# How Human Brain Works During Financial Investment Decisions?

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## Abstract

This investigation is among the first to analyze the patterns of brain activity associated with financial decision making in male and female. We try to identify brain areas associated with risk evaluations of stock investments. Based on EEG technology and Low Resolution Brain Tomography we find something very new in the area: men and women use different neural circuits to make financial investment decisions. We also find that, on average, female trade less stock in each investment decision and make more decisions to sell than men, what is congruent with literature that describes that normally male have more optimistic aspirations in negotiations than female (Babcock , 2003 and Riley & Babcock, 2002) and female try to make investments decision that produce financial return in short-term period (Overman et al., 2004). More interesting, the final portfolio value were not quite different for males and females what implies that although using different neural circuits to make decisions, both genders are equally efficient in their decisions, even using different part of the brain to make the same kind of investment decisions.

Keynwords: Financial Investment Decisions; Brain Neural Activity; Low Resolution Brain Tomography

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## 1. Introduction

Recent Literature, essentially from neuroscience, describes several differences in terms of brain activity and function between male and female. Ziada (2010) made an extensive review of literature about these interesting differences.

At same time interdisciplinary groups of researchers from economics, finance and neuroscience are trying to understand how the brain works when makes financial decisions. In this line, Gehring and Willoughby (2002) used electroencephalogram (EEG) to map the brain during a financial decision process and found that when investors win or lose they activated different parts of the brain, and Kuhnen and Knutson (2005) described that an area of the brain called nucleus accumbens[4] is activated before investor make risky choices as well as risk-seeking mistakes, and the anterior insula is activated after make riskless choices as well as risk-aversion mistakes.

Authors like Rocha and Rocha (2011) discuss that an wide network of neural circuits is involved in evaluating risk, benefit and conflict in decision making, as well as in calculating intention to buy or sell. Understand the functionality of these circuits is very important to also understand the dynamics of financial markets and Tian et al. (2011) remark that men and women brains functional network are different in terms of organization what leads to gender differences in terms of behavior and cognition.

According our knowledge, no investigation analyzed yet if male and female use, or not, different parts of the brain to make financial investment decisions. This way, this investigation is among the first to analyze possible gender differences concerning these brain patterns, based Low resolution Brain Tomography and EEG that record the brain activity while individuals are participating of a simulated investment decision.

The paper is organized as follows: Section 2 discusses the literature review. Section 3 describes the experimental design. Section 4 explains the data and the experiment research methodology. Section 5 explains the results, and Section 6 presents the conclusions.

## 2. Literature Review

During last years some neuroscientists analyzed if the brain of the men and women works different in a vast group of activities and effectively, in some cases, literature shows that this differences exist (Gills and O´Boyle, 1997; Ziada 2010).

Mohr and Heekeren (2010) describe that dopaminergic and serotoninergic brain systems have been identified as key neurotransmitter systems involved in economic behavior.

Based on Iowa Card Task (ICT) Overman (2004) found that males and females had a different response pattern. Females tended to choose cards associated with both immediate wins and with short-term outcome and males tended to choose cards related with long-term outcome. Cazzel et al. (2012) complement these finds describing that in situation of active losses women display a bilateral activation in dorsal lateral prefrontal cortex higher than males but in the case of wins they don´t find significant difference between men and women.

Xue et al. (2010) found that insula is activated by past experiences of risk that influences on future decisions and Lee et al. (2009) analyzed gender effects on the process of risk-taking and found a activation in the right insula and bilateral orbitofrontal cortex in Risky-Gains task that is stronger in female than in male. When taking the same level of risk, relative to men, women tend to engage in more neural processing involving the insula and the bilateral orbitofrontal cortex to update and valuate possible uncertainty associated with risk-taking decision making. Becker et al. (2012) complement this information describing that males are more likely than females to engage in risky behaviors, meaning that women normally are more risk averse than men.

A vast literature in economics and finance also shows that, on average, women are more risk averse than men when making financial decision investment (e.g., Vandegrift & Brown, 2005, among several others) but investigating how the brain works in risky financial decision making is very recent.

