Measuring the differences between Spatial Intelligence in different individuals using Lyapunov Exponents

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Abstract. In this paper it is studied that there are statistically relevant differences in the brain activity intensity between subjects with an alleged higher development of Spatial Intelligence and those subjects without this alleged higher development. We will analyze their performance on a Spatial Intelligence task of identification, attention and recognition of virtual tridimensional geometric patterns. The interest group with alleged higher development of Spatial Intelligence was composed of Civil Engineering undergraduate students. These subjects are supposed to have a predisposition to develop the Spatial Intelligence, or develop it by exercising it in the everyday activities of the Civil Engineering undergraduate course. The other subjects are undergraduate students of Humans and Social sciences, who are supposed to have any special development in their Spatial Intelligence. The previous classification hypothesis was strengthened by applying a Battery of Reasoning Tests (BPR-5) to these subjects. We have recorded an 8-channel EEG from each subject during a Spatial Intelligence task of three-dimensional figures identification, attention and recognition. The EEGs were analyzed using their Largest Lyapunov Exponents (LLE) to test if they had statistically relevant differences between the two subjects groups brain activity.

Keywords: Electroencephalography, EEG, Multiple Intelligences, Spatial Intelligence, Chaos Theory, Lyapunov Exponent, LLE

1 Introduction

What is intelligence? This is a very old question, and one that has many answers but any of those is universally accepted. In this paper, we will focus on one of the many theories that were developed about the human intelligence. We will focus on Gardner's Multiple Intelligences Theory - which we will describe better on the next section (see section 2). Psychologists are studying for a long time ways to measure the capabilities of a person to help him/her to choose a carrier that will be more appropriate for him/her [21]. If we can know beforehand what kind(s) of intelligence a person is more prone to develop maybe this can affect the choices of his life.

In this paper we will show that there are statistically relevant differences in the brain activity of subjects with one kind of intelligence, the Spatial Intelligence, and of subjects who do not have any special development of this intelligence. The differences will be analyzed when the subjects are performing a Spatial Intelligence task of three-dimensional figures identification, attention and recognition. This task consists of showing two three-dimensional figures to the subject. After this process, he will be questioned if the figures were the same or not. More details will be given in the section 4, where we will describe the done experiments. Knowing that this difference exist we can go some steps further and try to recognize if someone has a developed Spatial Intelligence or not, but this is a problem for future researches.

It is well known that are observable differences in the brain systems that support working memory and attention control, leading to differences in general cognitive abilities between different subjects [10]. Gevins and Smith have used a Wechsler Adult Intelligence Scale(WAIS-R) test to classify subjects between ones with verbal cognitive style and with nonverbal cognitive style and have analyzed the differences between their parietal activation during work memory tasks. They have concluded that subjects with nonverbal cognitive style tend to have more right parietal activation and those with verbal cognitive style tend to have more left parietal activation [10]. Glass and Riding analyzed subjects in two different dimensions of cognitive style: wholist-analytic and the verbal-imagery dimensions [11]. The wholist-analytic dimension describes whether an individual tends to organize information in wholes or parts. The verbal-imagery dimension indicates whether an individual is inclined to represent information during thought, verbally or in mental pictures. Their experiment consisted in subjects viewing words presented at different rates then pressing a button if the seen word was in a target conceptual category. They have recorded the EEG from: i) midline, ii) paramedial and iii) lateral electrode clusters. The captured EEGs were processed using Fast Fourier Transform. The differences between the different cognitive styles were then analyzed and compared [11].

Vernon *et al.* have studied the effect of training distinct neurofeedback protocols on aspects of cognitive performance [28]. They used two groups of subjects: one that has neurofeedback-trained the theta activity $(4-7Hz)$ aiming to enhance their working memory, and a group that have neurorofeedback-trained the sensorimotor rhythm (SMR) activity $(12-15Hz)$ aiming to enhance their attentional processing. Comparing both groups with non-neurofeedback-trained control groups showed that the SMR-group were able to selectively enhance their SMR activity, as indexed by increased SMR-theta and SMR-beta ratios, while the group that have trained to selectively enhance theta activity failed to exhibit any changes in their EEG [28]. Zoefel *et al.* evaluated the neurofeedback-training of the upper alpha frequency band in enhancing the cognitive performance. They evaluated the cognitive performance of a subjects group that showed improvement over: i) themselves before training and ii) over a non-neurofeedback-trained control group, performing a mental rotation test [30].

