and interpretation

The observations that could be withdrawn from the detailed analysis of test results assessing mathematical skills (of *The Numerical* test and of *The Verbal and Numerical Reasoning test*) suggest that the subjects did no longer manifest difficulties in mathematical calculation (caused by deficits in updating or in verbal access) and that the number of operand errors (caused by deficits in attention and in executive functioning), of algorithm errors (caused by deficits in working memory), of errors in the comprehension of the numerical system in base 10, as well as the number of difficulties in solving problems (caused by a verbal dysfunction) decreased. These types of mathematical difficulties were described by Feifer in his study since 2007.

The qualitative analysis of the results and of the qualitative observations (from the *Response Sheet* which is part of the testing materials) obtained by applying NEPSY Battery revealed a significant ***improvement both on the cognitive level***, by increasing performance in all targeted fields (attention/executive functions, language, visual-spatial, senzoriomotor, memory and learning) ***and on the behavioural level***, the students manifesting no more frustration, hyperactivity, stress or anxiety during the testing. ***On the educational level***, these led to the increase of mathematical performance for the students in the experimental group. These findings show that ***the overall objective of the intervention program*** was achieved, that the difficulties in acquiring number, in calculation and in solving problems were reduced by stimulating the cognitive processes involved in the mathematics learning disabilities of primary school students.

The use of specific methods and strategies for stimulating the poor cognitive processes, detailed in the Cognitive intervention program developed in Part A of Study III led to a better performance obtained by the subjects in the experimental group at the tests on the cognitive processes, this performance being correlated with that of the tests on mathematical skills, and therefore demonstrating that the final objective of the research was achieved, i.e. ***the Cognitive intervention program*** was implemented and its effectiveness in reducing the difficulties in learning numbers, in calculation and in problem solving was analysed.

Practical applications of the study

Carroll et al., (2006) support the implementation of validated intervention programs based on curriculum (Curriculum Based Measures) and on RTI (Response to Intervention) Models (Green and Bavelier, 2008), and the program that was developed and implemented in this study is founded on these theoretical assumptions.

The subjects from the experimental group were selected based on the *Response to Intervention model* (Carroll et al., 2006, Green and Bavelier, 2008, Fuchs et al., 2006), situated on "Level 3" - a stage that requires individualized intervention (Fuchs et al., 2006) - after a previous evaluation using curriculum-based tests (CBM - Carroll et al., 2006), e.g. *the Numerical*, where items were constructed according to the curriculum requirements of class III so as to assess the mathematical skills and to identify not only the existent difficulties but also what the child knows and is able to do, in order to develop an individualized intervention plan.

Based on the theories of mathematics learning disabilities and on the models of number processing, calculation and problem solving, taking into account the information from Study I (regarding the cognitive deficits) and the information from Study II (regarding the mathematical and/or test anxiety) identified at students with mathematics learning disabilities and the qualitative observations on the difficulties that children have in solving tasks during capture or collection of information (input), in the problem-solving phase (processing) and in the phase of expression, communication of the results (output) (Feuerstein, 2002) I developed a cognitive intervention plan, complete and comprehensive, that aimed to decrease all cognitive deficits involved in this disorder. Moreover, in addition to the cognitive strategies, this stimulation of the cognitive processes is augmented also by strategies of achieving transfer, by metacognitive strategies and by strategies for reducing mathematical anxiety, a complex approach that addresses all individual needs of the subjects, since individualized intervention plans could be derived from this general program.

Conclusions:

From the analysis of the results obtained for tests of the NEPSY Battery (targeting the cognitive process involved in the mathematics learning disabilities), the following observation could be withdrawn: the students from the experimental group had scores of the core domains like *attention/executive function, language, visual-spatial, learning and memory* in the same interval of 3-10 percentiles, this representing a result lower than expected.

Geary and colleagues (2008) stated that deficits observed at the children with mathematics learning disabilities externalized also in misrepresentations of number line and of the system that represents the size, magnitude of the numbers (Geary et al., 2008), deficits identified in Study I of the research, too, particularly at the *Numerical* test on mathematical skills, but also at the basic evaluation and additional tests for calculation difficulties in the *visual-spatial* domain of the NEPSY battery.

Acquiring the number line is mandatory in the curriculum, but it is also a field of study in the cognitive psychology and neurocognitive sciences because the representation of the quantities, (including of those underling the number line) may be founded on an intrinsic number-magnitude/size system supported by specific areas in the parietal cortex of the left hemisphere and, in particular, of the right hemisphere, so deficits in any of these areas would cause mathematics learning disabilities, particularly in the ability to represent the spatial number line (Geary et al., 2008).

