Neurosciences and Education: One example of a two-way cooperation

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Neurosciences and Education: One example of a two-way cooperation

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Abstract

The relationship between education and cognitive neuroscience is an old issue from which the idea of the 'neuroeducators' was proposed 25 years ago. The premise of this idea is that the knowledge about how the brain operates our learning could help teachers in the classroom. Despite of being an old issue, there are yet some unsolved matters. Firstly, how neuroscience and education could integrate biological understanding about learning cerebral process has not been yet clearly discussed. The present paper presents the results from Enscer–Teaching the Brain Project – that has been developed in Brazil for five years. During that time educators attended to neuroscience courses conducted by researches involved in the project, and were taught about brain learning mechanisms, language and arithmetic neural circuits and how this knowledge may be used for teaching the brain. On the other side neuroscientists were informed by educators about social and cultural demands for optimized learning. Good results came from this mutual relationship making us to believe that neuroeducation is a two-way traffic.
**Introduction**

The relationship between education and cognitive neuroscience is an old issue from which the idea of the ‘neuroeducators’ was proposed 25 years ago. The premise of this idea is that the knowledge about how the brain operates our learning could help teachers on their work (Cruickshank, 1981; Fuller and Glendening, 1985). From this premise, back in 1988 it was already established the Brain, Neurosciences, and Education SIG (a special interest group from the American Educational Research Association - AERA), the oldest organizational entity specifically dedicated to link research in the neurosciences and education. It is also the only organizational group in the world which annually hosts a peer-reviewed venue for authors to present papers on that subject.

Despite of being an old issue, there are yet some unsolved matters. Firstly, how neuroscience and education could integrate biological understanding about learning cerebral process has not been yet clearly discussed on previous papers, specifically regarding the teaching praxis applied not only in the schools but mainly in the classrooms.

Secondly, although the relationship between education and cognitive neuroscience can be profitable, it can also be damaging. Profitable because noninvasive brain imaging methods are providing unprecedented views of the structural and functional development of the child’s brain, and such new views of the maturing brain may provide relevant information to enhance educational practices (Fumiko et al, 2007). Damaging because, although there is a growing body of peer-reviewed papers acknowledging the progress of cognitive neuroscience studies about learning, simultaneously, there are questionable media reports and numerous others ‘brain-based learning’ claims that often oversimplify and misrepresent such works, allowing the flourishment of ‘neuromyths’ (Ansari and Coch, 2006).
Maybe by these questions, some scientists believe that there is a *gulf* between current neuroscience and direct classroom applications and that filling the gulf is still premature. Nevertheless, teachers are currently at the receiving end of numerous 'brain-based learning' packages. Some of these contain alarming amounts of misinformation, yet such packages are being used in many schools. What, if anything, can neuroscientists do to help good neuroscience into education? (Goswami, 2006). John Bruer (1997) argues that education cannot be directly informed by neuroscience, as the former is unable to generalize from specific details of neural functions to the cognitive behaviors observed in classrooms. His arguments constitute now the classical metaphor that neuroeducation is "*a bridge too far*". In an attempt to claim that this bridge is chimerical, Ansari and Coch (2006) proposed that multiple bridges can be built to make connections between education and cognitive neuroscience, including teacher training, researcher training and collaboration. These bridges – *concrete mechanisms that can advance the study of mind, brain and education* – will benefit both educators and cognitive neuroscientists, who will gain new perspectives for posing and answering crucial questions about the learning brain. Geake (2004) has questioned if information exchange between education and neuroscience is a two-way traffic or one-way street?

Bearing these questions in mind, the present paper presents the results from Enscer– Teaching the Brain Project – that has been developed in Brazil for five years. During that time educators attended to neuroscience courses conducted by researches involved in the project, and were taught about brain learning mechanisms, language and arithmetic neural circuits and how this knowledge may be used for teaching the brain. On the other side neuroscientists were informed by educators about social and cultural demands for optimized learning. Good results came from this mutual relationship making us to believe that *neuroeducation* is a two-way traffic.

The beginning
The project began as a course aimed to provide the teachers a better understanding of some subjects of interest to their classroom activities, namely: Intelligence, Memory, Attention, Learning, Neural circuits for oral and written language, Neural circuits for arithmetic, Learning Disabilities, Emotion and Behavior.

