THE NEURODYNAMICS OF AN ELECTION

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Abstract: In October 23, 2005 a national referendum was carried out in Brazil about the prohibition of firearm commerce in the country. We combined classic poll opinion tools and electroencephalography (EEG) analysis to study vote decision one week before the referendum. Our poll opinion allowed people to provide us a second opinion on if and how they could change vote until Election Day. We also asked people to estimate the influence of media propaganda upon their vote decision. Here we show that election results were predicted by our poll if the vote migration disclosed by the second opinion was taken into consideration. We also found that vote decision correlated with the EEG recorded during vote decision-making. The estimated propaganda influence also correlated with the EEG recorded during the reading of 6 of the most frequent media advertisement and provided information to model the Vote Decision Space associated with the referendum campaign.

Introduction

Traditionally, rationality is claimed to be the core of political decision but neurosciences are disclosing emotion as equally important in political decision-making (Marcus et al, 2000; Hinich and Munger, 1996; Downs, 1957). Emotion was shaped by evolution as the tool to assess how adequate a behavior is for adapting individuals to the environment (Berridge, 2003; Panksepp, 1998; Graeff, 2003; Ledoux, 1996; Walter et al, 2005)**.** If action is successful the appraisal is joy, happiness, etc., otherwise the felling is pain, displeasure, etc. Also, emotion evaluates if the environment is supportive (agreeable, pleasant, peaceful, etc.) or life threatening (inspiring anger, fear, panic, etc.)

The rational elector is supposed to play an active role in politics, knowing the proposals of each party/candidate and being able to evaluate their benefits to the collectivity. Both are complex tasks and political campaign focuses discussions on a minimal number of relevant themes to reduce dimensionality of the vote decision space, **VDS** (Downs, 1957). Game Theory is at the core of the Spatial Modeling of Vote Decision (Hinich and Munger, 1996; Downs, 1957), proposing that rational elector: a) has precise and transitive preferences defined in **VDS**; b) uses procedures agreed by the majority of other electors to order those preferences and c) evaluates the proposals of each party/candidate as a function of the distance from those proposals and his/her preference in **VDS.**

Stability of individuals as singular entities is dependent on environmental demands. So, environments are classified as *friendly* (inspiring pleasure) (Berridge, 2003; Panksepp, 1998), *neutral* or *threatening* (inspiring fear) (Graeff, 2003; Ledoux, 1996; Walter, 2005) depending on the region occupied by the state point in a Personal Emotional Space (**PES**). The increasing complexity of living in-group demanded the development of the Interpersonal Emotional Space

(**IES**). The adequacy of collective actions to promote group survival is assessed in this space (Fehr and Rockenbach, 2004; Britton et al, 2006). The **VDS** dynamics is dependent on **PES** and **IES** because preferences on personal and collective actions are assessed in the corresponding emotional space. Conflict may arise from the simultaneous evaluation of the same personal or collective action preferences in **PES** and **IES**.

Neuroeconomics is providing the tools to study the cooperative role between cognition and emotion in decision-making and conflict solving (Glimcher and Rustichini, 2004; McClure et al, 2004; Paulus, 2005; Sanfey et al, 2006; Greene et al, 2001). Here, politics is defined as the art and science of solving such conflicts and neuroeconomic tools are used to investigate political decision-making, exemplified by the recent referendum on firearm commerce prohibition in Brazil.

Investigating Political Decision-Making

Brazilians were called on October 23, 2005 for a national referendum about the prohibition of firearm commerce in the country. Voting is mandatory in Brazil and political campaign takes advantage of Radio/TV free propaganda during 40 days before election. Two political alliances arouse in the Brazilian Congress to run the campaign for the **Yes** (for the prohibition of firearm commerce) and **No** (against the prohibition of firearm commerce) voting and defined the themes to compose the **VDS** dimensions. Political advertisement of both **Yes** and **No** campaigns proposed vote as a moral dilemma solution, because they had the following structure: proposition $\mathbf{P_1}$ provides information about right/wrong use of firearms and proposition $\mathbf{P_2}$ states that voting **Yes** or **No** creates a moral conflict. The conflicts arouse because the **Yes** arguments were mainly defined in **IES**, whereas the **No** arguments were mainly defined in **PES**.

Advertisements varied in their emotional load. Some advertisements were highly emotionally charged. Examples are (see the complete list of the advertisement in Table I): **Yes** advertisement - *A gun in the house may cause a fatal accident killing innocent people, mainly children. You may prevent such events by banning firearm commerce;* **No** advertisement - *People have the right to defend themselves from criminals. To ban firearm commerce hurts you in your personal rights*. Other advertisements were less emotionally charged. Examples are: **Yes** advertisement - *The robbery of firearms from the honest citizen is the main source of guns for the criminals. You may contribute to disarm criminals banning firearm commerce;* **No** advertisement - *To prohibit the firearm commerce will not reduce criminal rates. Voting Yes will not diminish criminality.*

Greene et al (2001, 2004) used fMRI, to show the enrollment of a set of widely distributed neurons in conflict dilemma solution and Rocha et al (2006) used EEG analysis to disclose many properties of these neural circuits. We decided to use the same EEG methodology combined with classic poll opinion tools analysis to study the intended vote one week before the referendum (Table I).