The study of the Göbel and colleagues (2006) on repetitive transcranial magnetic stimulation in the parietal and occipital sites of healthy subjects provides further evidence supporting the use of spatial representations, i.e. the mental representation of number line (with the small numbers in the left site and great numbers in the right site) in basic numerical processing tasks, for example finding the half of numbers.

Because the mental representation of the number line is very important in the development of the mathematical skills, at the beginning of the cognitive training, I performed activities for the acquirement and/or the development of number sense, as well as activities for the acquirement of the mental number line spatially oriented, based on the results of studies in the field (Baddeley, 1998; Dehaene and Cohen, 1995, 1997, Göbel et al., 2006; von Aster and Shalev, 2007; Geary et al., 2008). The number line was used for the calculation and problem solving throughout the training that is why it was attached on the desk of the subjects with deficits in the visual-spatial field, so that they could permanently visualize it. The students also drew it as a support for addition, subtraction, multiplication or division. These activities resulted in the correct representation of the number size by the subjects, as shown in the studies of Noel and Russell (2011), to the development of the concept of number sense – that underlies the acquisition of the mathematical skills - as stated by Butterworth (1999, 2005), Butterworth et al., (2001), Mazzocco and Myers (2003), Butterworth et al., (2003), von Aster and Shalev (2007) and to the development of calculation and problem solving skills, the results of the final evaluation with *the Numerical* and the *Reasoning tests* representing a conclusive proof of the significant increase in the mathematical performance following the intervention through the implementation of the cognitive program developed in this research.

GENERAL CONCLUSIONS AND NEW PROSPECTS OF RESEARCH

THE NECESSITY OF THE RESEARCH:

The applicability of the neuroscientific research in the field of pedagogy has been limited so far (Kaufmann, 2008).

There is a great discrepancy between the development of psychology and the minimal application of this research in pedagogy, particularly in the methodology of teaching mathematics. This discrepancy occurs between the psychological and pedagogical plan because the notable and recent results of some multiple psychological research on the development of mathematical skills were not accounted in the Didactics and Methodology of this subject. A possible reason for that is the lack of such interdisciplinary research starting from the deficits that could lead to mathematics learning disabilities. A practical contribution of my research is the application of the theories and observations of the research on neurosciences and psychology in a novel context, the outcome of the three studies confirming the hypothesis that the program is efficient in the frame of the current Romanian education system.

The novelty of my research is that the part of improvement of mathematical abilities is focused on the problems related to gaining these abilities, a highly important approach for the Sciences of education, which has not been performed before.

The proposed program is complex and innovative, being structured according to the current mathematics curriculum for third grade students. It identifies the deficits and engages all the adjacent functions in learning mathematics based on the models and theories on mathematics learning disabilities and also based on the knowledge I gained in my teaching line experience (including the 17 years of teaching). Another element of novelty is the fact that there are mathematics exercises and problems within this program, proposed for the reduction of deficits implied in the mathematics learning difficulties, on the field of attention/executive functions, memory, learning, language, visual-spatial processing and senzoriomotor.

The undertaking of this research is based on the principle of chance equality in the improvement of mathematical performance, aiming for school failure/drop out prevention.

Fingers' gnosis or knowledge and discrimination of fingers is a complex function involving sequential memory and was assessed by the *Finger Discrimination* subtest from the senzoriomotor field of the NEPSY battery. Fingers are instinctively used by children as natural counters, the fingers of both hands are a mirror of the decimal system and their use helps both in the mental representation of numbers (by mapping an actual non-symbolic amount), in the abstract processing of the number and in acquiring the numeracy and the calculation skills. But, in addition to knowledge and discrimination of fingers, other processes are also involved in the mental representation of numbers, in numeracy and in acquiring calculation skills, e.g. visual-spatial abilities (with a role in the formation and development of the mental number line spatially oriented, and in the comprehension of Arabic decimal system), working memory (that facilitates handling the quantities in solving arithmetic tasks, monitors the procedures with multiple steps), language (helps in counting and reproducing arithmetic results from the memory) and fluid intelligence (facilitates the process of mapping between the concrete and symbolic arithmetic).

The results obtained at the initial evaluation of students from the experimental group with tests that assess the development of cognitive processes (NEPSY battery) and the tests on mathematical skills (*The Numerical* and *The Reasoning Test*) reveal that the deficits and the developmental delays that lead to mathematics learning disabilities may be related to dysfunctionalities of the central executive, including attention control and poor inhibition of irrelevant associations and/or difficulties in representing and handling information in the linguistic or visual-spatial systems, conclusions confirmed also by the results of Geary and Hoard (2005).

