Development of Logic Skills in High School Students: A Proposal Based on Neuroscience

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Abstract - This paper proposes a study on the development of logic skills in high school students, based on Neuroscience. In order to investigate the possible contributions of computational logic training to the development of logical thinking in high school students, our approach tries to identify possible changes in brain physiology pre and post computational logic training and to characterize brain activity during resolution of the logic test problems. To conduct this study, the collection of brain signals was required in two stages: before the training in computational logic and after it. The data were taken while the students solved some logic questions. From these data we analyzed the areas with greater brain activity during the resolution of each proposed question, which they were collected through non-invasive technique, using an EEG machine. The results of our study are promising, even that initial, because they can contribute to a better understanding of the brain areas that suffer post-training changes in computational logic, and the importance of teenager students learn computational logic.

Keywords – computational logic, Neuroscience, Brain-computer interface.

1. INTRODUCTION

Neuroscience studies the operation, structure and development of nervous system. Commonly treated as a branch of biology, it has become an interdisciplinary science, contributing to fields such as medicine, education, chemistry, computing, and so on. According to [8] “Current thinking argues that teenagers development thinking develop largely depending on the problems content and the contexts in which they are.” Hence the importance of providing intervention activities. Technology has offered several tools for young people to exercise skills such as logic, which plays a fundamental role in the ability to solve problems encountered in daily life. In this way, educational spaces can use technology as a tool in order to provide the opportunity for development of cognitive abilities in the students. In this scenario emerges the following questions: How provide the development of logical skills? Technological tools can contribute to this development? These questions have leveraged this work, which aimed to investigate possible contributions of computational logic training to the development of logical thinking in high school students. For that, it was necessary to identify possible changes in brain physiology pre and post training in the logic areas and to characterize the brain activity during the applications of a logic test before and after the training. Finally, we assess the competence/ability logical of students, thereby identifying possible gender differences. This work is structured in four sections. Section II presents all theoretical review in this area, treating about neuroscience and education, BCI (Brain Computer Interface) systems and cognitive performance and learning logic. Section III presents the methodology. Section IV presents a discussion about data generated. Finally, in Section V are presented the conclusions and further works

2. THEORETICAL REVIEW

a) Brain and Learning

The brain is the most important part of the nervous system, because it is the access to information awareness by the sense organs and we process these information, comparing them with our experiences and expectations, being able to modify our behavior and learn, creating the thinking, the judgment and the attention as results of its operation [4]. These capabilities are only possible because they are made through neural circuits, the neurons.

According to [4], as regards our species, it is known that no two brains are alike, but it can be said that “all have motor and sensory pathways that follow the same pattern.” And that these roads “are planned in genetic information of our cells and they built as our body develops inside the mother's womb.”

The nervous system begins its training in the first week of embryonic life. The authors point out that even in the first phase, the most important event is the continued division of stem cells, thus forming new neurons that, in a short period of time will significantly increase their small initial number, arriving in billions.

It is important to note the statement of [4], that says that "The interaction with the environment is important because it will confirm or induce the formation of nerve connections and, therefore, learning or the appearance of new behaviors stemming from.", because the nervous system in the early life has the highest plasticity index, the new synapses training capacity is very large, which is explained by the long period of maturation of the brain, which extends to the teenage years. However, even with a relatively low level in adult, nerve plasticity occurs throughout life, thus completing the learning capability is maintained even though requires a little more time and effort to occur.

In all process of development of the nervous system, one of the most important periods is corresponding to the time of teenagers, when there is an acceleration in synapse elimination process, a "synaptic chopping", which occurs in different regions of the cerebral cortex [4]. All theses changes that occur in adolescence prepare the individual for adult life. The increase in cortical cells is progressive during the period of childhood, but it declines during adolescence until the adult pattern, which reflects the learning potential optimization. At this stage reduces the learning ability of new information, but a gain in the ability to develop and use what has been learned.