Table I - Poll Opinion Questionnaire

Next week, you will vote on the referendum about banning firearm commerce in the country. *Select the alternative bellow that best describe your opinion about the banning of the firearm commerce in Brazil.*

You may provide a second opinion if you believe your first opinion may change until election day:

1) I will certainly vote No, *2) I will probably vote No,* *3) Certainly I will not vote No,* 4) I have not yet decided my vote, 5) *I will certainly vote Yes,* *6) I will probably vote Yes,* 7) *Certainly I will not vote Yes.*	*1) I will certainly vote No,* *2) I will probably vote No,* *3) Certainly I will not vote No,* 4) I have not yet decided my vote, *5) I will certainly vote Yes,* *6) I will probably vote Yes,* *7) Certainly I will not vote Yes.*
First opinion	*Second opinion*

Now, you are asked to provide your opinion about some statements made in the free propaganda in the Radio and TV.

1 or Y1: *A gun in the house may cause a fatal accident killing innocent people, mainly children. You may prevent such events banning firearm commerce.*

Please, select one of the following options to best describe your opinion about this statement:
a) I agree b) I disagree c) I have no opinion

Please, select one of the following options to evaluate the influence of this statement on your vote in the Election Day:
a) Will influence my vote b) Will not influence my vote

2 or N1: *People have the right to defend themselves from criminals. The proposal of banning firearm commerce hurts you in your personal rights.*

Please, select one of the following options to best describe your opinion about this statement:
a) I agree b) I disagree c) I have no opinion
.
Please, select one of the following options to evaluate the influence of this statement on your vote in the Election Day:
a) Will influence my vote b) Will not influence my vote

3 or Y2: *Having a gun facilitates murder in the case of neighboring, family or traffic dispute. You may prevent such events banning firearm commerce.*

Please, select one of the following options to best describe your opinion about this statement:
a) I agree b) I disagree c) I have no opinion

Please, select one of the following options to evaluate the influence of this statement on your vote in the Election Day:
a) Will influence my vote b) Will not influence my vote

4 or Y3: *The robbery of firearms from the honest citizen is the main source of guns for the criminals. You may contribute to disarm criminals banning firearm commerce.* Please, select one of the following options to best describe your opinion about this statement: a) I agree b) I disagree c) I have no opinion Please, select one of the following options to evaluate the influence of this statement on your vote in the Election Day: a) Will influence my vote b) Will not influence my vote
5 or N2: *To ban firearm commerce disarms the honest citizen but not the criminals. You have the right to defend yourself.* Please, select one of the following options to best describe your opinion about this statement: a) I agree b) I disagree c) I have no opinion Please, select one of the following options to evaluate the influence of this statement on your vote in the Election Day: a) Will influence my vote b) Will not influence my vote
6 or N3: *To prohibit the firearm commerce will not reduce criminal rates. You have the right to defend yourself.* Please, select one of the following options to best describe your opinion about this statement: a) I agree b) I disagree c) I have no opinion Please, select one of the following options to evaluate the influence of this statement on your vote in the Election Day: a) Will influence my vote b) Will not influence my vote

The poll opinion questionnaire (Table I) asked volunteers: 1) to declare their intended vote **v** and if they could change their mind (**v'**) until the Election Day; 2) to evaluate (**$e(a_i)$**) a selection of 6 advertisements **a_i** of the **Yes** and **No** Radio/TV propaganda; and 3) to declare if **a_i** would influence (**$i(a_i)$**) their voting (Figure 1). The poll took place during the week preceding the election and involved 1136 people, 32 of whom (**EEG group**) had their EEG registered while answering the poll. Factor and regression analysis were used to study data about **v**, **$e(a_i)$** and **$i(a_i)$** (see Table II and Figure 1). The correlation **$R_{i,j}$** between the EEG activity recorded at the recording sites **r_i,r_j** was calculated for all the 20 electrodes of the 10/20 system and for the EEG epochs associated to voting (**V**), advertisement evaluations (**E**) and influence assessment (**I**) (Foz et al, 2001; Rocha et al, 2004a; Rocha et al, 2004b). The correlation coefficients **$R_{i,j}$** were used to calculate what we call *correlation entropy* **$h(R_{i,j})$** as

$$h(R_{i,j}) = - R_{i,j} \log_2 R_{i,j} - (1 - R_{i,j}) \log_2 (1 - R_{i,j})$$

which was used for the estimation of the correlation entropy $\mathbf{h(r_i)}$ for each recording electrode $\mathbf{r_i}$ as:

$$h(r_i) = \sum_{j=1}^{20} h(\check{r}_i) - h(r_{i,j})$$

with

$$h(\check{r}_i) = -\check{r}_i \log_2 \check{r}_i - (1 - \check{r}_i) \log_2 (1 - \check{r}_i), \qquad \check{r}_i = \left(\sum_{j=1}^{20} R_{i,j} \right) / 20$$

Here, $\mathbf{h_V(r_i)}$, $\mathbf{h_E(r_i)}$ and $\mathbf{h_I(r_i)}$, calculated for the **V**, **E** and **I** epochs, respectively, are assumed to measure how much the recorded activity at $\mathbf{r_i}$ is related with the task event **V, E** or **I**. Finally, regression analysis discloses the possible relations between $\mathbf{h_V(r_i)}$, $\mathbf{h_E(r_i)}$ or $\mathbf{h_I(r_i)}$ and **v,** $\mathbf{e(a_i)}$ and $\mathbf{i(a_i)}$ (see Figures 2 and 5).