Almost 300 teachers of the Municipal Bureau of Education of Mogi das Cruzes, teaching students with learning difficulties, attended this course. An hour lecture introduced each subject, followed by an hour discussion to better promote its comprehension. For these discussions, teachers we:

a) asked to collect information about the student’s development history (HD), specifically about the pregnancy period, birth conditions and about s/he neuropsicomotor development.

b) instructed to investigate other cases of learning difficulties in their families; and

c) asked to submit their students to Enscer® standard tests, developed to characterize the student neurocognitive development concerning language and arithmetic.

This compiled data supported, in most of the instances, diagnose criteria regarding: attention and hyperactivity disorders (ADHD), dyslexia, dyscalculia, unspecific language development impairment, oppositional defiant disorder and unsocial behavior. They also helped educators to understand the possible physiopathology of the learning difficulties and promoted discussions about the best classroom program for these children.

The discussions resulted in:
1) proposing sets of special classroom activities to be used with both the students with learning difficulties and the students with no learning difficulties;

2) visits to the schools with the highest incidence of learning problems, in order neuroscientist to have a better idea of the daily problems faced by teachers with their students having learning difficulties and behavioral misconducts, and

3) deciding about the involvement of neurosciences at these high problematic schools in order to develop, through an one year program of meetings, new methods for promoting the school progress of children with learning difficulties.

The year neurosciences enrolled at the school

Two different elementary schools located in low socio-economic neighborhoods were selected: School One (S1) enrolls around 300 children from a countryside district and School Two (S2) enrolls around 1200 children from an affordable housing development. A high criminal rate plagued this late neighborhood. Around 25% of these students in these two schools failed in the standard test procedure and were considered as learning disabled children. High rates of familial learning disabilities, neurological impairments and psychiatric disturbances were observed. Stressed pregnancy and maternal health problems were common findings in the history of development of these learned disabled students. Bad behavior (hyperactivity, oppositional defiant disorder and unsocial behavior) was the main concern of teachers and principals of these schools, because high distress in school allied to learning difficulties, were responsible for high rates of school evasion. In general, the evading student joined teenager gangs and became involved in criminal offense.
The neuroscientists met the principal and the teachers of these schools twice a month for four hours session of discussions, and conducted standard academic and neurocognitive tests to better understand the students and the school problems. Teachers and principals were instructed to collect specific classroom information about their learned disabled and/or bad behaving students for the discussions. Data collected by both the neuroscientists and teachers were used to classify the underlying cerebral dysfunction; to decide about an intervention program and to explain the teachers how to interact and to promote the academic and behavioral progress of these children.

The elaboration of the Social Contract Rules defining the rights and duties for the learning disabled and/or bad behaving children and for the teachers and principals was one of the achievements of the second year. The rights and duties were defined taking into account the knowledge provided by neurosciences about the physiopathology of the ADHD, oppositional defiant disorder, unsocial behavior, etc. (e.g., American Psychiatry Association, 1994; Biederman, and Faraone, 2005; Michele et al, 2005; Sonuga-Barke, 2003), and aimed to help the children to improve his/her behavior. Also, these rules and duties were thought to reduce school evasion.

The discussions were also very helpful for establishing the main guidelines for developing classroom activities to improve the learning of these children. These guidelines took into account the knowledge provided by neurosciences about the physiopathology of dyslexia, dyscalculia, unspecific language development impairment, etc. (Bishop and Snowling; 2004; Fumiko et al, 2007; Naghavi and Nyberg; 2005; Nation, 2005; Temple, 2002; Trauzettel-Klosinski et al; 2006). Emphasis was put on semantic reading in comparison with phonological reading (Fumiko et al, 2007; Trauzettel-Klosinski et al; 2006), because many of the learned disabled students experienced late speech onset and suffer phonological disturbances. The traditional approach focusing on phonological reading put these children in disadvantage concerning the normal peers. In addition, emphasis was
also put on a procedural learning of arithmetic in comparison with semantic learning of mathematical facts (Rocha et al, 2005). Quantification and quantity manipulation (arithmetic) was assumed to be a visuo motor process instead of a symbolic reasoning (Rocha et al, 2005; Rocha, Massad and Pereira Jr., 2004).