According to cognitive neuroscience, learning and memory are closely related, where the memory the organic basis for learning occurs. Memorize is not the same as learning, but learning just occurs when the information is stored in our memory. To [11] "Memory is the process what is learned persists over time."

According to [12], learning emerges from an experiment, resulting in a change in engrama, i.e. the set of memories of the subject. Thus, the mental representations of these experiences are recalled because the memory involves the ability to redeem or recognize previous experience, featuring a memory trace.

In this way, when the learning creates opportunities for acquiring new knowledge, modifies the brain and the conduct of the individual. Memory is the process that retains knowledge over time [16].

In their studies, [3] points out that thinking, learning and memorizing are biological processes carried out in the brain, but they are distinct. Selective archiving, the evocation of information involves a number of neurobiological and neuropsychological processes that characterize the memory. Learning is decisive for thought, which derives from the ability to deal with the information in the areas of motor pool, sensory and mnemonic. But the thought is the benchmark for the guidance of behavior because its processing involves receiving, perception, understanding, storage, handling, monitoring and control essential to deal with the constant stream of data aimed at planning actions.

b) BCI and Brain Areas

The brain is the main component of the nervous system. It is the operation that exert mental functions such as concentration, thinking, learning capacity and motor control. These capabilities are implemented through neurons, which can currently be explained by neuroscience.

The human brain is divided into two hemispheres, right and left, initially it was believed that there was a dominant hemisphere and the other dominated. However, this concept has become outdated, and that there are actually two specialized hemispheres. Thus each hemisphere is responsible for a set of functions that end up working together.

Experiments revealed that the specialties of the hemispheres may differ, but hardly this specialty is exclusivity functional.

To [4], the left hemisphere is usually responsible for language processing, which in most people is much more competent that the right hemisphere in their perception and expression, with some exceptions, such as left-handed individuals who possibly may have areas of language located in the right hemisphere. To [13], the left hemisphere is also better on mental performance of mathematical calculations, in the writing command and its understanding through reading. Already, the right hemisphere is better perception of musical sounds and face recognition.

Although the left hemisphere is better in mathematical calculations, the right hemisphere is better in the detection of spatial relations, particularly in the metric quantifiable relationships which are helpful for our walking. The left hemisphere participates in these function, but with the ability to recognize spatial relations and qualitative categorical. Although each hemisphere has its specialty, they often complement each other, and the right hemisphere is especially able to identify general categories of objects and living beings, the left is that detects the specific categories.

In contrast to the complexity of the pattern of the human brain turns, anatomists usually grouped into major regions, called lobes, whose boundaries are not always accurate, but transmit an initial idea of regional location. The lobes are five: four externally visible and positioned inside the large grooves of the brain, the lateral sulcus [14]. These four lobes are: the frontal which is related to the forehead; the parietal, which is located under the cranial bone with the same name; the temporal, which is associated with the tempora; and the occipital, which is located in occipital cranial bone. The fifth lobe, the insula lobe can only be seen at the time it opens the lateral sulcus [8] [14]. There are many other structures situated in the central nervous system (CNS), which often are located inside, but in this work, we have used just the four major areas, the four lobes.

Each one of these regions have specialized functions: the occipital lobe is primarily concerned with the sense of sight is divided into multiple distinct visual areas in which the higher the primary visual cortex. The parietal is partially dedicated to the sense of touch, brings together body sensitivity functions and spatial recognition. The temporal lobe contains the primary auditory cortex, processes audio data, developed aspects of vision, language understanding and some aspects of memory. Finally, the frontal lobe which is essential for the planning cognitive actions, memory and movement [8] [13].

The BCI systems appear as tools that allow a communication method based on neural activity generated by the brain, without requiring any other type of stimulus, such as muscle movements created by brain commands. These are systems that use electrical signals detected on the scalp of cortical or subcortical surface areas. Their goal is to create interaction between the user and the external devices, such as computers, switches or prosthesis [15].

