A Study of 16 years old student learning strategies from a neuropsychological perspective: an intervention proposal

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Abstract

Scientific achievements related to brain processes provide innovation and improvements in students' learning. The aim of this study was to analyse, relate, and compare learning strategies and academic performance of students from a neuropsychological perspective. For this, we applied the ACRA scale to 438 students to evaluate learning strategies such as acquisition, codification, retrieval and information processing support. Further, we analysed the influence of these strategies on academic performance. The results reveal that, with respect to academic performance, the students show lower scores on acquisition strategies and retrieval compared with the others, and they show more difficulties in Language and Chemistry and Physics. We found that the use of strategies was related to enhanced academic performance for all the students. We also found differences in the use of all strategies depending on academic performance. Thus, we propose an innovative, neuropsychological and technological intervention program that focuses on learning strategies.

Keywords: neuropsychological abilities, learning strategies, performance, innovation, educational neuropsychology.

Introduction

Learning strategies are a key aspect in Educational Neuropsychology, given that they involve cognitive processes and brain activity that come into play when we face a learning task. Further, these strategies are not limited to the area of cognition, but they also refer to motivational and metacognitive matters that force the student to plan, manage and individually control their own learning process. This study focuses on the neuropsychological basis of the use of strategies by students, along with the relevant factors that have an impact on the learning process.

Neuropsychological basis of learning: superior thinking functions

The study of the relations between behaviour and brain is the main focus of Neuropsychology. These relationships can be studied via a range of multi-disciplinary areas such as Neuroscience and Psychology [1]. The study of the brain and its implications for education has become more prominent in the analysis of the anatomy, functioning and impact of learning [2]. Various studies have shown that both a developing brain and a mature brain can be structurally modified during the learning process [3, 4].

Many relevant results have been found in studies using neuroimaging technology that analyse the neuropsychological basis of learning strategies. These studies have provided important findings for education [4, 5, 6, 7, 8, 9, 10]. Moreover, these technologies are able to reveal the neuroanatomical basis of higher-order behaviours such as language, memory, and psycho-motor skills, where we can find a greater number of brain areas involved as the psychological process becomes more complex [2].

The human brain receives a great amount of information through different sensory pathways [11]. Its development has an impact on the way in which the information input occurs and, thus, on the coding, processing and storing mechanisms involved. It is well established that during the XXI century, one of the main aims of education was to consider the student to be the main agent in the learning process [12]. In order to achieve significant learning, the brain has a main role to play, given that it needs to establish neural connections with other existing connections [13].

The relationship between learning strategies, neuropsychological factors, and academic achievement

The majority of studies have focused on the causal relationship between strategies and achievement and, more recently, on the neuropsychological factors that have an impact on academic achievement [14].

For instance, [15] Beltrán (1993) conducted a study with students between 16 and 17 years of age, which showed the relevance of interventions that make use of strategies to optimise academic achievement. In addition, Tejedor, González & García [16] obtained similar results when they applied the ACRA questionnaire [18]. They found that exploratory attentional strategies were used more often by high achieving students and that the use of these strategies decreased throughout secondary school. Other authors point out the relevance of support strategies in academic achievement [18, 19].

Other related studies [20] have demonstrated a low level of visual-motor integration, verbal auditory discrimination and working memory in students between 13 and 16 of age with low academic achievement. They therefore suggested the need for neuropsychological intervention in order to improve academic achievement.

Authors such as Weinstein & Mayer, Monereo, and Beltrán (1993) [21, 22] define strategies as the actions that the students plan, begin, and control in order to reach goals. Román & Gallego [17] constructed the ACRA questionnaire and established the classification of these strategies based on classical theories of information processing levels and mental representation, which suggests that brain functioning is based on the development of the three basic cognitive processes i.e. acquisition, codification and storage, and retrieval and evocation. The use that the students make of such strategies when they learn can be classified into four scales (acquisition, codification, retrieval and support).

Several studies have focused on analysing these cognitive and affective strategies and their influence on achievement. However, only relatively few studies have analysed the relationship between thinking abilities and the neuropsychological processes of learning, in spite of the clear advantages of applying our knowledge from neuropsychology to improve learning processes within the educational system [2, 23, 24, 25, 26]. Moreover, some researchers suggest that teachers can better understand the brain through neurosciences, which could therefore improve the teaching process.

A. Neuropsychological basis of information acquisition

These strategies are the cognitive processes that select and transform the information from the context from sensory input, which then move to the short-term memory (STM). Sensory brain areas send the information to temporal, limbic, para-limbic, prefrontal and frontal areas for complete processing [27]. Further, whilst thought activity has been related to language and symbols, it is also linked with sensory perception and motor functioning [28].

Acquisition cognitive processes involve attentional and repetition strategies to acquire, select, transform and transport information from the context to short term memory, which allows for establishing new connections in order to create new ways of thinking.

There are exploratory attentional strategies that are often triggered by previous knowledge and that are activated when we have a clear learning objective and the information available is well organised. With respect to repetition strategies (the main function of which is to move the information received to the short-term memory) these can involve techniques such as aloud or mental repetition, which allows the student to store the information received through different sources.

B. Neuropsychological basis of Information Codification

Information codification strategies allow for the transfer of content from short-term memory to long-term memory, along with its integration with previous information. These strategies involve understanding and interpreting abilities and they also require sensory, motor, lateral, spatial-temporal, language and memory abilities [29]. For this, certain brain areas are activated, such as the occipital, temporal and inferior parietal cortex, temporal gyrus, and inferior frontal cortex, as well as the inferior frontal and temporal cortex for the lexical-phonological and semantic components [4, 5, 6, 8, 30, 31].