**Neuroeducation starts**

The above discussed guidelines for teaching learning disabled children were used to develop a set of 3,000 different educational computer games (CG) following the Ministry of Education Guidelines for Kindergarten and Elementary School. Infantile subjects were used to develop CGs and a set of infantile characters were created to turn CGs more interesting (Figs. 1). This software is called ENSCER® and it was aimed to supported a controlled study of how neurosciences may support education of learning disabled children.

For such a purpose the Municipal Bureau of Education of Mogi das Cruzes selected 4 schools for homing the study: School 1 is far from downtown and enrolls children from a low social, economical and cultural environment; School 2 enrolls children from an affordable housing development program where drugs addiction plays an important role; School 3 enrolls children from different downtown neighborhoods and variable social, economical and cultural profiles, and School 4 is sited on a low middle class neighborhood.

ENSCER® was used to evaluate the cognitive development of 600 children enrolled in these schools: 400 of them considered LD by their teachers, and 200 (from the same classrooms) of them considered as mastering the school program (NO students). All students were tested on reading (Fig. 2) and arithmetic capabilities.
<table>
<thead>
<tr>
<th>Story</th>
<th>Letter recognition</th>
<th>Word recognition</th>
</tr>
</thead>
<tbody>
<tr>
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<td><img src="image" alt="Letter recognition" /></td>
<td><img src="image" alt="Word recognition" /></td>
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<tr>
<td>Word meaning</td>
<td>Phrase comprehension</td>
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<td><img src="image" alt="Word meaning" /></td>
<td><img src="image" alt="Phrase comprehension" /></td>
<td></td>
</tr>
<tr>
<td>Quantity recognition</td>
<td>Numeral recognition</td>
<td>Quantity/Numeral Association</td>
</tr>
<tr>
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<td><img src="image" alt="Numeral recognition" /></td>
<td><img src="image" alt="Quantity/Numeral Association" /></td>
</tr>
<tr>
<td>Manipulated Addition</td>
<td>Manipulated Subtraction</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 1 – Some educational computer games**
After listening to an illustrated story (Fig. 1), the student was requested, for evaluation purpose, to solve a set of CGs depending on his/her school degree and teacher’s evaluation:

a) **letter recognition**: match the suggested letter to one out of five other letters.

b) **word recognition**: match the suggested word to one out of five illustrated words on the same semantic group. Illustration provided the word meaning.

c) **word meaning comprehension**: match the suggested word to one out of five illustrations providing the meaning of words of the same semantic group.

d) **phrase comprehension**: match the suggested phrase to one out of five illustrations providing the meaning of five different scenes from the presented story.

and the tasks in the arithmetic tests are:

a) **quantity recognition**: match the suggested figure containing a given number of elements to one out of five other figures with different quantities of elements.

b) **numeral recognition**: match the suggest numeral to one out of five examples.

c) **quantity/numeral association**: select among five examples, the numeral that represents the quantity of elements of the suggested figure.

d) **manipulated addition**: choose the correct result for a one-digit illustrated summation.

e) **manipulated subtraction**: choose the correct result for a one-digit illustrated subtraction.

The student performance on this set of standard tests aimed to evaluate his/her reading and arithmetic capabilities, confirmed (with rare exceptions) teacher’s evaluation of the students as **NO** or **LD**. In general, **NO** children had an error rate around 20% in any of the tested activities, while the **LD** students attained an error rate greater than 60% (see figure 2). The **LD** performance on the different tests allowed them to be grouped into 4 different neurocognitive levels:
1) **Level LD1**: children having great difficulty in recognizing words and quantities;
2) **Level LD2**: children having great difficulty in reading words and associating quantities to numerals;
3) **Level LD3**: children having great difficulty in reading phrases and solving addition and subtraction, and
4) **Level LD4**: children having great difficulty in simple text reading phrases and solving multiplication and division.

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**Fig. 2 – The cognitive tests and group performance**

A – Percentage of children completing the task; E – Percentage of errors;
NO – Normal children; LD – Learning Disabled children.
The percentage of LD children classified in each of these neurocognitive levels is shown in figure 3.