Hans Berger in 1929, presented papers on a device that over the years came to be known as electroencephalogram (EEG) [17], which could record electrical potentials generated by brain activity. From this idea, forty years later, the researchers were able to develop primitive control systems based on brain electrical activity.

UCLA project about BCI laboratory (University of California, Los Angeles), directed by Jacques Vidal, proved that the brain activity signals can be used to effectively communicate the user's intention [17].

Nowadays, BCI systems are tools that can help users communicate and perform daily activities, but which nevertheless have limited success and they mainly in research settings. However, they have been designed for users with mental and physical disabilities, for people who do not have any kind of disability and especially in entertainment, in the digital games industry.

Some of their features are to provide a new communication channel and expand the interaction of humans with the outside world (such as patients with neurological diseases). To assist in the rehabilitation of motor functions through equipment as neuroprostheses and to benefit the analysis of brain data to assist in the understanding of neurological activity.

c) Cognitive Performance and Logic Learning

A comparative study between video game players and no players [9] shows that playing video games provides advantages in different aspects of visual attention and spatial distribution. No players, after 10 days of training in video game action, have the ability to visual attention, spatial resolution and increased temporal resolution because demand detect targets, track items in the visual field and quickly change the action from one task to another.

This study was extended by [1], to involve tasks that require attention, memory and control of executive functions, and it revealed that video game players tracked objects more quickly, they detected changes in objects stored in short-term memory and advancing more quickly change tasks, in addition to the mental rotation of objects more efficiently.

With regard language and reasoning abilities, both of these skills influence on learning logic. Frequently, the logic is only associated with mathematics, not being perceived its applicability and its relation to the other sciences, among them linguistics, mathematics and computer science. The logic, according to [6] can be seen differently, as can be associated with the “correction of thought”, as one of its functions is to determine which operations are valid and which are not valid, making analysis of the forms and laws of thoughts. Also as part of philosophy, it searches answers to why it is thought one way and not another. As an art or a technique, it teaches to properly use the laws of thought. It is observed also that being the reasoning, the most complex form of thought, logic studies the “correction of reasoning”, studies and teaches how to bring order to the thought. Given these ideas, it is possible to note the importance of logic in life, not only as a theory but as practice, since, when a human wants to think, speak, write or act properly, he/she needs to put “order in thought”, using logic.

The importance of having a good logical thinking ability, it is essential for the individual to solve more efficiently problems of everyday life, which are often poorly structured problems. There are two classes of problems: well-structured or well-defined, and poorly-structured or poorly-defined .

The well-structured problems have clear resources, clear path for the solution, such as a mathematical formula. Poorly structured problems do not present clear and readily available resources to the solution. People who propose to solve these problems have difficulties to develop appropriate mental representations to model these problems and their resolutions. For such problems, much of the difficulty is to develop a plan to follow sequentially a series of steps that advance ever closer to the solution [18] [5].

When the theory of multiple intelligences was proposed, in early 1980, [7] highlights the logical-mathematical intelligence, which is the ability to perform numerical operations and done deductions. The author states that this way of thinking can be developed in a confrontation with the world of objects, since it is confronting objects, ordering them, rearranging them and evaluating their quantity that young children get their initial knowledge and more fundamental about the logical-mathematical ability. Considers further that it is during early adolescence, at least in Western societies studied by Piagetian, the child becomes capable of performing, formal operations. In this moment, they no longer operate only on own objects, images or mental models of these objects, but also on words, symbols or sequence of symbols that relate to objects and actions on objects. They are able to state a set of hypotheses and infer the consequences of each [7].

Returning to the influence of the social environment in the development of cognitive skills, undoubtedly the brain is modifiable by culture, because neuronal plasticity is possible to reconfigure the neural networks and rebuild knowledge. [18] points out that “Human intelligence is highly malleable. It can be molded and expanded by means of various types of interventions”. The adolescence is a time of intense brain development. Recent studies using brain images showed that there is a continuous maturation in the prefrontal cortex during early adulthood, mainly as a result of increased myelination, indicating that they develop axons while in a larger number of synapses (communication between neurons) and, therefore, increasing neural connections. This increase in frontal circuits in adolescence can support the development of new cognitive skills [8] [10].