In addition, the frontal lobe aids abstract thinking, planning and higher cognitive functions, but the latter are influenced by the student´s attention, concentration and emotional state [31 32]. These codification processes require mnemonic, elaboration and organisation strategies in order to give meaning to the information. Moreover, working memory is a prior requirement for cognitive flexibility, strategic planning, and the rapid transfer of information to long-term memory.

First, mnemonic strategies are the most superficial type of codification and place a lower cognitive demand on the individual. Some examples of these strategies are rhymes or acrostics, which are used for superficial learning and facilitate the use of working memory for planning and transferring the information to long-term memory [33, 34].

The elaboration strategies can be reflected in simpler tactics that lead to intra-content associations (relations, images, metaphors, etc.) or in other, more complex tactics (applications, self-questioning, and paraphrasing).

Finally, organisation skills allow for the codification of the information through grouping processes, conceptual maps, logical sequences and diagrams, which give a higher significance and structure to the contents in order for these to be more accessible and manageable. For this, brain processes related to executive functions are activated such as: frontal lobes, associative areas, processes, and complex neuronal circuits that play a role in resistance to interference, filtering irrelevant information, and the inhibition of dominant patterns that are inappropriate during the execution of the task [35].

C. Neuropsychological basis of information retrieval strategies

The cognitive system requires the retrieval capacity of knowledge storage in long-term memory. Retrieval strategies facilitate *information searching* in memory, conditioned by the organisation of the knowledge in memory, by the codification strategies, and by the generation of an answer. Memory is a neurocognitive function, which forms the basis of the learning process [36], and that needs the activation of the prefrontal cortex circuits, the temporal lobe (hippocampus, amygdala, and entorhinal cortex), frontal lobe (dorsolateral, ventromedial and orbitofrontal areas), parietal lobe, diencephalon, basal ganglia and cerebellum [37]. The brain structures that are involved in working memory (verbal and visual), are the frontal lobe [38], (primary visual, auditory and association cortex, which also play a role in the performance of this executive ability along with language learning, writing and speaking learning, mathematics, and science [39, 40, 41].

D. The neuropsychological basis of processing support strategies

There are support processes that facilitate or obstruct the learning process along with metacognitive strategies that are related to neural circuits in prefrontal areas. Further, affective and emotional states related to the limbic system might play a role in all of these processes [42, 43].

As described in previous sections, various learning strategies and their neuropsychological basis have a general influence on the student´s performance, and they can either optimise or hinder the student's progress, thus provoking a higher or lower level of efficiency for the student while studying. Thus, we proposed a study of learning strategies with students with 16 years old, using an intervention program that encompasses the relevant neuropsychological factors, targeting students that tend to have lower scores on learning strategies.

Objectives

The main objective of this study was to analyse the relationship between learning strategies and academic performance in a sample of students of 16 years old. We analyse the results from a neuropsychological perspective and we propose an intervention program for those students that show low-medium levels of academic performance and strategy skills.

Our specific objectives were:

(1) To analyse the learning strategies (acquisition, codification, retrieval and processing support) used by 16 years old students and academic performance on each of their academic subjects.

(2) To analyse the relationship between the use of learning strategies and performance on a range of subjects.

(3) To analyse whether there are significant differences between the strategies that the students use depending on their academic performance (low, medium, or high)

We can thus propose the following hypothesis:

(1) Students, on the one hand, use often strategies to acquire and register their learning objectives and, on the other hand, present average levels of academic performance –their marks on the different subjects go around 5-.

(2) Those students, who use more frequently acquisition, codification, and information processing support strategies to learn, achieve higher scores on academic performance.

(3) The students that demonstrate good use of acquisition, codification, retrieval and support strategies, obtain generally better scores on academic performance.

Method

Population and sample

The target population for this study was obtained from a private high school that offers official education in health sciences, technology and social sciences. We recruited a total of 438 participants of 16 years old, 258 males and 180 female participants.

Instruments

In order to evaluate the Learning Strategies, we use the ACRA test: Learning Strategies Scale [17]. This test included four independent scales that evaluate the students' use of seven different acquisition strategies, thirteen codification strategies, four information retrieval strategies and nine processing support strategies. This test can be applied both individually or in groups. The student has to answer each of the items with four Likert like scores, which can run from "never or almost never" to "always". For each of the scales we can obtain a direct score that can be transformed into percentile scores.

Procedure

This study was approved by the Ethic Committee at the University and the management team of the school, through the guidance department. For each student, we obtained informed consent from the parent in order to apply the test. During application of the test, the students displayed an excellent level of cooperation after explaining the test and its objectives. The psychologist in the school submitted the results to the teachers in charge of each course. To obtain information regarding the academic performance of the students, the teachers provided us with numerical scores for the following subjects: Language, English, Philosophy, Environmental Knowledge, Physical Education and Chemistry and Physics.

Results

The results obtained from the descriptive, correlational, and comparative analysis of the data, using the statistical package SPSS, version 22 are displayed below.

Descriptive analysis for levels of learning strategies and scores per subject

At a descriptive level, Table 1 displays the means and typical deviation of the scores obtained by the students on the learning strategies scale.

Insert Table 1 here

It is clear from Table1 that the students obtained scores within the average range for the four scales. The highest scores were for codification and information processing support strategies. Table 2 displays the results with respect to the academic subjects.