![Bar chart showing distribution of LD children according to their neurocognitive development.]

**Fig. 3 – The distribution of LDs children according to their neurocognitive development**

Four different sets of other CGs, called here Instructional CGs were defined to be used to improve the academic progress of the LD children according to their neurocognitive development. To accomplish this, the LD children attended two hours sessions twice a week, to play these CGs in four laboratories specially designed for such a purpose. Teachers specially hired for these laboratories worked with groups of 5 children, each one using his/her own computer to play their scheduled CGs.

Data about pregnancy and delivery conditions, familial antecedents of learning disabilities, mental retardation and psychiatric illness, as well as about the neuropsychomotor development of the LD and NO students were collected and correlated with the academic performance on CG solution. The results (Rocha, Rocha and Massad, 2008a) disclosed interesting associations between maternal health, pregnancy and delivery conditions, familial antecedents and the neuropsychomotor development, as well as between this development and the academic progress.
The brain activity during CG solution was recorded in a subset of 123 of the LD students and 61 of the normal children. The results (Rocha, Rocha and Massad, 2008b) showed that LD and NO students use distinct neural circuits for reading and doing arithmetic, and that LD progress in these activities it is accompanied by changes of the neuronal enrollment for CG solution.

Most of the 2006 year was devoted to the development of both the evaluating and instructional CGs; the training of the hired teachers; the laboratories implementation; the student evaluation and the first essays with the instructional CGs in the laboratories.

**The year the results come out**

A group of 358 LD children was selected at the end of 2006 to start their training in the laboratories at the beginning of the 2007 academic year. They were distributed into 4 different training programs according to their neurocognitive evaluation:

**Language**

1) Training program 1 (TP1): included activities for oral word meaning understanding; for letter and written word recognition, and for oral phrases and texts understanding;
2) Training program 2 (TP2): included activities for word meaning understanding; to read words and for oral phrases and texts understanding;
3) Training program 3 (TP3): included activities for simple phrase reading and for oral texts understanding;
4) Training program 4 (TP4): included activities for phrase and simple text reading.

**Arithmetic**
1) **TP1**: included activities for quantity recognition; for quantity/numeral association and for set manipulation associated of union and separation of its elements according to specified quantities;

2) **TP2**: included activities for quantity/numeral association and manipulated addition and subtraction;

3) **TP3**: included activities for mental addition and subtraction operations; and solution of mathematical situations of sum and subtraction;

4) **TP4**: included activities for manipulated multiplication and division operations; and solution of mathematical situations of multiplication and division.

**TP1** was specially designed to **LD1** children; **TP2** for **LD2** students, **TP3** for the **LD3** and **TP4** was thought to help **LD4** people.

Data about the student’s performance - correct responses and errors - in each **CG** played during each instructional session, were annotated in ENSCER® data base together with the teacher’s report about how the planned activities were executed. Sets of **CGs** associated with the same cognitive task \( h \) (e.g., word reading, one digit summation, etc.), were played in the two training sessions of the same week.

The performance index \( I \) was calculated for each **CG** played by the student as \( I(CG) = 1 - \frac{\text{errors}}{\text{correct responses}} \) and also included in the data base. The \( I(CG) \) tended to 1 (\( I(CG) \to 1 \)) if the number of errors tended to zero; \( I(CG) \to 0 \) if the number of errors tended to be equal to the number of correct responses, and \( I(CG) < 0 \) if the number of errors outnumbered the number of correct responses.

The mean index \( \bar{I}(h,n) \) for all **CGs** associated with the cognitive \( h \) played during the week \( n \) was calculated as the mean of the corresponding \( I(CG) \) calculated for each played **CG** \( n \). The \( t \) of Student was computed to measure the statistical significance \( p(n,h) \) (for \( n > 1 \)) for the difference between \( \bar{I}(n,h) \) and \( \bar{I}(1,h) \), that its
between the index for the training sessions in the week $n$ and the index calculated for the first week. Table I display the calculated $\tilde{I}(n,h)$ and $p(n,h)$ for reading, quantifying, addition, and all these activities together and figure 4 illustrate $\tilde{I}(n,h)$ temporal evolution.