Davis (2010) debates in what way using neuroscience technologies in economic will help to transform economics. In other words, what advances in economics, finances and other areas will be supported by neurosciences? We believe this approach is at same time extremely promising and innovative. Is the case of Roy et al. (2011) that analyzed the neural correlates of risk avoidance and found that precuneus and striatal are activated in decision-making under uncertainty representing putative neural markers of risk avoidance both in laboratory experiments as well as in a real world activity. Also Gehring and Willoughby (2002) found that brain activity is related with final game results and Kuhnen and Knutson (2005) showed that nucleus accumbens[4] activation preceded risky choices as well as risk-seeking mistakes, while anterior insula activation preceded riskless choices as well as risk-aversion mistakes. The authors also describe that a positive emotional state induces people to take risk and be confident to evaluate investment options and negative emotions like anxiety reduce the propensity to take risk (Kuhnen and Knutson, 2011) report that financial decision process change across the life and old adults made more suboptimal choices than younger adults when choose risk assets.

Jones et al. (2012) analyzed what they call the "shopping brain" using event-related potential (ERP). They investigated the gender brain response during consumer choices of products having or not a price discount (15%) and found that the conceptual processes interact with anxiety and gender to modulate brain responses during this type of consumer choices. Finaly, Tian et al. (2011), report that the men and women brains functional networks are different in terms of organization and this leads to gender differences in terms of behavior and cognition.

In terms of gender differences in investments authors like Buchan et al. (2008) and Croson and Buchan (1999) described that women normally obtain an higher investment proportion, than men, of the amount they invested in a game but and Babcock et al. (2003) and Riley and Babcock (2002) found that males normally have more optimistic aspirations in negotiation than females and that aspirations partially mediate gender differences in negotiation performance. In other words, men may trust more (send, or invest, more money) because they expect to receive more in return in the future than women.

Supported by this literature we use EEG analysis and Low Resolution Brain Tomography to analyze whether gender differences exist or not stock market investment decisions.

## 3. Experimental Design

EEG is recorded while the volunteer play a stock make investment game. The electrodes are placed according to the 10/20 protocol (see Figure 1); adjusted to have impedance below 10 Kohm; low-pass filter 50Hz, sampling frequency of 256 Hz and 10 bits of resolution.

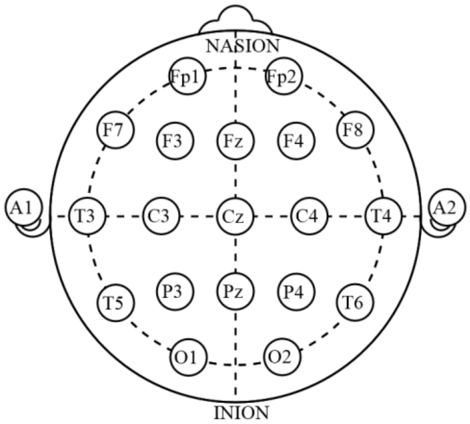


**Figure 1-** EEG electrodes location and name

The letters F, T, C, P and O are related with Frontal, Temporal, Central, Parietal, and Occipital lobes, respectively. Is important to describe that there exists no central lobe. The "C" letter is used only for identification purposes. A "z" (zero) refers to an electrode placed on the midline. In the case of the numbers (2,4,6,8) refer to electrode positions on the right hemisphere. This way, odd numbers (1,3,5,7) refer to those on the left hemisphere. In addition, the letter codes A, Pg and Fp identify the earlobes, nasopharyngeal and frontal polar locations respectively.

The investigation is done based on a sample composed by 40 undergraduate students of the School of Business Studies from Polytechnic Institute of Viana do Castelo, Portugal. The sample is composed by 20 women and 20 men from age 20 to 45 years. This will guarantee that students are homogenous in term of financial knowledge.