Kothe and Makeig have done a comprehensive study of different techniques to estimate task workload from EEG [18]. [25]. Roberts e Bell have studied the parietal activation differences between male and female subjects performing 2-D and 3-D image rotation tasks [23]. During 2-D rotation tasks male subjects showed more left parietal then right parietal activation, and the female subjects showed more right parietal activation than left parietal activation (an inversion). In 3-D image rotation task both male and female subject showed more right parietal activation then left parietal activation [23]. Lange *et al.* have studied the coordinate processing during the left-to-right hand transfer [19].

The searching for a cognitive pattern in the Engineering undergraduate students was target of previous studies ([13][4][5]). One of the features of this pattern is a higher development degree in the Spatial Intelligence of the subject, and this will be the focus of our paper. Using EEG signals with Event-Related Potential(ERP) technique - a method which allows noninvasive electrophysiological measure of signals ranging from $2 - 20\mu V$(amplitude) and up to 100Hz frequency [20] - to record the cognitive attention process on 2D and 3D images was assessed by Spindola *et al.* [1]. These papers are the main inspiration for the present paper and the research performed by the authors.

The main difference between [13][4][5][23][11] papers and ours is the method we have chosen to analyze the EEGs. We have chosen to measure their Largest Lyapunov Exponent (LLE) instead of applying Fast Fourier Transforms over the EEG. Subha *et al.* describes the LLE as the rating which two initially arbitrarily close orbits diverge in the phase space [26]. The LLE is widely used to study chaotic dynamical systems. Measuring the LLE from a signal gives the reconstructed attractor (a system with the same topology of the system that generated the series) stretching (or contracting) rating in the phase space. Subha *et al* say that nonlinear techniques describe the signals generated by biological systems in a more effective way then linear techniques[26]. The reason behind it: EEG signals are highly non-Gaussian, non-stationary and have a non-linear nature [26].

In this paper, our subjects had their cerebral activity captured during the task described in the section 4.3. Their EEG were captured by using a 10 / 20 (Jasper - [15]) placement system and the electrodes we have used are: **FP1**, **FP2**, **F3**, **F4**, **T3**, **T4**, **P3**, **P4**. Their positioning in the subject scalp can be viewed in the picture 1. The guidelines of Luck were followed - use a few electrodes if the interest points are already identified in the scalp [20].

This paper is structured as follows: this introductory section gives a short overview of the paper itself. The section 2 gives a fast introduction to Gardner's Multiple Intelligences Theory. The section 3 shows the theoretical basis of the methods we have used to analyze the EEG. We will show our experiments in the section 4. We will use the section 5 to discuss the physiological basis behind the results, trying to explain what we have seen and why the observed behavior happened. Finally we will show our conclusions and the possibilities of following studies in this area in the session 6.

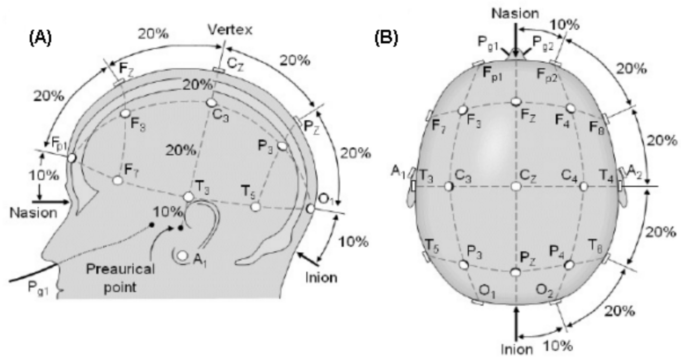

Fig. 1. 10/20 electrode placement system (Jasper)[15][2] views: left (A) and top (B)