Insert Table 2 here

These results show that the subjects with the lowest scores are Language and Chemistry and Physics whilst higher scores are obtained in subjects such as Sciences for the Environmental Knowledge and Physical Education (see Table 1).

Correlational analysis between the levels of learning strategies and subject scores

We carried out a correlation test using the Pearson Correlation Coefficient. Table 3 shows the results obtained for the relationship between the student´s scores on the various ACRA subscales and the scores on the different subjects.

Insert Table 3 here

The results from these analyses show that there is a significant correlation between the four learning strategies that were evaluated and all of the subjects.

Comparison between students with low-medium and high performance in the use of learning strategies

In order to evaluate the differences between the students with low, medium or high performance results, both in different subjects (Language, English, Environmental Knowledge, Physical Education, and Philosophy) and at a global level (average performance for all the subjects) we conducted one-factor ANOVA analyses. The data did not meet the homogeneity criteria for the variance, but we succeeded in obtaining identical results when carrying out a non-parametric test (*Kruskall-Wallis).* Table 4 shows the group means and standard deviation scores for each group in terms of global performance.

Insert Table 4 here

As shown in Table 4, the students with high performance were those that also displayed higher scores for acquisition, retrieval and support strategies. However, the highest score for codification strategies was obtained by those students in the medium performance group (*M*=57.34).

We detail below the results obtained when comparing all the groups for the use of acquisition, codification, retrieval and support strategies. We have selected those for which we found significant differences between groups with different academic performance.

Performance in the Language subject

Table 5 shows the results obtained on the language subject by the students in the various groups:

Insert Table 5 here

These analyse yielded significant differences between the three different performance groups for the Language subject in terms of the use of learning strategies (see Table 5). More specifically, a post-hoc test yielded significant differences between the following pairs: low<medium, medium<high, and low<high.

Performance in English

Table 6 displays the results of the comparison between the low, medium and high groups for the English subject in the use of learning strategies:

Insert Table 6 here

As Table 6 shows, groups low, medium and high performance for the English subject differ between them in terms of the use of learning strategies. There are significant differences between all the groups, low<medium, medium<high and low<high.

Performance in Environmental Knowledge

Table 7 displays the results of the comparison between low, medium and high performance groups for the Environmental Knowledge.

Insert Table 7 here

There are differences among the groups in terms of scores for this subject. The highest scores are for the high performance group, followed by the medium group, with the lowest performance group displaying the lowest scores.

Performance in Physical Education

Table 8 shows the results of the comparison between groups for the Physical Education subject.

Insert Table 8 here

As shown in Table 8, groups low, medium and high (performance) differ in terms of their scores on Physical Education (low<medium, medium<high, and low<high).

Performance in Philosophy

Table 9 displays the results for the group comparisons in terms of performance on Philosophy, regarding their use of learning strategies:

Insert Table 9 here

As shown in Table 9, groups low, medium and high differ in terms of the use of learning strategies for Philosophy. There are significant differences between all the groups:

low<medium, medium<high, and low<high.

Global performance

Table 10 displays the results for the comparison between low, medium and high global performance.

Insert Table 10 here

These analyses revealed significant differences between the global performance of the three groups in terms of the use of their learning strategies (see Table 9). More specifically, following the post-hoc contrast analyses, we found significant differences between pairs for all the groups: low<medium, medium<high and low<high.

Discussion

The main objective of this study was to analyse the learning strategies of 16 years old students, adding a neuropsychological perspective to strategies such as acquisition, codification, retrieval and support. There are other studies that have analysed learning strategies with students between the ages of 12 and 16 years [16, 44, 45, 46, 47, 48, 49]. Other studies have analysed the neuropsychological factors that influence the academic performance of students between 13 and 14 years of age [20]. There are relatively few studies, however, that have focused students around 16 years of age with low scores on academic performance.

Thus, we considered it relevant to investigate the learning strategies adopted by students of this age, in order to design and apply intervention programs that incorporate the latest scientific knowledge regarding brain functioning, with the aim of improving the studying strategies for students with low academic performance.

Our results show a significant correlation between acquisition, codification, retrieval and information processing support strategies, and the academic scores from the students for different academic subjects, without exceptions.

These results are consistent with other work that has analysed the neuropsychological basis of scholar failure, where students between 7 and 11 years of age that failed subjects such as Language and Mathematics were found to have a lower level of development in visual, auditory, motor, spatial-temporal, language and memory factors. Those students significantly differed from students that succeeded in all the subjects [14] in terms of the neuropsychological factors that have an impact on performance for students between 13 and 14 years old [20].

The results of Scale I for information acquisition reveal a lower level in the students and it would thus be convenient to exercise neuropsychological skills such as vision, audition, or sensory integration, which facilitate this type of strategy and which, according to Martín-Lobo [23, 29] have an impact on academic performance. In general, we found significant differences between the following pairs of groups: low and medium, medium and high, and low and high, and we therefore believe that it would be beneficial to apply neuropsychological skill programs, particularly for students in the low and medium groups.

The results of the Scale II of codification also reveal significant differences between groups low, medium, high and low and high, respectively. Thus, this result implies the need to improve codification and understanding processes in order to avoid comprehension issues such as problems with the Language subject or dyslexia, according to some studies that relate visual processes and visual skills with reading and learning [50], phonological awareness difficulties [51, 52, 53], and other neurocognitive risk factors [54, 55].