Considering only the **Possible/Certain** votes (Table I), our poll opinion disclosed equilibrium between the **Yes** and **No** votes (intention in Fig. 1a), similar to that published by the Brazilian pollster Ibope (Ibope, 2005) on October 16. However, 13% of the volunteers provided a second opinion showing that they could change their mind in the Election Day. Taking this into account, the final result would be **No**=67% and **Yes**=33% (expected voting in Fig. 1a), equal to the actual result of the election (actual vote in Fig.1a). This was mainly due to a possible migration of the **Certainly-not-Yes** vote to a **No** vote signaled in the second opinion (R in Fig. 1a and Table I). This result was not forecasted by any of the polls published before the election, even in the one of October 21, estimating **No**=53% and **Yes**=45%. The observed percentage of **Undecided** votes was 16% and its projection for the Election Day was 21%. If indecision influences abstention (Hinich and Munger, 1996) our result showed a value close to the real abstention of 23% (Fig. 1a).

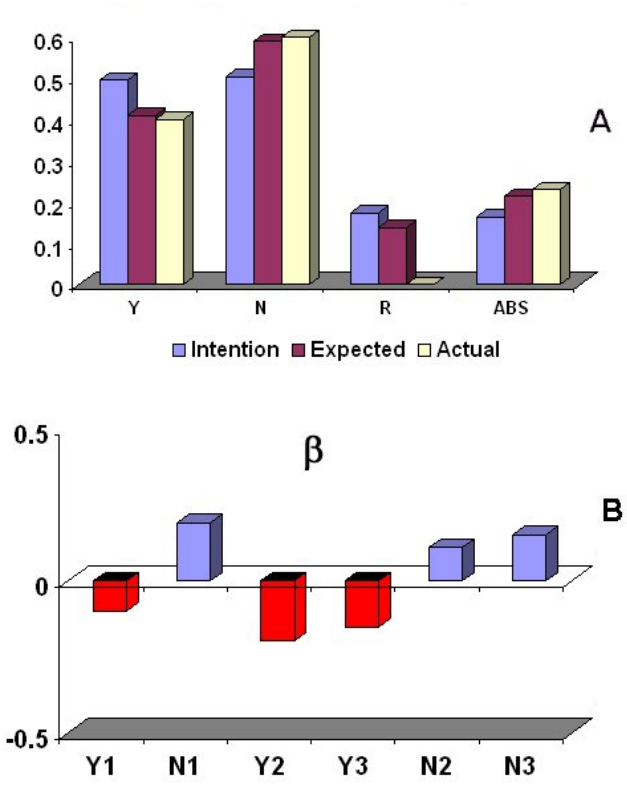

Fig. 1 – Analyzing poll data

A – Comparison of poll (Intention) intention voting; voting calculated from the intended vote and the declared voting intention change (Expected) and the Election results (Actual) for the **Yes (Y), No (N)** votes, **Yes + No** rejection (**R**) and undecided (**ABS**) voters.

B – The angular coefficients β for the regression (R^2 = 0.22) $\mathbf{v} = \alpha + \beta_i \mathbf{e(ai)}$ calculated for the vote intention **v** and each advertisement evaluation $\mathbf{e(a_i)}$. $\mathbf{Y_i}$ are advertisement of the **Yes** propaganda and $\mathbf{N_i}$ of the **No** propaganda.

Table II – Poll Statistical Analysis

Evaluation Principal Component Analysis

Factor Loadings (Varimax raw)

	Factor 1	Factor 2	Name
a_1	0,752491	0,116388	Y1
a_2	-0,13168	0,634763	N1
a_3	0,728809	0,106496	Y2
a_4	0,542518	-0,22754	Y3
a_5	0,197443	0,804263	N2
a_6	-0,08518	0,712196	N3
Expl.Var	1,775039	1,712014	
Prp.Totl	0,22188	0,214002	

Vote x Evaluation Regression Analysis

R= .60950511 R^2= .37149648 Adjusted R^2= .35853765

F(6,291)=28.667 p<.00000 Std.Error of estimate: 1.2425

	t	p-level	name

α	2,298062	0,413558	5,556807	6,21E-08	
β1	0,541126	0,162667	3,326594	0,000992	Y1
β2	-0,59052	0,128469	-4,59656	6,41E-06	N1
β3	0,679837	0,176616	3,849226	0,000146	Y2
β4	0,5421	0,133406	4,063532	6,22E-05	Y3
β5	-0,43547	0,142324	-3,05968	0,002422	N2
β6	-0,41885	0,136801	-3,06173	0,002406	N3