2 Multiple Intelligences

In 1985 the psychologist Howard Gardner proposed a new theory about the human intelligence, his famous Multiple Intelligences Theory, which was presented in his book "Frames of Mind: The Theory of Multiple Intelligences" [7]. This theory says - in a rough mode - that humans have several kinds of different intelligences, each one concerned with a core of functions needed to perform the tasks of them. He listed (in this first publication and in the following ones: see [8]) 9 kinds of intelligence:

- **Bodily-kinesthetic :** how to use your body
- **Existential :** philosophical and religious questions
- **Interpersonal :** how to understand people
- **Intrapersonal :** how to understand yourself
- **Linguistic :** how to communicate: writing, listening and speaking
- **Logical-mathematical :** how to use logic and math
- **Musical :** how to play, listen and write music
- **Naturalistic :** understanding of the nature
- **Spatial :** how to manipulate the space inside your mind

Each one of these intelligences or special capabilities is concerned with some kinds of tasks. But every single task usually requires the interaction between two or more kinds of intelligence in different degrees. Persons who use more frequently a specific kind of Intelligence, let us say civil engineer undergraduate students, have an alleged higher development of the needed intelligence, for example, Spatial Intelligence. Otherwise they will develop this intelligence by using it in the cognitive tasks that are innate to the chosen course [4].

Other studies in the area of the Intelligence showed us that there are differences between the brain processes performed by subjects who have and who do not have trained their brain [28][30]. There are also differences between the functional model of male and female subjects, as showed in [23]. Somehow one can say that having Spatial Intelligence is the equivalent of have training it in a task. But the concept of Spatial Intelligence is far more abstract than a specific training for a task, so it needs to be addressed in a different way. For an overall view of the history, evolution, drawbacks and misinterpretations of Multiple Intelligences Theory in the last 20 years see [9].

3 Theoretical Basis

In this section we will show the theoretical basis of the Lyapunov Exponents. We aim to make clear the reason why we have chosen this measure to quantify and analyze the EEGs recorded during the aforementioned experiment. The main point here is show that the Lyapunov Exponents are linked with the volume of the attractor, and this volume can be used to measure the brain activity level, or the brain effort (energy spent) to perform the aforementioned task.

3.1 Larger Lyapunov Exponent (LLE)

The Lyapunov Exponent (λ) is the measure that represents the rating which two initially arbitrarily close orbits diverge in the phase space [26]. The LLE is widely used to study chaotic dynamical systems: if a system has one or more positive LE it is a chaotic system (without knowing the system initial condition we cannot predicted its future state), stable attractors give us a LLE of zero and trajectories we have a negative LLE [26].

Reconstructing the phase-space of the system is the first step to calculate the LLE. We need to transform the 1-D time-series $s(n); n = 1, 2, \cdots, N$ we have into a m-dimensional attractor in the R^m Euclidean Space. To create an attractor that preserves the topological properties of the original unknown attractor the most common method is the method of delays introduced by Takens [27][26]. The reconstructed m-dimensional vectors are in the form:

$$x_n = [s(n), s(n-\tau), s(n-2\tau), \cdots, s(n-(m-1\tau))] \quad (1)$$

where $s(n)$ is the original time-series, m is the embedding dimension and τ is the embedding delay. To estimate the embedding-delay τ (in samples) that we will use to reconstruct the attractor we can use the first minimum of the Mutual Information function as suggested by Fraser and Swinney [6]:

$$I(\tau) = \sum_{y[n], y[n+\tau]} P(y[n], y[n+\tau]) \ \log_2 \frac{P(y[n], y[n+\tau])}{P(y[n]) \ P(y[n+\tau])} \quad (2)$$

The most used method to estimate the embedding dimension (m) is the False Nearest Neighbor (FNN), suggested by Kennel *et. al* [17]. R_t is the arbitrary threshold point having false nearest neighbor. For each point in the time-series $\boldsymbol{S_i}$ let $\boldsymbol{S_j}$ be the look for its nearest neighbor in m-dimensional space. The distance between them is given by $\|\boldsymbol{S_i} - \boldsymbol{S_i}\|$. Iterate both points and compute:

$$R_i = \frac{|S_{i+1} - S_{j+1}|}{\|\boldsymbol{S_i} - \boldsymbol{S_j}\|} \tag{3}$$