We use the EEG technology, and not fMRI, because this will allow volunteers to take the time they need to make decisions during the trading simulation of selling, buying or maintaining stock portfolio (Rocha et al, 2011). Each volunteer played the investment game describe below, with a portfolio composed by 200 stocks of 7 different companies trade at the Portuguese Sock Market (Banif, Portugal Telecom, Energias de Portugal; Banco Comercial Portugues; BRISA, Cimentos de Portugal and Futebol Clube do Porto).

They made a total of 100 investment decisions (50 decisions in series 1 ($\mathbf{S_1}$) and 50 decisions in series 2 ($\mathbf{S_2}$)) and they can buy, sell or hold these stocks. Volunteers were restricted to 50.000 euros to trade on each session. Is also important to say that none of the volunteer has any information about the way each of the stock will behave across the investment simulation process. During all this decisions we use EEG technology to record the brain electrical activity trying to identify what areas of the brain are activated when they make each investment decision.

Half volunteers (10 females and 10 males) made 50 trading decisions on a bull market **m1** in session 1 and another 50 trading decisions on bear market **m2** in session 2. The other half of volunteers traded initially on the bear market **m2** and on the bull market **m1** during session 2. Relative stock prices were used to calculate stock price, by multiplying it by the value of the stocks at Portuguese Stock Market on February, 1, 2012 and information about this relative index was available to the volunteers.

**Figure 2** – The initial portfolios for markets **m1** (above) and **m2** (bellow). Indice -the relative bourse index

IND– the relative stock price; VAR –difference between actual and previous relative stock price, Valor – actual real stock price, QT – quantity of owned stocks, Total – total invested in each stock; D-QT – proposed number of stocks to trade; D-Valor – proposed transaction price; V – selling option; C – buying option; OK – to finish proposal. TI – actual total investment; RE – amount of money spent to buy the stocks; R – revenue (gain or loss) and A – available money for new buyings.

| NOME | IND | VAR | VALOR | QTD | TOTAL | D-QTD | D-VALOR | V | C |
|---|---|---|---|---|---|---|---|---|---|
| INDICE | 0,96 | -0,01 | | | | | | | |
| BANIF | 1,04 | 0,00 | 22,01 | 200 | 4.402,39 | | EU | | |
| Portugal Telecom | 1,63 | 0,04 | 34,93 | 200 | 6.985,11 | | EU | | |
| Energias de Portugal | 0,94 | -0,00 | 20,90 | 200 | 4.180,35 | | EU | | |
| Banco Comercial Português | 1,11 | 0,00 | 7,28 | 200 | 1.455,84 | | EU | | |
| BRISA | 1,01 | -0,01 | 31,70 | 200 | 6.340,69 | | EU | | |
| Cimentos de Portugal | 1,00 | -0,01 | 8,35 | 200 | 1.670,99 | | EU | | |
| Futebol Clube do Porto | 0,98 | 0,03 | 35,85 | 200 | 7.170,95 | | EU | | |
| | | | | TI | 32.206,31 | | OK | | |
| A | | | | RE | 31.670,00 | | | | |
| 18.330,00 | | | | R | 536,31 | | | | |

Trading simulation progressed as follows. While the EGG was being recorded, the volunteer digitized number and price of stock to trade for one and just one company and selected trading option V or C and pressed OK in order to sell or buy the chosen stock, respectively; or just pressed OK to maintain portfolio unaltered ( see figure 2).

If price offer was within 5% variation of the next stock price, offer was accepted and the corresponding number of stock adjusted; otherwise, offer was rejected and the corresponding number of stock was maintained unaltered.

After OK was pressed a new screen was presented for another trading simulation. This new screen showed updated information of the experimental variables.

EEG samples (called here, EEG epochs) were selected for the 2 seconds preceding decision making (OK button pressing) were used for analysis.

## 4. Experimental Results

In this part we describe some financial results related we our experiment.