The results from the Scale III of retrieval show a lower level in this study, given the significant differences between the groups, low, medium and low and high respectively. These results can be explained, given the need to develop memory strategies from a neuropsychological perspective in order to apply them to the learning process, given that learning is a process that encompasses three basic processes that happen in a sequence: codification of the information, storage, and retrieval of the information [56]. Therefore, it is necessary to evaluate the memory level of the students in order to plan an intervention that can work both with short term and long memory [57].

The results of the Scale IV of support show significant differences between the groups low, medium, high and low and high respectively. Some authors highlight the role of affectivity and cognition in the learning processes [58, 59, 60, 61, 62, 63] and the impact of executive functions on Language performance, mathematics, sciences and inhibition capacity [64, 65].

Our global performance results reveal significant differences between the three groups of students from levels low-medium, medium-high, and low-high. These groups differ in terms of their use of learning strategies, which is in line with the findings of previous studies [15, 16].

There are some studies that have analysed the relationship between the neuropsychological factors and learning strategies in students aged between 13 and 16 years [20]. The authors found that 86 participants showed lower levels for visual integration, verbal auditory discrimination and working memory, but this was only the case for those participants with lower academic performance. The authors concluded that it is necessary to apply neuropsychological development programs in order to improve academic performance.

Our results imply the need to design an intervention program that makes use of the neuropsychological skills that form the basis of the strategies that have been analysed i.e. acquisition of information, codification, retrieval and support, for students that have low academic performance. Another objective of this intervention program would be to train educational psychologists and teachers of subjects such as Language, Physics & Chemistry, and Philosophy as well as the students that show a low-level use of strategies. In particular, the teachers and students could learn how the brain works while studying and, thus, improve their neuropsychological skills and their strategies and implement a personal plan for improvement and self-regulation of learning.

This program could potentially be used in schools, in guidance departments, the methodologies that are used in the classroom, or in Psychology centres that specialise in interventions with students with learning difficulties.

In conclusion, this study found that learning strategies are more developed in 16 years old students that have good academic performance. We therefore suggest that it would be necessary to apply a strategies questionnaire to students, as well as design programs to improve those strategies and neuropsychological skills such as information acquisition, codification, retrieval and support in order to use them with students with low and medium academic performance.

Finally, this study provides an innovative procedure for applying scientific advances in brain and learning strategies and the neuropsychological skills that are necessary to improve academic performance for students of 16 years old.

Intervention program proposal

Presentation/Justification

The results of this study show the need to carry out an intervention program to allow the students improve their academic performance with the use of learning strategies from a neuropsychological perspective.

This program will include activities for information acquisition, codification, retrieval and support strategies, based on Luria´s neuropsychological model [66], and programs to improve neuropsychological skills related to learning and strategies [23, 27, 28, 67, 68, 69].

Regarding the subjects, we would expect an improvement in mathematics, given that this subject shows the lowest performance. We will also take into account the fact that parietal areas are activated during numerical activities such as enumeration, comparison, quantity measuring and calculus [70, 71]. Thus, we will include object magnitude physical manipulation activities, more socially and culturally dynamic digital screens [72], and family activities [73]. The teachers would facilitate the transition from manipulating concrete objects to developing abstract concepts [74, 75], therefore improving understanding and thus the codification process [75].

The program includes activities for visual, auditory, visual-motor coordination, motor control, laterality development, spatial-temporal, language and memory, executive functions and specific strategies for information acquisition, codification, retrieval and support skills.

Information acquisition skills are cognitive processes that select and transform the information received by the students through exteroceptive senses in order to transfer it to the working memory and, thus, projecting the information to temporal areas in the brain [27]. Once the information is in the temporal lobe, the information codification strategies allow for the transfer of content from working memory to long term memory and its transformation, by integrating it with previous knowledge in a cognitive structure - with the implication of posterior cortical regions in the occipital and temporal cortex, inferior parietal regions, higher temporal gyrus, and inferior frontal cortex [29]. Once the information has been processed, the cognitive system needs to have retrieval capacity. For this, the limbic system plays an important role, given that variables such as emotions and motivation play a relevant role throughout the cognitive process.

Objectives

(1) To improve the strategies from a neuropsychological perspective
(2) To train teachers to incorporate a neuropsychological perspective when working on learning strategies with the students

Methodology

The proposed methodology is an active methodology where the student plays the main role in the learning process and is continually seeking to think in a critical and creative manner.

People involved

The key people involved are the management team, psychologist, teachers, and students, and their work is always carried out in association with the student´s parents.

Context

This is the educational centre where all teaching activities are carried out on a daily basis, as part of the classroom program.

Timeframe

Throughout a full academic year.

Resources

Neuropsychological and technological programs, digital board and didactic materials related to the contents of the subjects taught.

Activities

All the activities to be used will be adapted to the needs of the students in terms of their neuropsychological skills, thinking styles, and personality.