According to [8], teenagers process information is faster, because they use processing resources more efficiently and have greater cognitive flexibility. Such efficiency of cognitive control during adolescence coincides with biological changes in brain development. Some authors point out that Piaget attributed the changes in teenagers thought to the emergence of formal operations. According to [2], the operative-formal stage, provides adolescents think logically about ideas that are not related to specific regarding the real world. “Typically, this stage is defined as the period during which adolescents develop operative schemes that allow them to think logically about abstract concepts”[2]. These authors still said that all adolescents and adults neurologically healthy have the capacity to formal logic, but only those whose life situations require this capability will actually develop it and the experience is an essential component of cognitive development.

d) Tool Collect Brain Signals

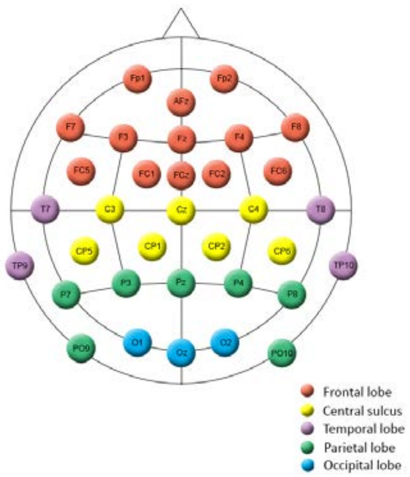
The tool that we have used to collect brain signals, called ActiChamp, was developed by Brain Vision LLC (www.brainvision.com/actichamp.html). It is modular amplifier system, which integrates large end components to electrophysiological analysis, as EEG, ERP (Event Related Potential) or BCI. The Actichamp is extensible for scanning up to 160 channels of EEG. However, it was used for data collection only a 32-channel module in combination with ActiCAP electrodes, which is a cap placed on the scalp, which uses the 1-20 standard with 32 electrodes in contact with the individual brain.

The signals acquired through the electrodes and sensors are amplified, digitized and then transferred to a computer via USB port, which enables the storage and display of data. Due to its high sampling rate of up to 100KHz and broadband, ActiChamp imposes new standards for neurophysiological research amplifiers.

The ActiCAP is connected to ActiChamp amplifier, making the transmission of data captured by the electrodes. In conjunction with the impedance converter, the electrodes have components that enable the system to capture amplifier impedances between the electrodes and the hairy skin of the user.

To have a better understanding, Figure 1 shows how they are distributed throughout the brain and its areas, that each capture electrode group, and the name of each channel.

The exact positions for each electrode are at the intersection of the lines calculated from measurements between standard landmarks on the skull. Also according to Figure 1, the name of each electrode, namely the letter indicates the region of the brain, where FP indicates the prefrontal lobe; F, frontal lobe; T, temporal lobe; C, the central groove; P, parietal lobe; O, occipital lobe. The number or the second letter identifies the hemispheric location, Z is the zero line in the center of the head; even numbers represent the right hemisphere; odd numbers represent the left hemisphere. The numbers are increased according increase the distance from the center [19].



Electrode locations related to 32 channels of Acticap (international standard "10-20").

The results of the analysis of brain signals based on the 3D topographic maps were validated on the basis of Neuroscience, with the aid of an expert in the field. Based on the literature, this expert formulated Table 1, which shows the brain regions as well as the electrodes spatially positioned as the international standard "10-20", regarding their features.