Table I – Performance: Means and statistical significance

<table>
<thead>
<tr>
<th></th>
<th>all activities</th>
<th>reading</th>
<th>quantifying</th>
<th>addition</th>
<th>subtraction</th>
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<tbody>
<tr>
<td></td>
<td>$\tilde{I}(h,n)$</td>
<td>$p(h,n)$</td>
<td>$\tilde{I}(h,n)$</td>
<td>$p(h,n)$</td>
<td>$\tilde{I}(h,n)$</td>
</tr>
<tr>
<td>1</td>
<td>0.613</td>
<td>0.569</td>
<td>0.706</td>
<td>0.640</td>
<td>0.458</td>
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<tr>
<td>2</td>
<td>0.709</td>
<td>0.285</td>
<td>0.636</td>
<td>0.452</td>
<td>0.634</td>
</tr>
<tr>
<td>3</td>
<td>0.721</td>
<td>0.068</td>
<td>0.666</td>
<td>0.435</td>
<td>0.662</td>
</tr>
<tr>
<td>4</td>
<td>0.709</td>
<td>0.095</td>
<td>0.61</td>
<td>0.437</td>
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<tr>
<td>5</td>
<td>0.712</td>
<td>0.103</td>
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<td>10</td>
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<td>0.034</td>
<td>0.697</td>
<td>0.01</td>
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</tr>
</tbody>
</table>

The evolution of the $\tilde{I}(n,h)$ calculated for all instructional activities showed that all LD children benefited from all training programs independently of their neurocognitive development. This academic progress changed from a 60% chance of correctly solving the instructional tasks at the beginning of the training program to 75% chance after 10 weeks (see table I). This means that after 10 weeks of training, the performance of the LD children was approaching that observed for NO students in the 2006 initial testing, since the NO mean error rate in that occasion was around 20%. The regression analysis (see figure 4) showed that the $\tilde{I}(n,h)$ improvement was constant and continuous during these 10 training weeks, because $\tilde{I}(n,h)$ was linearly correlated with $n$, and this correlation explained around 63% of $\tilde{I}(n,h)$ variance. The analysis of $\tilde{I}(n,h)$ evolution for the specific learning activities: reading, quantifying, adding and subtracting confirmed and expanded these findings.
Most of the reading activities in all training programs were concerned with word recognition and word meaning understanding, because LD1 group was composed by those children having great difficulty in word recognition; LD2 students were beginning to understand the meaning of the words and LD3 children were being able to understand very simple phrases. The reading error rate at the beginning of the training program was around 45% and decreased to 30% after 10 training weeks. This improvement was also linearly correlated with the number of the training sessions and explained around 55% of the $\bar{I}(n,h)$ variance.

The difficulty in quantifying experienced by the LD1 group was around 30% at the beginning of the year and decreased to 20% after 10 training weeks. This was the smallest observed improvement rate, but it must be noted that the observed difficulty at the beginning training program for this kind of activity was the smallest one. The linear dependence of $\bar{I}(n,h)$ on $n$ explained 75% of performance variance. Therefore, it may be concluded that, even in this case, learning was boosted.

\[ y = 0.0115x + 0.6547 \]
\[ R^2 = 0.633 \]
Addition Subtraction

Fig. 4 –The LD performance in the training program

The LD2, LD3 and LD4 groups trained addition and subtraction because even the LD4 children still experienced appreciable difficulty with these tasks in the 2006 testing. The mean success rate on addition was around 65% and on subtractions was around 45% at the beginning of the training program. Despite this initial difference successful performance in both activities attained around 80% after the 10 week training. This implies a high learning rate for subtraction in comparison to addition. This was confirmed by regression analysis showing that the learning rate for subtraction was 0.0267 for training session and for addition it was 0.174 (see figure 4). $R^2$ was around 85% for addition and around 62% for subtraction, showing that the linear dependence of $\tilde{I}(n,h)$ on $n$ explained most of the performance variance in both activities.
Conclusion

The above describes four years of a profitable two-way collaboration between neuroscientists and teachers that shows that neuroeducation is real (not a bridge too far) and promotes the academic progress of LD children. ENSCER is the initial small step of a long journey of a profitable joint endeavor of education and neurosciences.

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