### 4.1 Financial Results

In table 1 and figure 3 we display information about the value of the investment, realized and final value of the portfolio. From table 1 is possible to see that, on average, female invest less than male, but realize more money across the experiment. More interesting, in the end of experiment the average value of the men and women portfolio is practically the same (the difference is not statistically significant). The results are congruent with literature that women are more risk averse then men (Vandergrift & Brown, 2005), prefer to get returns of your investment in short term periods (Overman et al., 2004) and also with Babcock et al (2003) and Riley & Babock (2002) that normally male have more optimistic aspirations in negotiations than female. From treh table is also possible to see that, even existing differences in stock market investment attitude between male and female the final result of the portfolio is practically the same (the difference is not statistically significant), what is also congruent with Haier et al. (2005) that describes that human evolution created two different brains but with equally intelligence.

**Table 1:** Investment, Realized Value and Final Result of the Portfolio

| Gender | Investment | Realized | Final Result |
|---|---|---|---|
| Male | 36298,79 | 7112,959 | 43411,75 |
| Female | 31590,15 | 11700,956 | 43283,77 |
| Mean Difference | 4708,64*** | -4587,997*** | 127,98 |

Significant at (***) 1% level, (**) 5% level and (*) 10% level.

The figure 3, describe not the average values, but all the absolute values across the experiment.

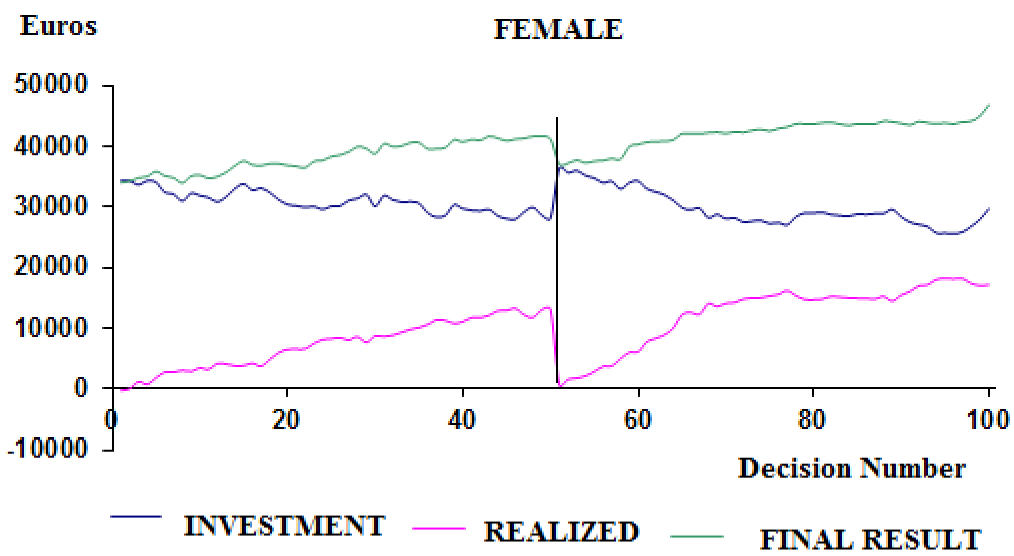


**Figure 3**: Male and Female Investment value, Realized and Portfolio Final Value

Table 2 complement all this information, describing the average value of stock traded by investment decisions and the average value of each.  On average, male trade more stocks in each investment decisions but with less value. The results are also congruent with literature that describe male like more optimistic than female in negotiation process (Babcock et al, 2003 and Riley and Babcock, 2002).

**Table 2:** Average Quantity of Stock by Transaction  ana Value

| | QTDE | VALOR |
|---|---|---|
| Male | 137,348 | 28,812 |
| Female | 79,362 | 32,754 |
| Mean Diference | 57,986*** | -3,942 |

Significant at (***) 1% level, (**) 5% level and (*) 10% level.

Figure 4 describes the same information but in absolute values across all the experiment ( 100 investment decisions).