Factor analysis (Table II) confirmed $\mathbf{a_1}$ (or $\mathbf{Y_1}$), $\mathbf{a_3}$ ($\mathbf{Y_2}$) and $\mathbf{a_4}$ ($\mathbf{Y_3}$) as **Yes**-advertisements and $\mathbf{a_2}$ ($\mathbf{N_1}$), $\mathbf{a_5}$ ($\mathbf{N_2}$) and $\mathbf{a_6}$ ($\mathbf{N_3}$) as **No**-propaganda. Regression analysis showed (Table II and Figure 1b) that **v** is a linear function of all $\mathbf{e(a_i)}$ and reinforced this conclusion, because the angular coefficient β was negative for $\mathbf{Y_i}$ and positive for $\mathbf{N_i}$ (Fig. 1b) and Certainly-**Yes** vote was encoded as 1 and Certainly-**No** vote was encoded as 0 (see Table 1). In other words, if $\mathbf{Y_i}$ is agreed and $\mathbf{N_i}$ is not then vote is **Yes** and vice-versa, if $\mathbf{N_i}$ is agreed and $\mathbf{Y_i}$ is not then vote is **No**. Because agreement about $\mathbf{N_i}$ was greater than about $\mathbf{Y_i}$ (Fig. 3a), **No** vote predominated.

We modified the technique used by Brazilian pollster companies (Ibope, 2005) by asking people to provide a second opinion on if and how they might change their vote in the Election Day, and this provided important information to increase the accuracy of the final forecast. Although polling has been successful in predicting election outcomes around the world (Sanders, 2003), from time to time gross error occurs. The evidence suggests that, in conditions of intense party competition, pollsters find it more difficult to accurately forecast the results (Sanders, 2003). This was the case of the studied referendum. Poll results in the beginning of the campaign pointed to a Yes victory with more than 70% of the votes. As the propaganda start to discuss the issues related with the vote decision, this tendency started to changed and ended-up with the No victory with 67% of the votes, a result predicted by our analysis, but not by Ibope using classical poll analysis.

The correlations of voting **v**, advertisement evaluation $\mathbf{e(a_i)}$ and advertisement voting influence $\mathbf{i(a_i)}$ between the EEG and POLL groups were 0.85, 0.95 and 0.90, respectively, showing that both groups behaved in a similar fashion. In view of this we analyzed the EEG activity recorded in **EEG group** (as described in the next section) in an attempt to understand this vote decision-making.

Brain Imaging and the Political Decision-Making

The regression analysis showed that **v** was a linear function of $\mathbf{h_V(r_i)}$ (R^2=0.40), given by the polynomial:

$$\mathbf{v} = \alpha + \sum_{i=1 \text{ to } 20} \beta_i \, \mathbf{h_V(r_i)}$$

The angular coefficients β_n for some electrodes $\mathbf{r_n}$ were positive indicating that high values of $\mathbf{h_V(r_i)}$ were associated to a **No** vote, while the coefficients β_y for some other electrodes $\mathbf{r_y}$ were negative indicating that high values of $\mathbf{h_V(r_i)}$ were associated to a **Yes** vote. Figure 2 shows the brain mapping associated to the above regression. In the figure the first column displays $\mathbf{h_V(r_i)}$ mapping; the second column shows the β_i mapping; and the third column shows the voting mapping. The $\mathbf{h_V(r_i)}$ **x** β_I map in Fig. 2 shows that the **Yes** vote is mainly associated with the central electrodes and the **No** vote seems to depend mostly on $\mathbf{C_3}$ and the right posterior cortex.

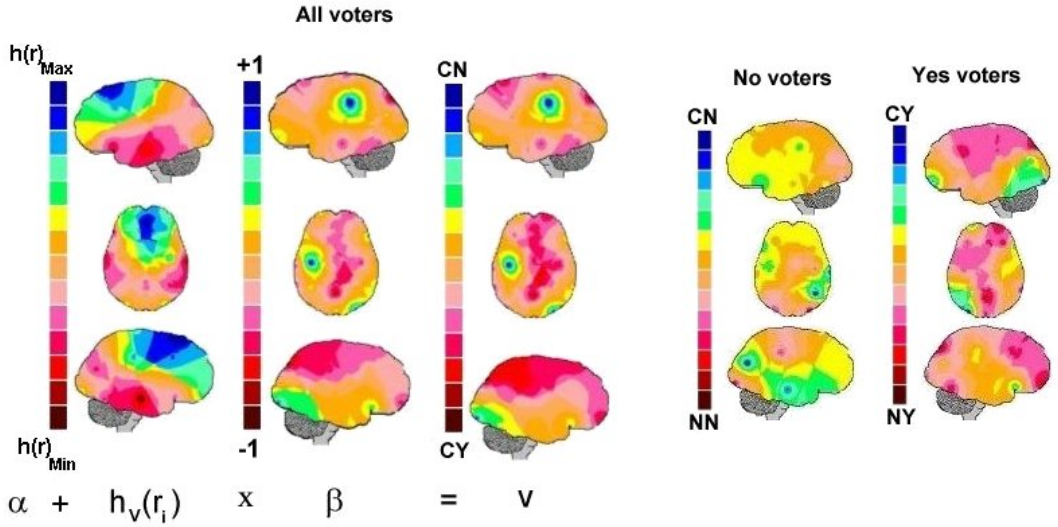

Fig. 2 – EEG mappings of the voting decision-making.