We should choose, embedding dimension high enough so that the number of points for which $R_i > R_t$ is zero or very small [26]. The LLE can be calculated using the method proposed by Wolf *et al.* [29]: let us have a point X_0 and another point $X_0 + \delta_{X_o}$. Both points will create orbits in the phase-space, δ_x away one from another, which we can write as $\delta_x(X_0, t)$. The largest divergence rating is the LLE (λ) and can be computed as:

$$\lambda = \lim_{t \to \infty} \frac{1}{t} \ \ln \ \frac{|\delta_x(X_0, t)|}{|\delta_{X_0}|} \tag{4}$$

4 Our experiment

As previously said our goal is to show that are statistically relevant differences between subjects with a higher development of Spatial Intelligence and subjects without it performing Spatial Intelligence tasks. In the following subsections we will explain each one of the items of our experiments: i) the subjects and their classification, ii) the EEG capture equipment and process, iii) the Spatial Intelligence task performed by the subjects, iv) the signal processing technique used and v) the data analysis we have performed to assert our conclusions.

First, we will explain some abbreviations we will use in describing the following experiments:

- **M:** Subjects of the Male gender
- **F:** Subjects of the Female gender
- **S.I +:** Subjects with higher development of the Spatial Intelligence
- **S.I. -:** Subjects with no special development of the Spatial Intelligence
- **M +:** Male subjects with higher development of the Spatial Intelligence
- **M -:** Male subjects with no special development of the Spatial Intelligence
- **F +:** Female subjects with higher development of the Spatial Intelligence
- **F -:** Female subjects with no special development of the Spatial Intelligence

Another factor that will vary during our analysis is if we consider all data (**ALL**) or a specific electrode. If we are considering a single electrode we will refer it as **FP1**, **FP2**, **F3**, **F4**, **T3**, **T4**, **P3**, or **P4** in a table or figure. It is important to know the position of each electrode in the scalp. Viewing the scalp as in figure 1 **(B)** we have the electrodes positioned as showed in table 1:

4.1 Subjects

We analyzed 37 undergraduate students - 19 men and 18 women. None of them with known brain or cognitive issues. These subjects were divided in two groups, the ones with a supposed higher development in their Spatial Intelligence (23 subjects) and those with no special development of the Spatial Intelligence (14

Table 1. Electrode position in the scalp

Left-Side	Right-Side
FP1	FP2
F3	F4
T3	T4
P3	P4

subjects). This classification is based on their undergraduate courses: the ones with a supposed higher development of the Spatial Intelligence were Civil Engineering students, who need to imagine and transform the space in their minds to design buildings and other structures. The other subjects were students of Humans and Social sciences courses, and have no special development of Spatial Intelligence during their undergraduate courses.

We have used a subset of the Battery of Reasoning Tests BPR-5, which is a set of tests of Abstract, Verbal, Numerical, Spatial and Mechanical Reasoning used by Psychology professionals (see [22]) to strengthen our classification hypothesis choice. We have use the BPR5 - SR subset, which is focused on Spatial Reasoning (SR) as a tool to recognize if our subjects can or cannot be classified as aforementioned, having higher or ordinary development of the Spatial Intelligence. The BPR5 - SR subtest is composed of 20 questions. In each one of the questions there are cubes in different positions, indicating their movements. We can have constant movements, like: always turn up, or alternated ones, like: turn up then turn right the cube. The task is composed of 2 parts: first, recognizing the movement pattern performed in the cube, and second, assigning what should be the next cube if the following movement was applied. There is 5 options in each question and the subject has up to 8 minutes to do the entire subtest. We can see an example of a BPR5 - SR subtest question in figure 2.

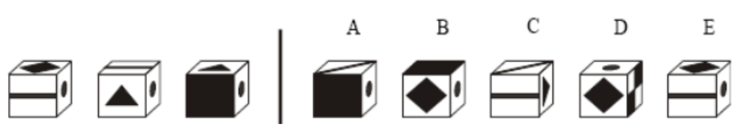

Fig. 2. One question of BPR5-SR subtest [22].