Knowledge acquisition strategies

Neuropsychological skills	**Learning skills**	**Technological programs**

Visual and perceptive skills Auditory discrimination Attention skills **Skills to select and transform context information** through the senses in order to transfer it to the working memory.	Lineal, idiosyncratic and epigraphic highlighting to achieve objectives. Study content revision using visual, auditory and visual language procedures.	Programs to develop attention skills such as "Find the differences". http://www.tudiscoverykids.com/juegos/ Programs to develop visual skills such as "puzzles". http://www.tudiscoverykids.com/doki/ Memory development programs such as "los memos". http://www.tudiscoverykids.com/juegos/

Information codification

Neuropsychological skills	**Learning skills**	**Technological programs**
Sensory integration skills to understand and transfer content to the cognitive structure. This process requires neuropsychological skills at a visual, auditory, motor, lateral, spatial-temporal, language and memory levels.	Codification searching (mnemonic, metaphorical, maps…) Key searching (keys, groups…) Strategies to generate responses that involve planning (free association, arrangement…), as well as the written response itself (writing, doing, applying…). - Memorisation - Organisation - Understanding and language expression	Tactile development programs on PDI or mobiles. http://genmagic.net/repositorio/displayimage.php?pos=-178 Auditory discrimination programs, such as: http://bit.ly/1UV3KAp Programs to develop laterality and spatial vision, such as labyrinths http://juegosflash.dibujos.net/puzzle/burbujas-acuaticas-.html Programs to develop spatial-temporal skills, such as timelines: http://aexy.club/tag/historia-de-la-ciencia-espanola-iv.

Information retrieval strategies

Neuropsychological skills	**Learning skills**	**Technological programs**
Memory skills - Short term - Long term	Use of conceptual maps in personal study.	Programs to develop mental and conceptual maps, both individually and in group.

		http://cmap.ihmc.us https://mind42.com/ https://www.mindomo.com/es/

Processing support strategies

Neuropsychological skills	Learning skills	Technological programs
Executive functions: sustained attention, organisation, integration and information management, working memory, inhibition, flexibility, planning, decision making. **Emotional self-regulation.** Emotions management.	**Metacognitive control.** Knowing one´s learning process, establishing objectives, controlling the degree of the necessary processes that are acquired and controlled. **Control of social-affective state or processes, including** anxiety states, expectations, attention. And also, the ability to obtain support, to avoid conflicts, to cooperate, to compete, and to motivate others.	**Programs to help the development of executive functions** as a whole, such as: http://bit.ly/1LYBrxe Development and learning of **self-regulation of emotions in the social network context.**

Depending on the results of the study, we will also use metacognitive strategies, a personal improvement plan, and cooperation with others. We will also focus on the correct study methodology for each subject, such as the use of diagrams, conceptual maps, and answer planning.

With respect to the familial context, we will inform the families about the results of the study and the personal improvement plan in order to establish targets that facilitate attention and a focus towards studying at home, with families learning how to constructively value children´s work.

Evaluation

We intend to evaluate if the procedure used with the students has been effective over a period of a year. For this, we could make use of questionnaires, presentations, conceptual maps, personal or group interviews, tasks, and tests with specific exercises.

Limitations

Although the sample in our study was extensive, we chose a private education centre and it would have been desirable to include students from different social-economical levels.

Future research prospects

To study the level of neuropsychological abilities of each student using specific tests to detect possible difficulties at neuropsychological levels. To apply the program proposed in this study and to analyse the results. To present the results of the application to the scientific community, school managers and teachers. To organise a research group including teachers from both the centres and universities to continue providing solutions and neuropsychology based programs to improve the school performance of the students.

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References

[1] M.J. Benedett, Metodología de la investigación básica en neuropsicología cognitiva [Basic research methodology in Neuropsychology], Rev. Neurol. 36 (2003) 457-66.

[2] M.L. De la Barrera, D. Donolo, Neurociencias y su importancia en los contextos de aprendizaje [Neuroscience and its relevance in learning contexts], Revista digital Universitaria. 10(4) (2009) 2-24.

[3] D. Bransford, A.L. Brown, R. Cocking, How people learn. Brain, Mind, Experience, and School, National Academy Press, 2003

[4] M. Posner, M. Rothbart, Influencing brain networks: Implications for education, Trends in cognitive Sciences. 9(3) (2005) 99-103.

[5] U. Goswami, Neuroscience and education, British Journal of Educational Psychology. 74 (2004a) 1-14.

[6] U. Goswami, Neuroscience, education and special education, British Journal of Special Education. 31(4) (2004b) 175-183.

[7] Y. Munakata, B. Casey, A. Diamond, Developmental cognitive neuroscience: progress and potential, TRENDS in Cognitive Sciences. 8(3) (2004) 122-128.

[8] M. Posner, M., Neural Systems and Individual Differences, Teachers Colleges Record.106(1) (2004) 24-30.

[9] S. Sereno, K. Rayner, The When and Where of Reading in the Brain. Brain and Cognition. 42 (2000) 78-81.

[10] N. Voets, P. Matthews, P., Clinical Applications of Functional Magnetic Resonance Imaging, Imagen Decisions. 1 (2005)

[11] A.R. Luria, El cerebro en acción [The brain in action], Barcelona, Editorial Martinez Roca, 1989

[12] P.R. Pintrich, A motivational science perspective on the role of student motivation in learning and teaching contexts, Journal of Educational Psychology. 95(4) (2003) 667-686.

[13] D. Manga, F. Ramos, Luria's Legacy and School Neuropsychology, Psychology, Society & Education. 3(1) (2001) 1-13.