Table-1: Brain region, electrodes and proprieaty functions

Brain region	Electrode	Proprietary functions
Frontal lobe	Fp1,Fp2,AFz,F7,F3, Fz,F4,F8,FC5, FC1,FCz,FC2,FC6	Executive functions (management of cognitive / emotional resources on a given task)
Temporal lobe	T7,TP9,T8,T10	Perception of biological motion
Parietal lobe	P7, P3, Pz, P4, P8, P9,P10	Somatosensory perception, spatial representations and tactile perceptions.
Occipital lobe	O1,Oz,O2	View images (including during a dialogue).

3. PROPOSED METHODOLOGY

This work aims to study the development of logic skills in high school students, based on Neuroscience. In order, to investigate the possible contributions of computational logic training to the development of logical thinking in high school students. For that, it was essential to identify possible changes in brain physiology pre and post computational logic training and characterize brain activity during resolution the logic test problems. To conduct this study, the collection of brain signals was required in two stages: before the computational logic training and after this training. The data were taken while the subjects solved a logic test.

From these data, we analyzed the areas with greater brain activity during the resolution of each proposed question, which were collected through non-invasive technique using an EEG machine presented in section II-D, which is based on records electrical brain activity measurements by surface of the scalp. These electroencephalographic techniques have been frequently used for the acquisition of BCI signals.

To achieve the objectives, we adopted the following steps:

1. Applied the profile questionnaire and logic test, to select the samples (students);

2. Select the group of students that were analyzed (high school students);

3. Collected the brain signals before the computational logic training;

4. Computational logic teaching workshop, using the Scratch language, with 24 hours/classes, during two months;

5. Complete analysis of data;

5. SIMULATION/EXPERIMENTAL RESULTS

To collect the brain signals, we have obtained permission of the CEP (Research Ethics Committee at the Health Area, CAAE: 34417214.3.0000.5324) in our university, for both pre and post training collection training. The test application occurred individually, using the same logic test for the 3 students. The brain signals were collected during the execution of each test of logic.

For that each student, we defined a specific time, to do not have interference. The location of the collection was a

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secluded place, only with the presence of the researcher and an assistant.

Two hypotheses were formulated, one for each stage of the analysis (pre and post training), with the intention of ensuring that the assumptions are admissible.

Brain areas activated		Student 1	Student 2	Student 3
Question 1	Frontal lobe	X	X	X
	Left temporal lobe		X	X
	Parietal lobe	X	X	X
	Occipital lobe		X	X
Question 1		Right temporal lobe	Right temporal lobe	Right temporal lobe
		Central sulcus	Right central sulcus	Prefrontal cortex
		Prefrontal cortex		
Question 2	Left frontal lobe			X
	Right temporal lobe	X	X	
	Right parietal lobe	X	X	X
	Occipital lobe		X	X
Question 2		Right frontal lobe	Right frontal lobe	Right temporal lobe
		Prefrontal cortex	Left temporal lobe	Right prefrontal cortex
		Left central sulcus	Left parietal lobe	Left temporal lobe
		Left parietal lobe	Right central sulcus	
Question 3	Left temporal lobe			X
	Tempora lobe	X	X	X
	Left parietal lobe	X	X	
	Occipital lobe	X	X	X
Question 3		Left central sulcus	Right frontal lobe	Right frontal lobe
		Left prefrontal cortex	Right parietal lobe	Right prefrontal cortex
			Right central sulcus	Right parietal lobe
Question 4	Frontal lobe		X	X
	Left temporal lobe		X	X
	Parietal lobe	X	X	X
	Occipital lobe	X	X	X
Question 4		Right temporal lobe	Right temporal lobe	Right prefrontal cortex
		Left central sulcus	Right central sulcus	
		Prefrontal cortex		
Question 5	Left frontal lobe			X
	Right temporal lobe	X	X	
	Parietal lobe	X	X	X
	Left occipital lobe		X	X
Question 5		Right prefrontal cortex	Right frontal lobe	Right frontal lobe
		Central sulcus	Left temporal lobe	Right prefrontal cortex
			Right occipital lobe	Right occipital lobe
			Central sulcus	

Fig.1. Summary of main areas activated during the first collection. The yellow cells correspond to the areas that should be enabled on each question. The "X" indicates that the individual has activated the corresponding area. The white cells correspond to the activated areas not expected. The "left" and "right" words indicate hemispheres.