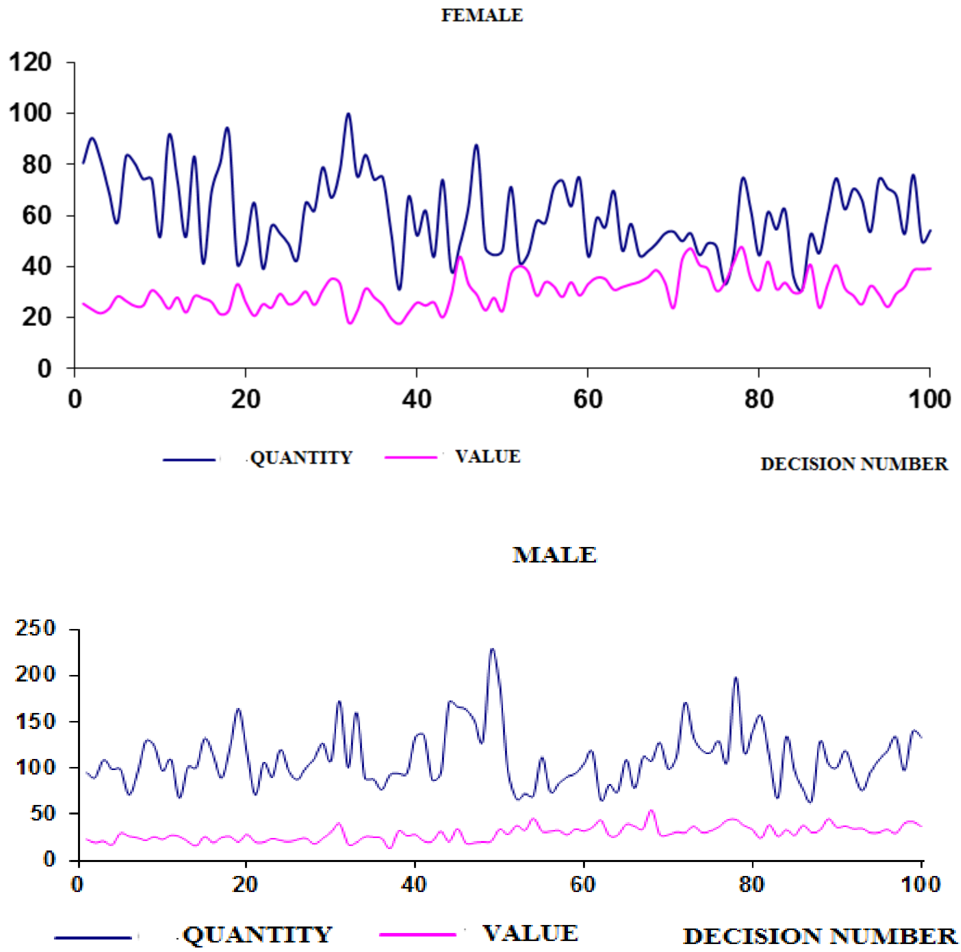


**Figure 4:** Male and Female Quantity of Stock Traded and Value

To complement all this information we also describe in table 3, the percentage of decision of buy, sell or maintain, that male and female made across all the experiement with 100 decisions. It is important to say that the simulation software was formatted to avoid inadequate decisions. If price offer was within 5% variation of the next stock price, offer was accepted and the corresponding number of stock adjusted; otherwise, offer was rejected and the corresponding number of stock was maintained unaltered. The number of refused decisions made by women and men was very low, meaning that volunteers made investment decisions with rationality and responsibility.

**Table 3** – Percentage  of Investment decisions by Gender

| Decison | Female | Male |
|---|---|---|
| Rejected | 0.40% | 0.39% |
| Mantain | 28.15% | 24.26% |
| Sell | 45.49% | 37.15% |
| Buy | 25.96% | 38.20% |
| Total | 100% | 100% |

On average, female made more sell decisions and male more decisions of buy. The results are congruent with Overman et al. (2004) finds that females tended to choose cards associated with immediate wins and males tended to choose cards related with long-term outcome.  In other words, it seems that women tend to sell faster than men trying to have short-term financial returns.

### 4.2 EEG results

Two different technologies were used for EEG analysis: Low Resolution Brain Tomography (LORETA)[4] and EEG entropy ($H(e_i)$) Principal Component Analysis ($H(e_i)$)[5]. These technologies are described bellow.