All voters: The column $\mathbf{h_V(r_i)}$ shows the entropy map of the EEG recorded during the voting decision. The β column shows the mapping of the angular coefficients estimated for each recording electrode $\mathbf{r_i}$ of the regression between **v** and the voting decision EEG entropy $\mathbf{h_V(r_i)}$. The **v** column shows the brain mapping for the product $\mathbf{\beta_i \, x \, h_V(r_i)}$ for each $\mathbf{r_i}$.

No voters: The product $\mathbf{\beta_i \, x \, h_V(r_i)}$ for each $\mathbf{r_i}$ in the sub-sample of individuals declaring an intended **No** voting.

Yes voters: The product $\mathbf{\beta_i \, x \, h_V(r_i)}$ for each $\mathbf{r_i}$ in the sub-sample of individuals declaring an intended **Yes** voting.

CN – Certainly-No; **CY** – Certainly-Yes; **NN** – Certainly-Not-No, and **NY** – Certainly-Not-Yes voting intention.

The partial $\mathbf{h_V(r_i) \, x \, \beta_I}$ maps calculated for **No** and **Yes** voters (Figure 2) disclosed other details of the neurodinamics of vote decision. On the one hand, decision about voting or possibly voting **No** was positively correlated (yellow, green and blue areas in **No voters** Fig. 2) with the activity recorded by electrodes distributed over the left anterior cortex and almost all over the right hemisphere. In contrast, the decision of **Certainly-not-No** voting was weakly and negatively (pink to red areas in **No voters** in Fig. 2) associated to the activity recorded by C4, O2, and O1. The determination coefficient R^2 for this correlation attained 0.88. These results are in agreement with the **No** victory and the small **No** vote rejection disclosed by our poll. On the other hand, decision about voting or possibly voting **Yes** was positively correlated (**Yes voters** Fig. 2) with the activity recorded by a small number of electrodes mostly in the left hemisphere. In contrast, the decision of **Certainly-not-Yes** voting was associated to the activity recorded by a large number of electrodes in both hemispheres. The determination coefficient R^2 for this correlation attained 0.55. Once again, the recorded brain activity aggrees with the low number of **Yes** votes and the greater **Yes** rejection registered by the poll.

Another interesting finding was that, considering all voters regression, all β_n contributed 61% and all β_y contributed 39% for the vote decision, values that are very similar to the final **No** and **Yes**

percentage in the referendum. It is noteworthy in the second opinion report the migration of **Yes** rejection (10%) to a **No** vote, while the **No** rejection (7%) seemed to be mainly transformed into abstention (Undecided votes). As vote has been considered to be dependent on off-line processing preceding Election Day (Lau, 2003; Taber, 2003), our EEG analysis forecasted the election results which are in agreement with the proportions $\beta_N/(\beta_Y+\beta_N)$ and $\beta_Y/(\beta_Y+\beta_N)$ estimated from $v = \alpha + \sum_{I=1 \text{ to } 20} \beta_i \, h_V(r_i)$.

The Voting Decision Space

Voting **v** was also found to be a linear function of both the evaluation $\mathbf{e(a_i)}$ and the influence $\mathbf{i(a_i)}$ of each advertisement content. The angular coefficient β for the **Yes** arguments ($\mathbf{a_y}$) were negative, indicating that agreement with $\mathbf{a_y}$ were associated to a **Yes** vote. And the other way around, the angular coefficient β for the **No** arguments ($\mathbf{a_y}$) was positive, indicating that agreement with ($\mathbf{a_n}$) was associated to a **No** vote**.** Those relationships can be seen in figure 3a, which also shows the proportional agreement and disagreement for each argument $\mathbf{a_i}$**.** In figure 3b we show the same kind of analysis for the influence of each advertisement content. Note that, with the exception of argument $\mathbf{Y_3}$ (slightly positive) the angular coefficient β for the **Yes** arguments ($\mathbf{i_y}$) were negative, indicating that the influence of $\mathbf{a_y}$ were associated to a **Yes** vote, and the other way around, the angular coefficient β for the **No** arguments ($\mathbf{i_n}$) was positive, indicating that the influence of $\mathbf{a_n}$ was associated to a **No** vote**.**