[14] V. Santiuste, P. Martin-Lobo, C. Ayala, Bases neuropsicológicas del fracaso escolar [Neuropsychological basis of academic failure], Madrid, Furgaz, 2006
[15] J. Beltrán, Procesos, estrategias y técnicas de aprendizaje, Madrid, Síntesis, 2003
[16] F.J. Tejedor-Tejedor, González-González, M. García-Señorán, Estrategias atencionales y rendimiento académico en estudiantes de secundaria [Attentional strategies and academic performance in secondary school students], Revista Latinoamericana de Psicología. 40(1) 2008 123-132.
[17] J.M. Román, S. Gallego, ACRA: Escalas de Estrategias de Aprendizaje [ACRA: Scale of learning strategies], Madrid, TEA, 1994
[18] J.M. Bolivar López, F. Rojas Velásquez, Estudio de la autopercepción y los estilos de aprendizaje como factores asociados al rendimiento académico en estudiantes universitarios, Revista de Educación a Distancia. 1(44) (2015)
[19] J.L. Kholer Herrera, Rendimiento académico, habilidades intelectuales y estrategias de aprendizaje en universitarios de Lima, Liberabit.19 (2) (2013) 277-288.
[20] M.J. Sospedra, M. A. Vidal, Factores neuropsicológicos relacionados con el fracaso escolar [Neuropsychological factors related to academic failure]. Comunicación presentada en XIII foro internacional sobre evaluación d la calidad de la investigación y la educación superior, Granada, España, 2016
[21] C.E. Weinstein, R.E. Mayer, The teaching of learning strategies. En M.C. Wittrock (Ed.), Handbook of research on teaching, New York, McMillan, 1986
[22] C. Monereo (Coord.) Estrategias de enseñanza y aprendizaje. Formación del profesorado y aplicación en la escuela [Teaching and learning strategies. Teacher training and school application], Barcelona, Graó, 1994.
[23] J. Beltrán, Procesos, estrategias y técnicas de aprendizaje [Processes, strategies and learning techniques], Madrid, Síntesis, 1993.
[24] P. Martín-Lobo, La intervención desde la base neuropsicológica y metodologías que favorecen el rendimiento escolar [Intervention from a neuropsychological basis and methodologies that facilitate academic performance], en: P. Martín Lobo (Coord.), Procesos y programas de neuropsicología educativa [Processes

and programs in Educational Neuropsychology], Madrid, Ministerio de Educación, Cultura y Deporte: Centro Nacional de Investigación e Innovación (CNIIE), 2016 pp. 14-32

[25] M. Béjar, Neuroeducación. Padres y Maestros [Neuroeducation. Parents and teachers], Publicación de la Facultad de Ciencias Humanas y Sociales. 355 (2014) 49-53.

[26] F.M. Cid, Neurociencia y educación [Neuroscience and education]. Exeplum, 3 (2010) 267-274.

[27] T.N. Tokuhama-Espinosa, The Scientifically Substantiated Art of Teaching: A Study in the Development of Standards in the New Academic Field of Neuroeducation (mind, Brain, and Education Science), East Eisenhower Parkway, ProQuest, 2008

[28] M.A. Rendón, Creatividad y cerebro: bases neurológicas de la creatividad [Creativity and brain: neuropsychological basis of creativity], Aula. 15 (2012) 117-135.

[29] V. Gallese, G. Lakoff, The Brain's concepts: the role of the Sensory-motor system in conceptual knowledge, Journal Cognitive Neuropsychology. 22 (2005) 455 – 479.

[30] P. Martin-Lobo, Reading. Neuropsychological Processes of Learning Difficulties. Intervention Programs and Case Studies (Book in Spanish), Barcelona, Lebón, 2005.

[31] K. Sawyer, The cognitive neuroscience of creativity: a critical review, Creativity Research Journal. 23(2) (2010) 137-154.

[32] M. Moore Sholberg, Cognitive rehabilitation. An integrative Neuropsychological Approach, A division of Guildford Publications, New York, 2001.

[33] M.C. Etcheparaborda, L. Abad, Memoria de trabajo en los procesos básicos del aprendizaje [Working memory in basic learning processes], REV NEUROL. 40 (Supl 1) (2005) S79-83.

[34] A. Baddeley, The episodic buffer: a new component of working memory?, Trends in cognitive sciences. 11(4) (2000) 417-423.

[35] N. Cowan, Multiple concurrent thoughts: The meaning and developmental neuropsychology of working memory, Developmental neuropsychology.35(5) (2010) 447-474.
[36] S. Sastre-Riba, N. Merino-Moreno, M.L. Poch-Olivé, Formatos interactivos y funciones ejecutivas en el desarrollo temprano [Interactive formats and executive functions in early development], Revista de Neurología. 44(2) (2007) S61-S65.
[37] L.M. García Moreno, Psicobiología de la Educación [Educational Psychobiology], Madrid, Síntesis, 2014.
[38] D. Redolar-Ripoll, Neurociencia cognitiva [Cognitive neuroscience], Barcelona, Universidad Oberta de Cataluña, 2014.
[39] R.F. Allegri, P. Harris, La corteza prefrontal en los mecanismos atencionales y la memoria [Prefrontal cortex in attentional mechanisms and memory], Rev. Neurol. 32 (2001) 449-453.
[40] J.R. Best, P.H. Miller, L.L. Jones, Executive functions after age 5: changes and correlates, Development Review. 29 (2009) 180-200.
[41] M. Kyttala, J.E. Lehto, Some factors underlying mathematical performance: the role of viso-spatial working memory and non-verbal intelligence, European Journal of Psychology of Education. 23 (2008) 77-94.
[42] P. Martin-Lobo, El salto al aprendizaje: cómo obtener éxito en los estudios y superar las dificultades de aprendizaje. Palabra, 2006.
[43] D. Coleman, La Inteligencia Emocional. ¿Por qué es más importante que el cociente intelectual? [Emotional Intelligence: Why is it more important than intelligence quotient] (25ª ed.), España, Editorial Vergara, 2000.
[44] R.A. Chávez, A. Graff-Guerrero, J.C. García-Reyna, V. Vaugier, C. Cruz-Fuentes, Neurobiología de la creatividad: resultados preliminares de un estudio de activación cerebral [Neurobiology of creativity: preliminary results from an brain activation study], Salud Mental. 27(3) (2004) 38-46.
[45] N. San Emeterio, Relación entre el uso de técnicas de estudio y el rendimiento académico en el área de Ciencias de la Naturaleza de la ESO [Relation between

the use of study techniques and academic performance in Science subjects in secondary school], Mastery Thesis, Universidad DE Oslo, 2010.