#### 4.2.1 Low Resolution Brain Tomography (LORETA)

The activity $V_{e_i}(t)$ recorded by a set of electrodes $e_i$ (EEG) is a weighted sum $\sum_{j=1}^{r} w_j * s_j(t)$ of the electric currents generated by sets $s_i$ neurons that are activated at different cortical areas by a given cognitive task, for example financial decision making.

LORETA is a technique aimed to calculate the location of these sources using the EEG recorded activity. Two different calculations are used for this purpose: Event Related Activity (ERA) and Time Varying Cross Spectra (TVCS).

[4] For more information please visit http://www.uzh.ch/keyinst/loreta.htm

[5] For more information related how to apply PCA to EEG data information please visit http://www.eina.com.br/eeg.php

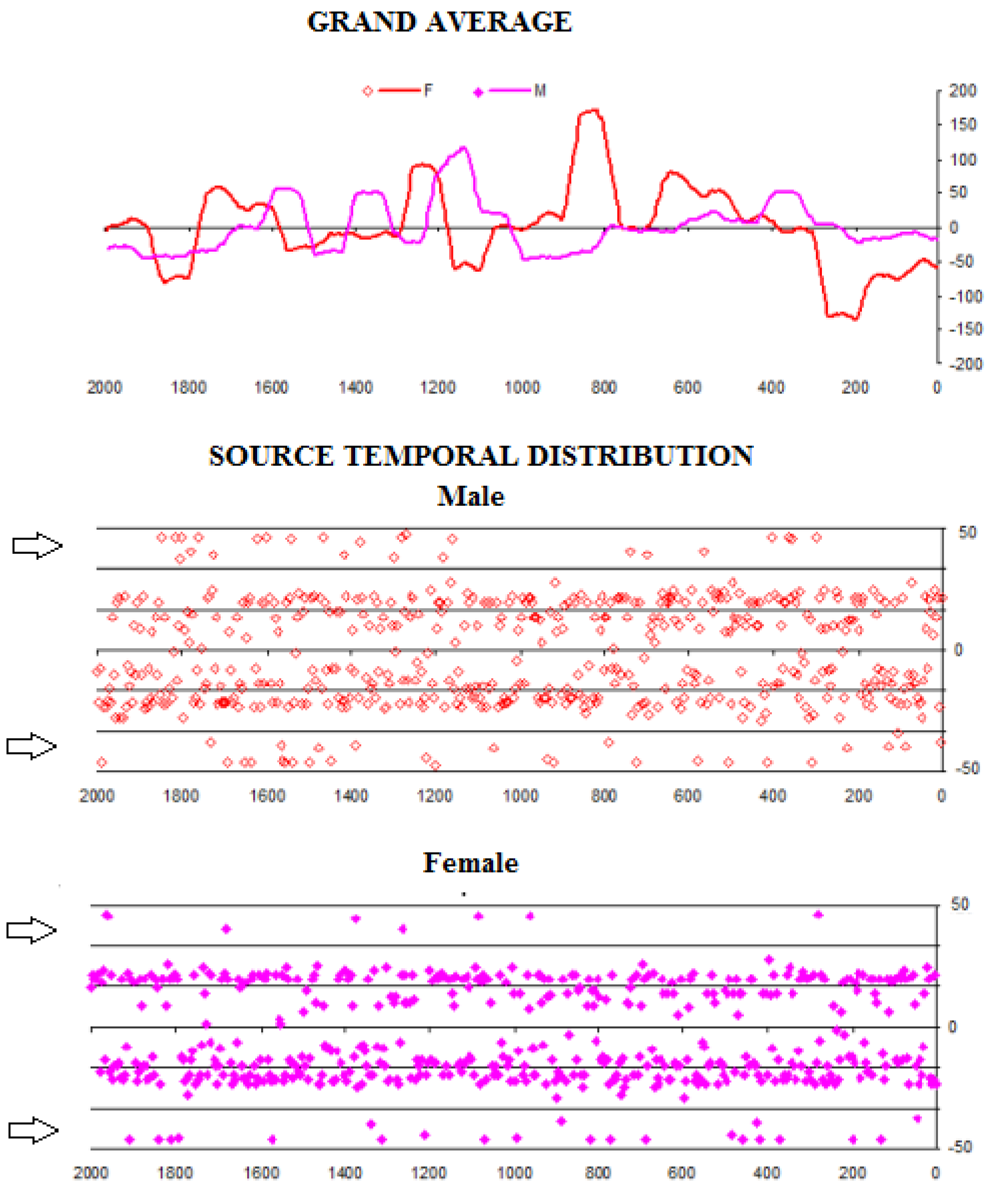


**Figure 5**: Gran Average and Loreta Source temporal distribution for males and females. Loreta Sources are displayed by their associated Brodman Area Number.

The EEG average ($\overline{V}_{e_i}(t)$, called Event Related Activity or ERA, of all (100 decisions)*(n volunteers) selected EEG epochs associated with financial decision making was calculated as

$$\overline{V}_{e_i}(t) = \frac{V^{v}_{e_i}(t)}{100 * n} \qquad (1)$$

The Gran Average $GA(t)$ is calculated as

$$GA(t) = \frac{\sum_{i=1}^{20} \overline{\overline{V}}_{e_i}(t)}{20} \quad (2)$$

and it is used to facilitate ERA comparison between experimental groups or cognitive tasks.

Figure 5 clearly shows that $GA(t)$ calculated for male and females are different. Therefore, it may be assumed that ERA calculated for these two experimental groups are different.

ERA ($\overline{\overline{V}}_{e_i}(t)$) was one of the EEG signals used for LORETA source identification (Figure 5, 6 and 8).

A total of 377 and 399 possible sources $s_l$ of ERA calculated for male and females were identified in 41 and 49 different cortical locations ($l_l$), respectively, because their calculated Z score was greater than 2.

The frequencies which $s_l$ were identified at these locations are shown in Figure 5. We find that 3 location of the brain were identified as unique and distinctive sources for males and 11 as unique for females. In other words, men and women used several similar areas to make financial decision but we found that men use 3 locations that women did not use, and women use 11 locations that men did not use.