The images were generated 3D format. In which represent an average of activation for brain areas, and more reliable information.

- Brain signals collection and analysis pre training

Hypothesis 1: The students without training in logical reasoning tend to activate different brain areas. According to [18], to solve ill-structured problems, such as logic questions, the biggest difficulty is to elaborate a plan to follow sequentially a series of steps that advance ever closer to the solution, favoring initial errors, making indirect paths and all types of errors. Thus, the domain knowledge and justification skills proved to be important for the resolution of problems. Therefore, since the individual has no good logical thinking ability, he/she will possibly be difficult to establish the correct sequence of steps to find the correct solution.

Figure 2 shows the areas that should be activated during the resolution of each logic question in the test before training. Moreover, it can be seen which areas had more activation and other areas that we were not expected activation.

For example in figure 2, we can see that the main areas that should be activated during the execution of Question 2 in the logic test in pre logic training: the left frontal lobe, right temporal lobe, parietal lobe and right occipital lobe. These issues are priorities on this issue because they involve space activity and recognition features.

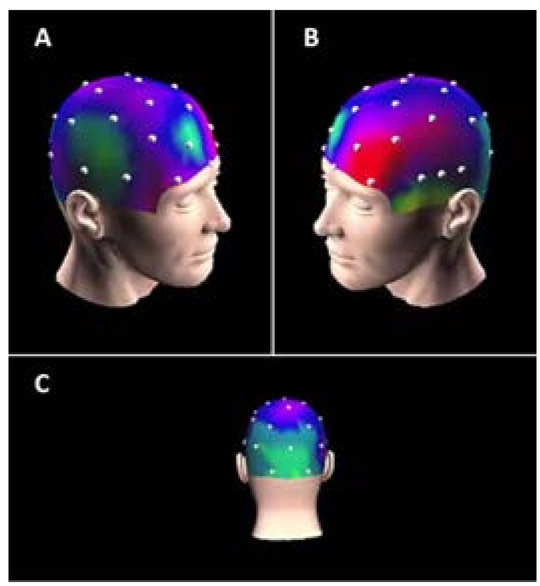

Fig.2. Main activated areas by the student 2 in the begin of the development of question during pre logic training.

Figure 3 shows the brain activity performed by the student 2 in the first moments of the development of the issue. It shows that were activated several areas beyond the expected, such as the right frontal lobe, left temporal, parietal and left central sulcus right.

- Brain signals collection and analysis after training

Hypothesis 2: Students with training in logical reasoning activate specific brain areas. In their studies, the authors [5] observed that individuals tend to activate brain areas less after practice exercises that involve reasoning. [18], in his researchers, states that the best students are more likely than less able to spend more time in the initial phase, deciding how to solve a problem and less time solving it effectively, because they spend more time in advance deciding to do, effective students are less likely to be victims of wrong beginnings, indirect routes and all kinds of errors. Thus, trained individuals are more likely to take shorter and direct ways to solve the problems (ill-structured problems), thus activating a smaller number of brain areas.

Brain areas activated		Student 1	Student 2	Student 3
Question 1	Left frontal lobe		X	
	Right temporal lobe	X		X
	Right parietal lobe		X	X
	Occipital lobe	X	X	X
Question 1		Right frontal lobe	Left temporal lobe	
		Left temporal lobe	Left parietal lobe	
		Left parietal lobe		
Question 2	Frontal lobe	X	X	
	Left temporal lobe	X	X	
	Parietal lobe	X	X	X
	Occipital lobe	X	X	X
Question 2		Right temporal lobe		Right temporal lobe
Question 3	Left frontal lobe		X	
	Tempora lobe	X	X	X
	Left parietal lobe	X	X	
	Occipital lobe	X	X	X
Question 3		Right frontal lobe	Right frontal lobe	Right parietal lobe
			Right parietal lobe	
Question 4	Frontal lobe	X	X	
	Left temporal lobe	X	X	
	Parietal lobe	X	X	X
	Occipital lobe	X	X	X
Question 4		Right temporal lobe		Right temporal lobe
Question 5	Left frontal lobe		X	X
	Right temporal lobe	X		
	Parietal lobe	X	X	X
	Left occipital lobe	X	X	X
Question 5		Right frontal lobe	Right frontal lobe	Right occipital lobe
			Left temporal lobe	
			Right occipital lobe	