The tables showed in figure 3 display the results achieved by the subjects in the BPR5 - SR subtest, showing an easily spotted difference between the S.I. + **(A)** and S.I. - **(B)** groups.

4.2 EEG signal recording

The EEG equipment we have used was described by Carra *et al.* in [3], and used in previously works (see [4][5][1]). This equipment belongs to the CENT

(A) Total	23		S.I. +
Right Answers	% right	subjects	% S.I. +
20	100%	2	9%
18+	90%	7	30%
15+	75%	13	57%
10+	100%	22	96%

(B) Total	14		S.I. -
Right Answers	% right	subjects	% S.I. -
20	100%	0	0%
18+	90%	2	14%
15+	75%	3	21%
10+	100%	8	57%

Fig. 3. BPR5-SR test results. **(A)** is **S.I. +** group and **(B)** is **S.I. -** group results.

(Exact Sciences Center) center of CARVI (Vine Region Campus) campus of UCS (University of Caxias do Sul, in the state of Rio Grande do Sul, Brazil), where the EEG recordings were performed. A stretch cap with electrodes placed in the 10 / 20 system (Jasper - [15]) was attached to the subjects head for the EEG recording. We have recorded 8 different electrodes: **FP1**, **FP2**, **F3**, **F4**, **T3**, **T4**, **P3**, **P4**, so the guidelines of Luck were followed - use a few electrodes if the interest points are already identified in the scalp [20].

A water-based conductive gel was used to fixate the electrodes in the subject scalp, resulting in a better quality signal recording. Then we have used a reference signal - a predefined electric current - with the same intensity in each electrode, thus we can guarantee that all outputs will have the same amplitude. It is good to say that every channel has the same reference point (System Ground) in both inputs, which are configured to monopolar mode.

Every channel has a set of amplifier circuits with a total gain of 2000 times, separately we have: an instrumentation amplifier with a 12.4x gain, an adjustable amplifier that ranges between 2x and 101x gain and the filter gain, adjusted to 84x. Each channel has a high-pass filter with a cutoff frequency of 0.01Hz, which eliminates the DC signal (constant 0Hz frequency signal). A National Instruments 16 bit PCI-MIO-16E-1 board was used to make the Analog to digital conversion.

Our EEG system used the National Instruments LabView 8.0 [14] as its software of signal capture, digitalization, digital-filtering, signal processing, programming and visualization.

4.3 Spatial Intelligence task

The Spatial Intelligence task chosen was the identification, attention and recognition of virtual tridimensional geometric patterns. The possible patterns are showed in figure 4, as proposed by Shepar and Metzler in [24].

All subjects were exposed to six different combinations of the aforementioned patterns (showed in figure 4) that will be named figures 1, 2, 3, 4, 5, 6, respectively. We can see these stimuli at figure 5. Every exposition to a figure was recorded (an 8-channel EEG recorded) has 10 seconds of difference between them. The EEG was sampled at 1.000 Hz (1 KHz) and 800 ms (the figure exposition time) of cerebral activity was recorded in 8 different electrodes: **FP1**, **FP2**, **F3**, **F4**, **T3**, **T4**, **P3**, **P4**.

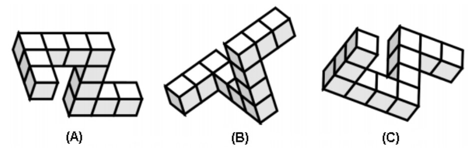

Fig. 4. Patterns used in the experiment [24].