[46] P. Miñano, J.L. Castejon, Variables cognitivas y motivacionales en el rendimiento académico de lengua y matemáticas [Cognitive and motivational variables for academic performance in language and mathematics], Revista Psicodidáctica. 16, (2011) 203-230.

[47] R. Ruiz, M. Tesouro, Técnicas de estudio en estudiantes de Secundaria que asisten a clases que asisten a clases extraescolares en la provincia de Gerona [Study techniques in secondary school students that attend extracurricular classes in Gerona county], Aula Abierta. 3 (2012) 125-136.

[48] A. Mejía Moreira, Incidencia de las técnicas de estudio en el rendimiento académico de los estudiantes del primer año del bachillerato de la unidad educativa PCEI temporal Patate [Impact of study technoques in academic performance of high school first year students from Patate PCEI temporal school unit], Mastery Thesis, Universidad técnica de Ambato, 2013

[49] A.C. Seder, H.B. Villalonga, Importancia de los hábitos de estudio en el rendimiento académico del adolescente: diferencias por género [Relevance of study habits in the academic performance of teenagers: gender differences], Educatio Siglo XXI. 34(1) (2016) 157-172.

[50] M.F.E. Villota, Hábitos y técnicas de estudio en la Universidad Mariana [Study habits and techniques in Mariana University], Revista UNIMAR. 31(2) (2014).

[51] S. Gori, A. Facoetti, How the visual aspects can be crucial in Reading acquisition: The intriguing case of crowding and developmental dyslexia, Journal of Vision. 15(1) (2015) 1-20.

[52] J. Hornickel, N. Kraus, Unstable representation of sounds: A biological marker of dyslexia, Journal of Neuroscience. 33, (2013) 3500-3504.

[53] J.D. Gabrieli, Dyslexia: A new synergy between education and cognitive neuroscience, Science. 325 (2009) 280-283.

[54] U. Goswami, Why theories about developmental dyslexia require developmental designs, Trends in cognitive Science. 7 (2009) 534-540.

[55] S. Franceschini, S. Gori, M. Ruffino, K. Pedrolli, A. Facoetti, Casual link between visual spatial attention and riding acquisition, Current Biology. 22 (2012) 814-819.

[56] S. Franceschini, S. Gori, M. Ruffino, S. Viola, M. Molteni, A. Facoetti, Action video games make dyslexic children read better, Current Biology. 23 (2013) 462-466.

[57] A. Caracuel, S. Santiago-Ramajo, A. Verdejo-García, M. Pérez-García, Rehabilitación neuropsicológica de la memoria [Neuropsychological rehabilitation of memory], in: A.L. Dotor Llerena, J.C. Arango Lasprilla (Eds.), Rehabilitación cognitiva de personas con lesión cerebral [Cognitive rehabilitation of people with brain damage], México, Trillas, 2014, pp. 105-119.

[58] J.A. Portellano, J.G. Alba, Neuropsicología de la atención, las funciones ejecutivas y la memoria [Attention, executive functions and memory Neuropsychology], Madrid, Síntesis, 2014.

[59] M. Ainley, N. Corrigan, N. Richardson, Students, tasks and emotions: Identifying the contribution of emotions to students' reading of popular culture and popular science texts, Learning and Instruction. 15 (5) (2005) Doi: 10.1016/j.learninstruc.2005.07.011.

[60] A. Buff, A. Reusser, K. Rakoczy, C. Pauli, Activating positive affective experiences in the classroom: "Nice to have" or something more?, Learning and Instruction. 21 (3) (2011) 452-466.

[61] A.C. Frenzel, R. Pekrun, T. Goetz, Perceived learning environment and students' emotional experiences: A multilevel analysis of mathematics classrooms, Learning and Instruction. 17(5) (2007) 478-493 Doi: 10.1016/j.learninstruc.2007.09.001

[62] T. Huk, S. Ludwigs, Combining cognitive and affective support in order to promote learning, Learning and Instruction. 19(6) (2009) 495-505.

[63] H. Jarvenoja, S. Jarvela, How students describe the sources of their emotional and motivational experiences during the learning process: A qualitative approach, Learning and Instruction. 15 (5) (2005) 465-480.

[64] R. Pekrun, The control-value theory of achievement emotions: assumptions, corollaries, and implications for educational research and practice, Educational Psychology Review. 18(4) (2006) 315-341.

[65] H.L. Clair-Thompson, Executive functions and working memory behaviours in children with a poor working memory, Learning and Individual Differences. 21 (2011) 409-414.

[66] H.L. Clair-Thompson, S.E. Gathercole, Executive functions and achievements in school: shifting, updating, inhibition, and working memory, The Quarterly Journal of Experimental Psychology. 59 (2006) 745-759.

[67] A. Luria, The working brain: An introduction to neuropsychology, New York, Basic Books, 1973.