The comparison of *the Numerical test* results with those for the NEPSY battery helps us identify the general and specific deficits (e.g. at the initial assessment, student CC got a good score in the visual-spatial field of NEPSY battery, but she presented a poor arrangement of the numbers in line or column at *the Numerical test*) so as the individualized plans for intervention be effective in reducing them.

Anxiety, along with working memory, the central-executive component (with a role in the reproduction of arithmetic results from the memory) and the visual-spatial abilities, respectively (important in solving geometry problems or in solving algorithms that depend on analytical or pictorial approaches), are factors that influence the mathematical performance, hence the program developed in this research also includes strategies for reducing the mathematical and/or test anxiety.

The results of initial evaluation in my research confirm the conclusions of most researchers (Geary, 2004; Geary and Hoard, 2005; von Aster and Shalev, 2007; Wilson and Dehaene, 2007) that there are multiple deficits in the mathematics learning disabilities and therefore their dynamic evaluation, based also on the development of the calculation model, scientifically validated, taking into account the requirements of the mathematics curriculum and of the neuropsychological development of the child (by assessing the skills of the five core domains) could cause the development of some effective intervention programs to reduce this disorder (Kaufmann, 2008), for example ***the Cognitive Program*** elaborated in this research, *the final evaluation* results ***proving its efficiency***.

PERSONAL CONTRIBUTIONS

Theoretical contributions:

My research provides a bridge between the neurological, neuropsychological studies and education. The individual pyscho-pedagogical interventions implemented the results of the neuropsychological approaches, of the studied models and theories, as well as of my teaching experience for 18 years, achieving the improvement of poor cognitive processes involved in the mathematics learning disabilities of children from primary school.

The results of implementing *the Program to stimulate the poor cognitive processes involved in the mathematics learning disabilities in primary school students* provide new evidence to support the concept of "equal chances", the children with mathematics learning disabilities caused by cognitive deficits were helped to reach the maximum cognitive potential through specific strategies targeting the cognitive modifiability.

Methodological contributions:

I translated the Verbal and Numerical Reasoning test of André Rey (Rey, 1967) from French.

Both tests on mathematical skills (*the Verbal and Numerical Reasoning test* of André Rey and the neurocognitive test for acquiring number and calculation entitled *the Numerical* of Gaillard and Willadino-Braga) were adapted so that the tasks met the criteria of the overall curriculum for the third class. Moreover, I myself constructed the items of *the Numerical* test based on the methodological requirements and theoretical instructions of the test as well as on the general mathematics curriculum for the third grade.

The methods and strategies of cognitive stimulation proposed in the intervention program I developed were appropriate for the individual characteristics and age of the students with mathematics learning disabilities in primary school.

Practical contributions:

I considered that other variables - that influence poor performance in mathematics along with the immature development of cognitive processes - for example the school environment and expectations, prerequisites, parental involvement (Desoete et al., 2012), should be investigated, so I filled in the *History Sheet* with this information that was important for establishing the differential diagnosis.

To find out the difficulties that students faced, I also met their parents. "Parents' School" ran its course in group - the meetings' topics were etiology and symptoms of the mathematics learning disabilities, but also individually - to establish during the meeting, together with the parents and students, the short and long term goals of the personalized intervention plan according to the deficits involved and previously identified by the examiner through specific tests, after an initial written agreement of the parents regarding the examination of their children. These meetings encourage the practical involvement of the parents in the educational process.

The impact that the intervention and implementation of the elaborated program had on the parents was a little unexpected but nicely surprised me. The good results that the students obtained after the intervention inclined the adults -parents of the children enrolled in intervention program- to willing to continue their studies, by enrolling in the program "the Second chance".

The analysis and interpretation of the results of the post-intervention evaluation following the implementation of the program (that reduced the cognitive deficits involved in the mathematics learning disabilities of the students from primary education) developed **in the third study** of my research, and the findings in **the first and second study** proofs that the good performance at the NEPSY battery tests correlates with the performance obtained at the tests designed to assess the mathematical skills, like *the Numerical* and *the Reasoning test* and thus, the overall objective of the research, i.e. to develop an educational cognitive program for stimulating the poor cognitive processes in order to reduce this disorder was achieved.