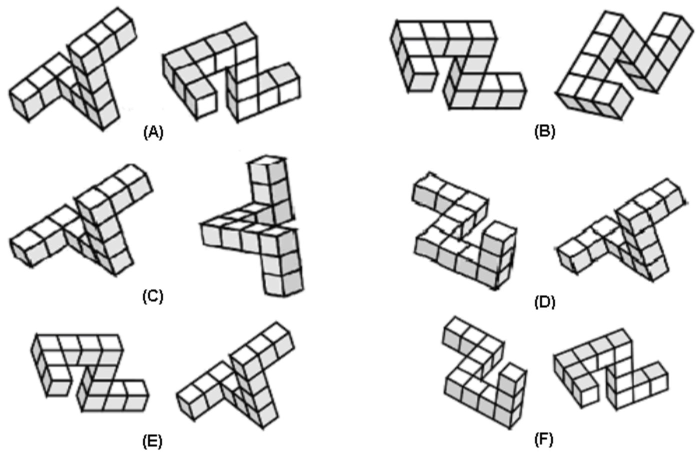

Fig. 5. The six different stimuli showed to the subjects: (A): $\neq$ figures, $=$ quadrants; (B): $=$ figures, $\neq$ quadrants; (C): $=$ figures, $\neq$ quadrants; (D): $\neq$ figures, $\neq$ quadrants; (E): $\neq$ figures, $=$ quadrants; (F): $=$ figures, $\neq$ quadrants; [24]

4.4 Signal processing: Largest Lyapunov Exponent

We have chosen the utilization of the Largest Lyapunov Exponent (LLE) of the EEG to describe the series behavior, as aforementioned. The reason behind this choice is the possibility to direct-link the LLE with the attractor's volume. The attractor's volume can be direct-linked with the energy spent by the brain during the task performance. The energy spent is a good measure of the effort done to perform the task [4][5][1]. We have used the TISEAN [12] to calculate the LLE of the EEG. We have chosen the Kantz method to calculate the LLE [16]. The table showed in table 2 displays some statistics about the LLEs we have calculated.

4.5 Data Analysis

And how we can claim that the subjects with a developed Spatial Intelligence are different from ordinary ones (with no special development of Spatial Intelligence) performing a Spatial Intelligence task? In a first analysis we can see figure 6. This figure shows us the LLE means for all subjects. We can clearly see that the subsets of subjects **S.I. +**, **M +** and **F +** have lower LLE means. This shows

Table 2. Data statistics

	Maximum	Minimum	Mean	Std. Deviation
ALL	0.07250	0.00080	0.03245	0.01203
F3	0.06110	0.00110	0.02831	0.00727
F4	0.07250	0.00140	0.02988	0.01082
FP1	0.06870	0.00760	0.03178	0.00998
FP2	0.06890	0.00630	0.03076	0.01091
P3	0.07240	0.00850	0.03309	0.01301
P4	0.06330	0.00080	0.02993	0.00740
T3	0.06790	0.00750	0.03180	0.01007
T4	0.07210	0.01370	0.04760	0.01625

that their reconstructed attractors have less expansion, dissipating less energy, implying less brain effort to perform the aforementioned task.

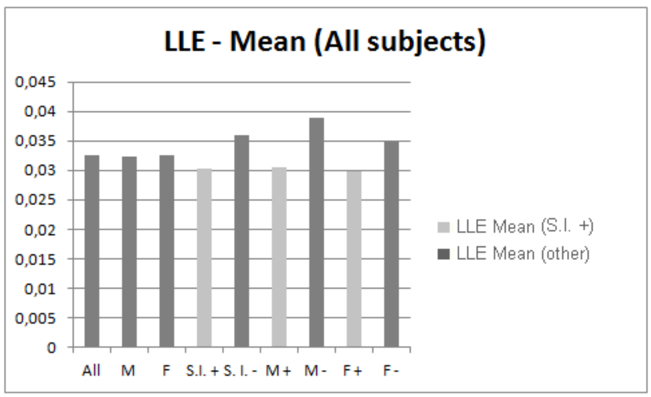

Fig. 6. LLE means for all subjects

The affirmation we have done in the previous paragraphs is sustained by the evidences showed in figures: 6 and 7, and in the table showed in table 3. We can easily see an equal qualitative behavior of the LLE means comparing **S.I. +** and **S.I -** groups with the other ones. And in every single electrode there is an akin behavior of a lower LLE mean in the **S.I. +** group and a higher LLE mean in the **S.I. -** group. We have the same qualitative behavior both in the system as a whole and locally, in each one of the electrodes.

We have chosen to perform a variance test over our data, testing if the subsets of subjects have the same variance in their LLE. Thus the null hypothesis is that both subsets have the same variance. We used a 95% confidence level to perform the Variance Test. The table showed in figure 8 proves our initial hypothesis in a statistical fashion: the rejection of the hypothesis of non-statistically relevant differences at a 95% confidence level.