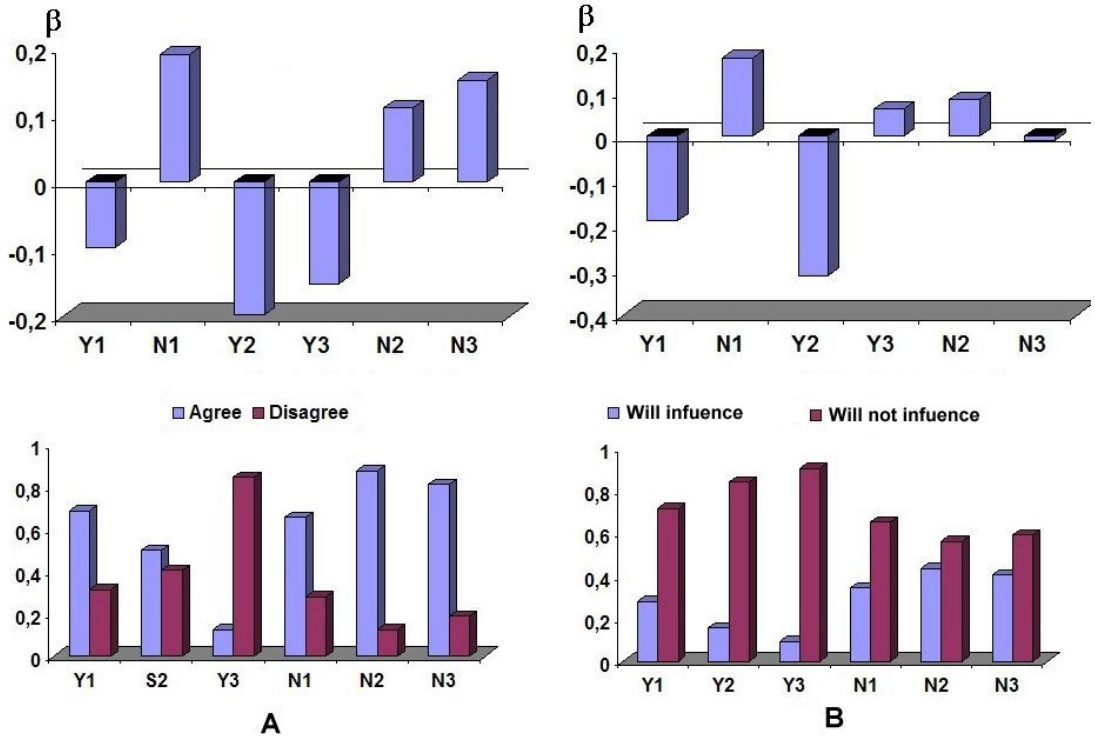

Fig. 3 – Dependence of the intended vote v on advertisement evaluation $e(a_i)$ (A) or influence $i(a_i)$ (B)

A: The upper graph displays the values of the angular coefficients β estimated for the regression between the intended vote **v** and the evaluation $\mathbf{e(a_i)}$ each advertisement $\mathbf{a_i}$**.** The lower graph displays the percentage of voters who agreed or disagreed with each advertisement contents.

B: The upper graph displays the values of the angular coefficients β estimated for the regression between the intended vote **v** and the influence $\mathbf{i(a_i)}$ each advertisement $\mathbf{a_i}$. The lower graph displays the percentage of voters who declared that the contents of $\mathbf{a_i}$ would or would not influence their voting decision in the Election day.
$\mathbf{Y_i}$ are advertisement of the **Yes** propaganda and $\mathbf{N_i}$ of the **No** propaganda.

Although most of the volunteers declared that the advertisement content would not influence their voting, the above dependences suggest a possible influence of each $\mathbf{a_i}$ on vote decision. As a consequence we decided to investigate the possibility of **VDS** being a tri-dimensional space (see Fig. 4A), where the **No** and **Yes** coordinates expresses the confidences μ**(N),** μ**(Y)** on the **No** ($\mathbf{a_N}$) and **Yes** arguments ($\mathbf{a_Y}$), respectively. We assumed $\mathbf{e(a_i),i(a_i)}$ to be fuzzy measurements (George and Bo Yuan, 1995; Pedrycz and Gomide, 1998; Rocha, 1992) of the **credibility** and **importance** of each $\mathbf{a_i}$ and that confidence μ **(N)** (or μ **(Y)**) in voting **No** (or **Yes**) is calculated as fuzzy inferences of the type (Pedrycz and Gomide, 1998; Rocha, 1992).

If **Q** ($\mathbf{e(a_n)*i(a_n)}$) then μ**(N)** and If **Q** ($\mathbf{e(a_y)*i(a_y)}$) then μ**(Y)**

where * is a t-norm (Pedrycz and Gomide, 1998; Rocha, 1992), and the operator **Q** is one of the following logic operators:

1) **all** → μ**(N) = min** $\mathbf{(e(a_n)*i(a_n))}$ and μ**(Y) = min** $\mathbf{(e(a_y)*i(a_y))}$
2) **most of** → μ**(N) = 1/k** $\mathbf{\Sigma_{N=1\ to\ k}\ e(a_N)*i(a_N)}$ and μ**(Y) = 1/k** $\mathbf{\Sigma_{Y=1\ to\ k}\ e(a_Y)*i(a_Y)}$, or
3) **at least one** → μ**(N) = max** $\mathbf{(e(a_n)*i(a_n))}$ and μ**(Y) = max** $\mathbf{(e(a_y)*i(a_y))}$

The regression analysis for the voting **v** and confidences μ **(N),** μ **(Y)** calculated for each of the above quantifiers, showed $\mathbf{R^2}$ tending to zero for **Q** = **all** or **at least one** and $\mathbf{R^2}$ = 0.25 for **Q** = **most of.** Figure 4 shows the VDS computed for this latter quantifier. Although the value of the determination coefficient $\mathbf{R^2}$ may seem low, it is in accordance with values described in the literature for similar analysis (Feldman, 2003; Marcus et al, 2000) and with data from Ibope (Ibope, 2005) indicating that media campaign would account at most for 30% of vote decision.