[68] A. Plaza, Procesos y Programas de habilidades de pensamiento desde la base neuropsicológica [Processes and programs for thinking skills from a neuropsychological perspective], en: P. Martín Lobo (Coord.), Procesos y programas de neuropsicología educativa [Processes and programs of educational neuropsychology], Madrid, Ministerio de Educación, Cultura y Deporte: Centro Nacional de Investigación e Innovación (CNIIE), 2016, pp. 100-113.

[69] I. Martínez, Procesos y Programas neuropsicológicos para la lectura [Neuropsychological processes and programs for reading], en: P. Martín Lobo (Coord.), Procesos y programas de neuropsicología educativa [Processes and programs in Educational Neuropsychology], Madrid, Ministerio de Educación, Cultura y Deporte: Centro Nacional de Investigación e Innovación (CNIIE), 2016, pp. 114-122.

[70] S. Pradas, Neurotecnología [Neurotechnology], Madrid: Ministerio de Educación, Cultura y Deporte, Centro Nacional de Investigación e Innovación (CNIIE), 2016.

[71] M. Piazza, A. Mechelli, B. Butterworth, C.J. Price, Are Subitizing and Counting Implemented as Separate or Functionally Overlapping Processes?, Neuroimage. 15 (2) (2002) 435-446 Doi: 10.1006/nimg.2001.0980.

[72] S. Dehaene, M. Piazza, P. Pinel, L. Cohen, Three parietal circuits for number processing, Cogn Neuropsychol. 20 (2003) 487-506.

[73] S. Benarós, S.J. Lipina, M.S. Segretin, M.J. Hermida, J.A. Colombo, Neurociencia y educación: hacia la construcción de puentes interactivos [Neuroscience and education: towards building interactive bridges], Rev Neurol. 50 (2010) 179-86.

[74] M.G. Millá, Atención temprana de las dificultades de aprendizaje [Early care for learning difficulties], Rev Neurol. 42 (Supl 2) (2006) S153-6.

[75] S.M. Linder, B. Powers-Costello, D.A. Stegelin, Mathematics in early childhood: research-based rationale and practical strategies, Early Childhood Education Journal. 39 (2010) 29-37.

[76] L. Kaufmann, H.C. Nuerk Numerical development: current issues and future perspectives, Psychol Sci. 42 (2005) 142-70.

Table 1. *Means of Percentile Scores and Standard Deviation for learning strategies*

Strategies	***N***	***M***	***SD***
Acquisition	438	50.22	25.28
Codification	438	51.88	24.91
Retrieval	438	50.77	23.82
Support	438	52.99	23.24

Table 2. *Means and Standard Deviations for performance on different subjects*

Subject	*N*	*M*	*SD*
Language	438	5.15	2.01
English	438	5.36	1.98
Philosophy	438	5.33	1.92
Environmental Knowledge	438	6.15	2.79
Physical Education	438	6.48	1.65
Chemistry and Physics	438	5.28	1.97

Table 3. *Correlations between learning strategies and performance*

Variable	**Language**	**English**	**Philosophy**	**ncesContemporary**	**Physical Education**	**ysicsChemistry and**
Acquisition	.86**	.73**	.78**	.38**	.60**	.85**
Codification	.85**	.72**	.79**	.38**	.61**	.85**
Retrieval	.81**	.69**	.78**	.40**	.64**	.82**
Support	.79**	.65**	.75**	.37**	.60**	.80**

*$p<.05$ **$p<.01$

Table 4. *Percentile scores and Standard Deviations for different subjects and each of the groups*

Strategies	**Low** *N*=164		**Medium** *N*=163		**High** *N*=111	
	M	*SD*	*M*	*SD*	*M*	*SD*
Acquisition	26.31	16.98	54.94	14.90	77.71	11.05
Codification	28.64	18.25	57.34	14.55	51.88	24.91
Retrieval	29.20	18.80	56.85	14.92	73.02	12.13
Support	32.11	19.51	59.46	14.07	73.70	11.83
Total	116.26	70.83	228.59	52.72	301.83	40.36

Table 5. *ANOVA results comparing group means for Language performance*

Strategies	***F***	***p***
Acquisition	475.62	.000
Codification	401.95	.000
Retrieval	315.18	.000
Support	289.72	.000
Total	422.97	.000

Table 6. *ANOVA results comparing group means for English performance*

Strategies	***F***	***p***
Acquisition	268.14	.000
Codification	253.65	.000
Retrieval	199.90	.000
Support	173.12	.000
Total	247.69	.000

Table 7. *ANOVA results comparing group means for Environmental Knowledge performance*

Strategies	***F***	***p***
Acquisition	161.27	.000
Codification	170.85	.000
Retrieval	194.09	.000
Support	162.73	.000
Total	190.60	.000

Table 8. *ANOVAs comparing group means for Physical Education performance*

Strategies	***F***	***p***
Acquisition	97.84	.000
Codification	104.23	.000
Retrieval	121.13	.000
Support	101.06	.000
Total	115.08	.000

Table 9. *Results of ANOVAs comparing group means for Philosophy performance*

Strategies	***F***	***p***
Acquisition	291.84	.000
Codification	295.88	.000
Retrieval	273.42	.000
Support	230.44	.000
Total	309.92	.000

Table 10. *Results of ANOVAs comparing group means for Global performance*

Strategies	***F***	***p***
Acquisition	562.58	.000
Codification	521.84	.000
Retrieval	441.46	.000
Support	344.54	.000
Total	550.43	.000