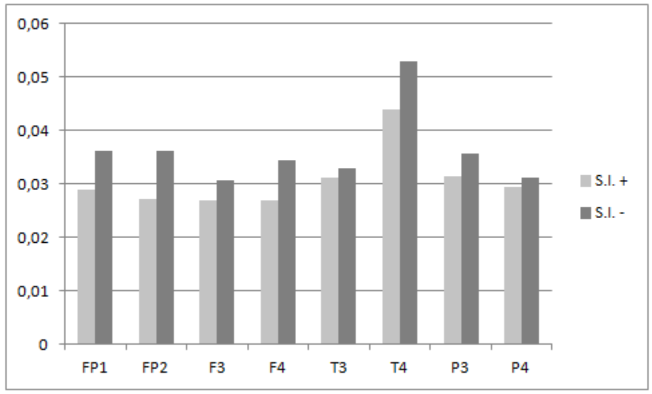

Fig. 7. S.I. + and **S.I. -** subjects LLE means in each electrode

Table 3. Differences between **S.I. +** and **S.I. -** LLE means

	S.I. + LLE-M	**S.I. -** LLE-M	difference	≈ %
ALL	0.03027	0.03595	0.00568	16%
FP1	0.02901	0.03621	0.00720	20%
FP2	0.02727	0.03629	0.00902	25%
F3	0.02684	0.03069	0.00385	13%
F4	0.02699	0.03451	0.00752	22%
T3	0.03110	0.03291	0.00181	5%
T4	0.04396	0.05301	0.00905	17%
P3	0.03130	0.03572	0.00442	12%
P4	0.02931	0.03105	0.00174	6%

Then we have done a Variance Analysis (ANOVA) over the data. The result is showed in figure 9, a **(**F**)** of 90.854 is greater than 0 - the critical σ - so we have statistical relevant differences between the intellects at a 95% confidence level.

The right hemisphere of the brain is said to have a greater activation during 3-D image processing [23]. Figure 10 shows it: we can see a greater activation of the Temporal (**T3**, **T4**) electrodes, being **T4** the most activated in the process. The sum of the LLE means in the left hemisphere of the brain is 0.12497, the sum in the right hemisphere is 0.13816, a difference of 0.01319, approximately 9.55%. Figure 11 shows the hemisphere differences between **S.I. +** group **(A)**: with left hemisphere sum of LLE means equal to 0.11827, right hemisphere equal to 0.12755, a difference of 0.00928, approximately 7.85%. Figure 11 **(B)** shows the hemisphere differences for **S.I. -** group: with left hemisphere sum of LLE means equal to 0.13555, right hemisphere equal to 0.15487, a difference of 0.01932, approximately 15.25%.

[ALL] S.I+ x S.I. -			
Descriptive Statistics			
VAR			
Mean	0,030228486	0,035952556	
Variance	0,00011496	0,000170022	
Standard Deviation	0,010721955	0,013039241	
Mean Standard Error	0,000338382	0,000521153	
Summary			
F	1,478960628	F Critical value (5%)	1,124876651
p-level 1-tailed	1,90E-08	p-level 2-tailed	3,79E-08
H0 (5%)?	**rejected**		

Fig. 8. Spatial Intelligence subjects versus Non-Spatial ones LLE statistical comparision

ANOVA

LLE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,012	1	,012	90,854	,000
Within Groups	,223	1629	,000		
Total	,236	1630			

Fig. 9. ANOVA analysis: **S.I +** and **S.I. -** (Intelligences) factor

5 Discussion

Together, the psychological evaluation performed by applying the BPR5 - SR subtest, which is strongly linked with the mental images representation and manipulation skills [22] and the methodology and instrumentation used in our experiment, lined up with the LLE and statistical analysis, offer a solid basis for our conclusions.