Fig.3. Summary of the main areas activated during the post logic training collection. The yellow cells correspond to the areas that should be enabled on each question. The “X” indicates that the individual has activated the corresponding area. The white cells correspond to the activated areas not expected. The “left” and “right” words indicate hemispheres.

For example figure 4 shows the main areas that should be activated during the development of Question 2 the post logic training, which involves language skills are: the frontal lobe and left temporal lobe, parietal lobe and occipital lobe. Figure 5 shows brain activity performed by the student 2 in the first moments of the development of the issue. It shows that only were activated areas required for the execution of the exercise. It can be seen that the frontal, left temporal, parietal and occipital that show more activities.

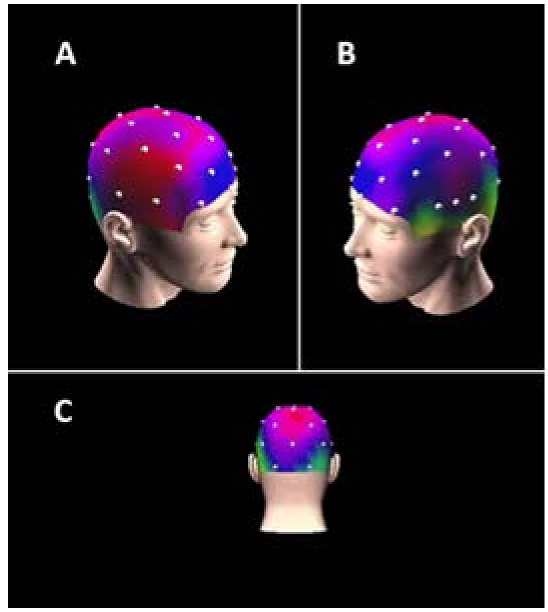

Fig.4.Main areas activated by the student 2 in the begin of the development of question 2 during post logic training.

During the collection of data to question 2 post logic training, we can note that just the necessary areas to develop this questions were activated.

6. CONCLUSION

This paper aimed to investigate possible computational logic training contributions to the development of logical thinking in high school students. To this end, we try to identify possible changes in brain physiology pre and post computational logic training, and also to characterize the brain activity during performing of pre and post logic tests. Basing to results, we can affirm that this study has been achieved satisfactorily.

Comparing the hypotheses 1 and 2, we can observe that there were changes in brain physiology, confirming both. As a first implication of the results, we can affirm that the students have more activated brain areas before done the logic training.

In computation area, this work is innovative, because are few studies related computational training and the capture of brain signals to analyze/monitor changes (physiological) during the learning of logic programming.

However, with regard to education (although not the main focus of this work), some questions were raised, such as: Is possible to provide such logic training education in basic schools? Are teachers able to develop these skills in the classroom? In this scenario, it is necessary to promote the revision of curricula of teacher, having continuing education.

In this context, it is vital to have a dialogue between academic research and the needs of the educational environment. For sure, it is the essence of university, makes concrete the idea of teaching, research and extension.

7. FUTURE SCOPES

As further works, we desire to do a study with more training time, greater numbers of individuals and along with the the signal acquisition using automated techniques of data mining to find more refined results, to do not compare just with 3D images. In addition, we want to deep the studies about gender differences in this area.

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