The stimulation of the poor cognitive processes that leads to the reduction of the deficits identified and implicit, to the improvement of mathematical performance is only one outcome of this program; other important benefits are the development of metacognition and increased self-esteem, all these representing premises of preventing school failure and/or dropout.

As demonstrated in this research, the cognitive modifiability is possible since it is a concept that should be adopted in the pedagogical practice so that the multidisciplinary team (practically involved in developing and implementing individualized plans) transform, "a novice student" in "an expert student", as stated by Mih (2010).

My contribution to the development of this program lies in its uniqueness, novelty and importance in that it encompasses the theories and models that have been developed by researchers in the field of psychology, neuroscience, education, and in that the results obtained by the subjects prove the effectiveness of the intervention proposed.

The program is complete because it regards all cognitive deficits involved in the mathematics learning disabilities and associated deficits such as mathematical anxiety; it is also complex because at its development rests upon the theories, models and researchers' results in psychology, neuroscience and education, and because it is multifunctional since it could be used both for dynamic evaluation and intervention.

<u>LIMITATIONS OF RESEARCH</u>

In the Third Study, entitled ***The impact of the Psychopedagogical intervention program - elaborated for the stimulation of poor cognitive processes- on the mathematics learning disabilities of the third grade students with mathematics learning disabilities,*** I tested the efficiency of the elaborated program on the target group by comparing the results of this experimental pre-test and post-test group and the statistical difference was significant. It is worth to mention that it is extremely difficult to find a control group of participants to the study with mathematics learning disabilities because the deficits in attention, executive functions, language, memory or vizuospatial field are different, and the composition of the control group would be heterogeneous. Furthermore, there are studies observing that the deficits of executive functions that stand over the first school years, thus implying that school tasks do not develop executive functions according to the grade the student is in (second, third, fourth). Even if the study did not have a control group formed of third grade students with mathematics learning disabilities, the experimental group manifested significant differences.

In order to nationally validate *the Intervention program for stimulating the cognitive processes whose poor functioning lead to mathematics learning disabilities at primary school students,* a larger lot of subjects to benefit from this intervention would be necessary.

<u>NEW PROSPECTS OF RESEARCH</u>

The next goal for a future research is to standardize/validate *the curriculum-based battery for dynamic assessment,* and *the intervention program for stimulating the poor cognitive process involved in the mathematics learning disabilities at students in primary school* by increasing the lot of subjects.

Another objective is to print *the Student's Workbook* and *the Evaluator's Workbook* so that they could be successfully used by the fellow psychologists and pedagogues in assessing and stimulating the cognitive processes involved in the mathematics learning disabilities at the primary school students.

Mathematical software, the training of acquiring numeracy or some mathematical operations by means of music represent a complementary way to reduce deficits in mathematics (Green and Bavelier, 2008).

An international collaboration with professors from the United States has already been initiated. The first study will focus on rroma students with transcoding difficulties that affect school performance and on proposals of intervention for their improvement. The findings of this study will be correlated with the findings of the American colleagues for the study regarding "code-switch from black English" at American students from primary school, and the interventions they proposed to improve the school performances.

I am currently the coordinator of the Educational Center "Save the Children", from Cluj, where *The School dropout prevention program* has been implemented (program consisting of material support, social assistance, health care, educational support for homework and intervention programs for dyslexia, dysgraphia, mathematics learning disabilities, behavioral problems and improvement of social relationships). I intend to carry out projects in collaboration with the Save the Children Organization and with other NGOs, on the topic of early interventions at the primary, secondary and tertiary education level in order to reduce the dropout, illiteracy and school failure.

PSYCHO-PEDAGOGICAL RECOMMENDATIONS

Children with mathematics learning disabilities should benefit of curriculum adaptation at this subject because such an action would facilitate the subjects achievement of the standard minimal performance, the acquirement of the respective knowledge, basic abilities and skills, thus preventing the school failure - a possible cause of school dropout. This adaptation could be performed after completion of Level 1 of the intervention (when the subject fails to achieve the general curriculum in mathematics) (Fuchs et al., 2006), i.e. at Level 2 of intervention (when the subject is trained in a small group), but particularly at Level 3 of the intervention (when he/she is individually trained) – the case of my research.

As Munro stated (2003), the analysis of poor mathematical performance from a neurological perspective provides introspection into the causes and remedies of learning disabilities, introspection that is not available in other sources of information. This perspective enables us to identify patterns and consistencies in the students' performance that might otherwise seem disparate. Very likely the cognitive, educational and neuropsychological prospects will merge, resulting in an integrative understanding of the poor mathematical performance.

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