Our experiment showed that there are statistically relevant differences between the subjects with an higher alleged degree of Spatial Intelligence development and those ordinary ones. The LLE-mean difference between **S.I.+** and **S.I.-** groups is 0.00568 ($\approx$ 16%), ranging from 5% to 25% in each electrode. The main reason for this is the familiarity of the subjects with the class of cognitive tasks which includes the aforementioned Spatial Intelligence task. The nature of their undergraduate course (Civil Engineering) demands either they have a previous higher degree of Spatial Intelligence development or develop it by exercising cognitive tasks related to their academic studies [4].

During their undergraduate course the Civil Engineering students are stimulated to work mentally with geometric figures. It is widely known that when one is often submitted to some specific stimulus lesser will be his/hers respective brain activation. Subjects who domain a specific knowledge use a limited number of cerebral circuits to perform complex tasks innate to their knowledge domain. In the other hand, subjects who do not domain a specific knowledge

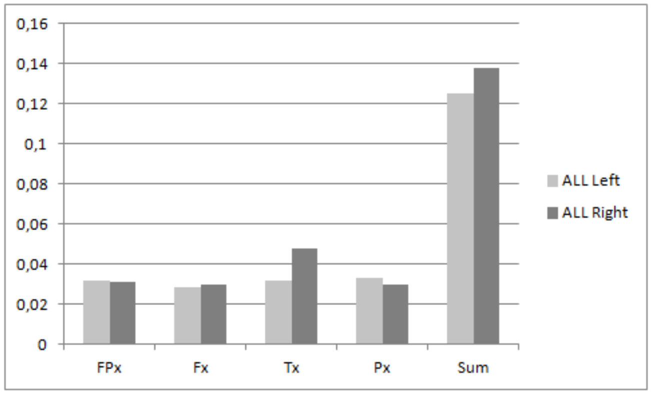

Fig. 10. Differences between left and right scalp-side electrodes

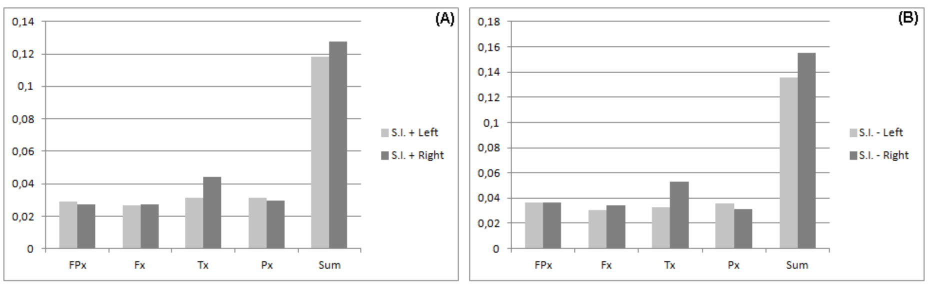

Fig. 11. Differences between left and right scalp-side electrodes in **(A)**: **S.I. +** group and **(B)**: **S.I. -** group

use a higher amount of cerebral circuits, some of them are even non-essential to perform the aforementioned task.

6 Conclusion and future works

In the previous section we have showed some experiments data that aimed to proof that are statistically relevant differences between subjects with a higher degree of Spatial Intelligence and those without it. Figure and 7 shows us a rough visual confirmation of the LLE mean difference between the subjects' subsets. This graphic gives an special attention for the **S.I +**, **M +** and **F +** subsets, those who are composed by the subjects with an higher alleged degree of Spatial Intelligence development - showing that these subsets have lower LLE means, implying less energy spent in performing the aforementioned task. Figure 7 shows that the **S.I. +** subjects have a lower LLE mean in every single electrode analyzed. This qualitative behavior is the same through the entire scalp. Finally the tables in figures 8 and 9 show that are statistically relevant differences between subjects with a higher degree of Spatial Intelligence development and those without it.

Knowing that there are quantitative differences between the brain activity of subjects with a higher degree of Spatial Intelligence development and those without it there is lot of room for future research. We can apply different measures and compare their sensibility, to seek the real dynamics of the underlying brain system involved in the task. We can also try to apply this knowledge to create automatic classification systems, for example: artificial neural networks, to detect if some subject do have or do not have a developed Spatial Intelligence, analyzing his EEG during the performance of a Spatial Intelligence task.

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