In figure 4A we see that votes for **No** are associated with positive values of μ **(N)** and negative values of μ **(Y)**, and the other way around, votes for **Yes** are associated with positive values of μ **(Y)** and negative values of μ **(N)**, as it should be expected. In figure 4B we show the frequencies of the observed pairs $\mathbf{[\mu_i(Y), \mu_i(N)]}$**.** The frequency of the pairs around **[**μ **(N)=0,** μ **(Y)=0]** was approximately equal to the sum of frequencies of the pairs **[**μ **(N) > 0.5,** μ **(Y) < 0.5]**, **[**μ **(N) < 0.5,** μ **(Y) > 0.5];** showing that advertisement did not influence the voting decision of at least 50% of the volunteers.

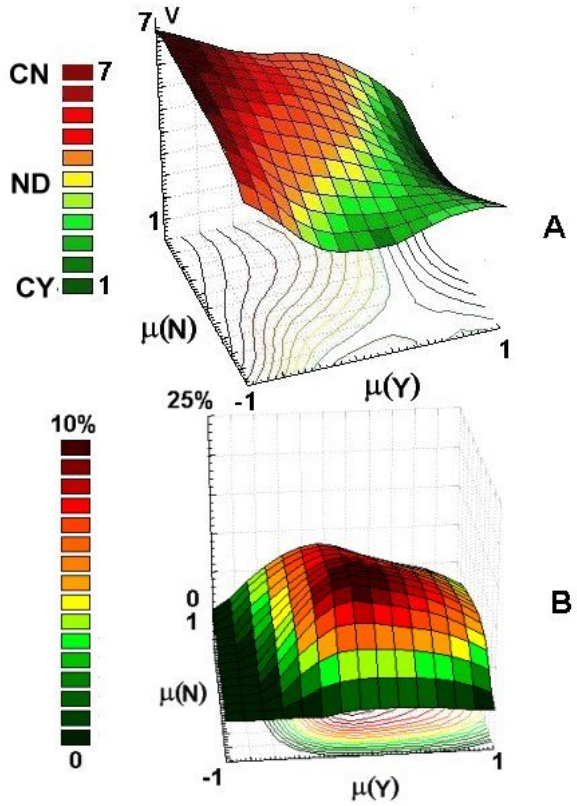

Fig. 4 – The Voting Decision Space

The graph in A displays the spline surface of the voting intention decision **v** as a function of the confidence **μ (N)** and **μ (Y)** on the **No** and **Yes** advertisements, respectively, calculated as fuzzy inferences supported by the fuzzy quantifier *most of all*. This means that **μ (N)** or **μ (Y)** approaches 1 if *most of* the advertisements were agreed and declared to influence voting decision in the Election day; approaches 0 if *most of* the advertisements were declared to not influence voting decision, and approaches –1 if *most of* the advertisements were not agreed and were declared to influence voting decision. **CN** – Certainly-No, **ND** – not decided and **CY** – Certainly-Yes vote.

The graph in B displays the spline surface of the frequency of pairs of **[μ (N), μ (Y)]** observed values. The frequency of the pairs around **[μ (N)=0, μ (Y)=0]** shows that advertisements did not influence the voting decision of at least 50% of the volunteers.

Regression analysis showed both μ_i**(Y)** and μ_i**(N)** to be linearly correlated with $h_E(r_i)$, $h_I(r_i)$**,** and $h_V(r_i)$**,** their R^2 ranging from 0.29 (μ_i**(Y)** and $h_V(r_i)$) to 0.45 (μ_i**(N)** and $h_V(r_i)$)) (Fig. 5). The main difference between the two $h_E(r_i)$ **x** β_i mappings is that values calculated for μ_i**(N)** are higher than those calculated for μ_i**(Y)**, a result in agreement with the fact that voter declared to agree more with the **No** arguments than with the **Yes** advertisements. The $h_I(r_i)$ **x** β_i mappings are characterized by the predominance of negative **β**(dominance of pink and rose areas) what is in accordance with the fact that most of the voters denied any influence of the contents of the advertisements on their vote decision. The $h_V(r_i)$ **x** β_i mappings also differed for μ_i**(N)** and μ_i**(Y).** Once again, the calculated μ_i**(N)** was greater than μ_i**(Y),** what is in accordance with the fact that **No** voting was higher than **Yes** voting decision.

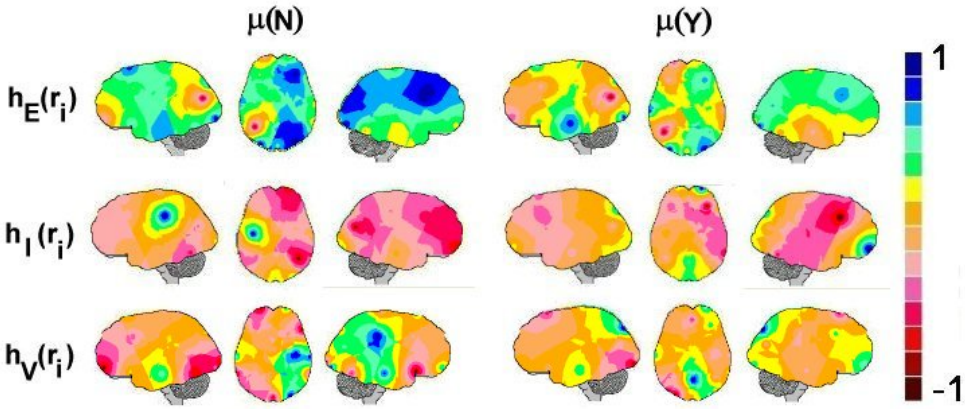

Fig. 5 – The EEG mappings and the Voting Decision Space

The $\mathbf{h_E(r_i)}$ row shows the $\boldsymbol{\beta_i}$ **x** $\mathbf{h_E(r_i)}$ map for each $\mathbf{r_i}$ and the regression between **μ (N)** or **μ(Y)** and $\mathbf{h_E(r_i)}$ calculated for the EEG activity recorded during advertisement evaluation.

The $\mathbf{h_I(r_i)}$ row shows the $\boldsymbol{\beta_i}$ **x** $\mathbf{h_I(r_i)}$ map for each $\mathbf{r_i}$ and the regression between **μ (N)** or **μ (Y)** and $\mathbf{h_I(r_i)}$ calculated for the EEG activity recorded during the decision if the advertisement would or would not influence the vote in the Election day.

The $\mathbf{h_I(r_i)}$ row shows the $\boldsymbol{\beta_i}$ **x** $\mathbf{h_V(r_i)}$ map for each $\mathbf{r_i}$ and the regression between **μ (N)** or **μ (Y)** and $\mathbf{h_V(r_i)}$ calculated for the EEG activity recorded during the decision of the intended vote.

Although both $\boldsymbol{\mu_i}$**(Y)** and $\boldsymbol{\mu_i}$**(N)** are theoretical concepts supported by the Spatial Voting Theory and Fuzzy Logic, they seem to have a brain existence by themselves once they were found to correlate with $\mathbf{h_E(r_i)}$, $\mathbf{h_I(r_i)}$ and $\mathbf{h_V(r_i)}$ (Figure 5). If this is the case, then **VDS** for the referendum was mainly computed by the right hemisphere, where positive **β** predominated for $\mathbf{h_E(r_i)}$ **x** $\boldsymbol{\beta_i}$ and a negative **β** predominated for $\mathbf{h_I(r_i)}$ **x β**. The correlations between $\mathbf{h_v(r_i)}$ and $\boldsymbol{\mu_i}$**(Y)** or $\boldsymbol{\mu_i}$**(N)** provide other pieces of evidence about **VDS** being a real brain construction, because brain activity during vote decision was associated to values of $\boldsymbol{\mu_i}$**(N)** higher than $\boldsymbol{\mu_i}$**(Y),** a fact that is in aggreement with the **No** victory in the elections and in our poll.

Discussion

Our analysis included both the study of vote migration intention signalized by the subjects' second opinion and the correlation of such migration intention with the EEG activity recorded during our simulation of voting. Our results strengthened the role of **VDS** in voting decision making by showing significant correlations between the concepts of argument credibility ($\mathbf{e(a_i)}$) and importance ($\mathbf{i(a_i)}$) and the decision determinant variables **μ (Y)** and **μ (N)**, as well between these determinant variables and the brain activity recorded during argument analysis (**E** and **I** epochs) and voting decision (**V** epoch). However, we have also observed that **VDS** accounted for at most 25% of vote decision in the studied population, a fact also observed in other studies (Feldman, 2003; Marcus et al, 2000) and supported by Brazilian polls (Ibope, 2005) showing that media campaign contributed at most with 30% of vote influence. The literature points to other factors that, in addition to media propaganda, also influence the voting decision and could explain the remaining 70% (Pattie and Johnston, 2001; Johnston et al, 2005; Mondak and

Huckfeldt, 2006; Todorov et al, 2005). As a matter of fact, the actual influence of media campaign on voting decision is still controversial (Andersen et al, 2005; Arceneux, 2006)**.**

Notwithstanding this apparent conflict, it is possible to understand the actual role of **VDS** on vote decision if we consider that: a) the vote $\mathbf{v_i}$ decision of the individual **i** is determined in his/her own $\mathbf{VDS_i}$, whose determinant variables $\mathbf{\mu_i(Y), \mu_i(N)}$ are defined in his/her individual $\mathbf{IES_i}$ and $\mathbf{PES_i;}$ and b**)** the cardinality of the intersection of the $\mathbf{VDS_i}$ of all voters with the generic **VDS** idealized by marketers determines how influential it is on the election results. In such a context and in the case of the Brazilian referendum analyzed here, this intersection is estimated to be around 30%. As a consequence, it may be stated that the study of the $\mathbf{VDS_i}$ dynamics is of crucial importance to the understanding of vote decision.

Our analysis allowed us to forecast the final election results with a very good accuracy. To the best of our knowledge, our approach and results represent a novelty in the study of political decision. As such, although encouraging, they must be taken with due caution and we hope that it may stimulate further research along the lines discussed here.

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