Brodmann[6] areas (BA) 18 ( Cuneus; Middle Occipital Gyrus) was the most frequent sites for both male and female, followed by BAs 19, 11, 10, 7 and 8 in male case, and BAs 19, 7, 10, 11 and 8 in female case. Inferior Frontal Gyrus in BA 27 is also a frequent site of source location for both male and females.

Temporal distributions of the above identified $s_l$ as encoded by their Brodman Area number are shown in Figure 4. These distributions for male and female were quite different since their Pearson's Determination Coefficient (PDC) was equal to -0.04. Female distribution is wider than male distribution. This confirms that ERA calculated for male and female are different.

Fast Fourrier Transform converts time to frequency and is used here to convert ERA ($\overline{\overline{V}}_{e_i}(w)$) calculated for time window of size $w$ (e.g., 100 ms as used here) into a family of components of different frequencies $\overline{\overline{V}}_{e_i}^{f}(w)$. The components for frequencies 1 to 15 Hz were used here as other EEG signals for LORETA source identification (Figures 5 and 6).

LORETA calculate the possible sources generating each studied frequency by moving the span window $w$ all over the studied ERA. This procedure generates a family of set of sources $s_l$ some of them common to all studied frequency and some other specific of a given frequency.

A total of 423 sources $s_l$ for each TVCS frequency were identified for male and females in 50 different cortical locations ($l_l$), because their calculated Z score was greater than 2. The frequencies which $s_l$ were identified at these locations are shown in Figure 6. Of the identified locations, 16 were identified as unique and distinctive sources for males and 4 as unique for females. Brodmann areas (BA) 18 was the most

[6] Brodmann K. Vergleichende Lokalisationslehre der Grosshirnrinde. Leipzig : Johann Ambrosius Bart, 1909

frequent sites for both male and female, followed by BAs 7, 19, 11, 10 and 8 in male case 10, 7, 11, 19 and 8 in female case.

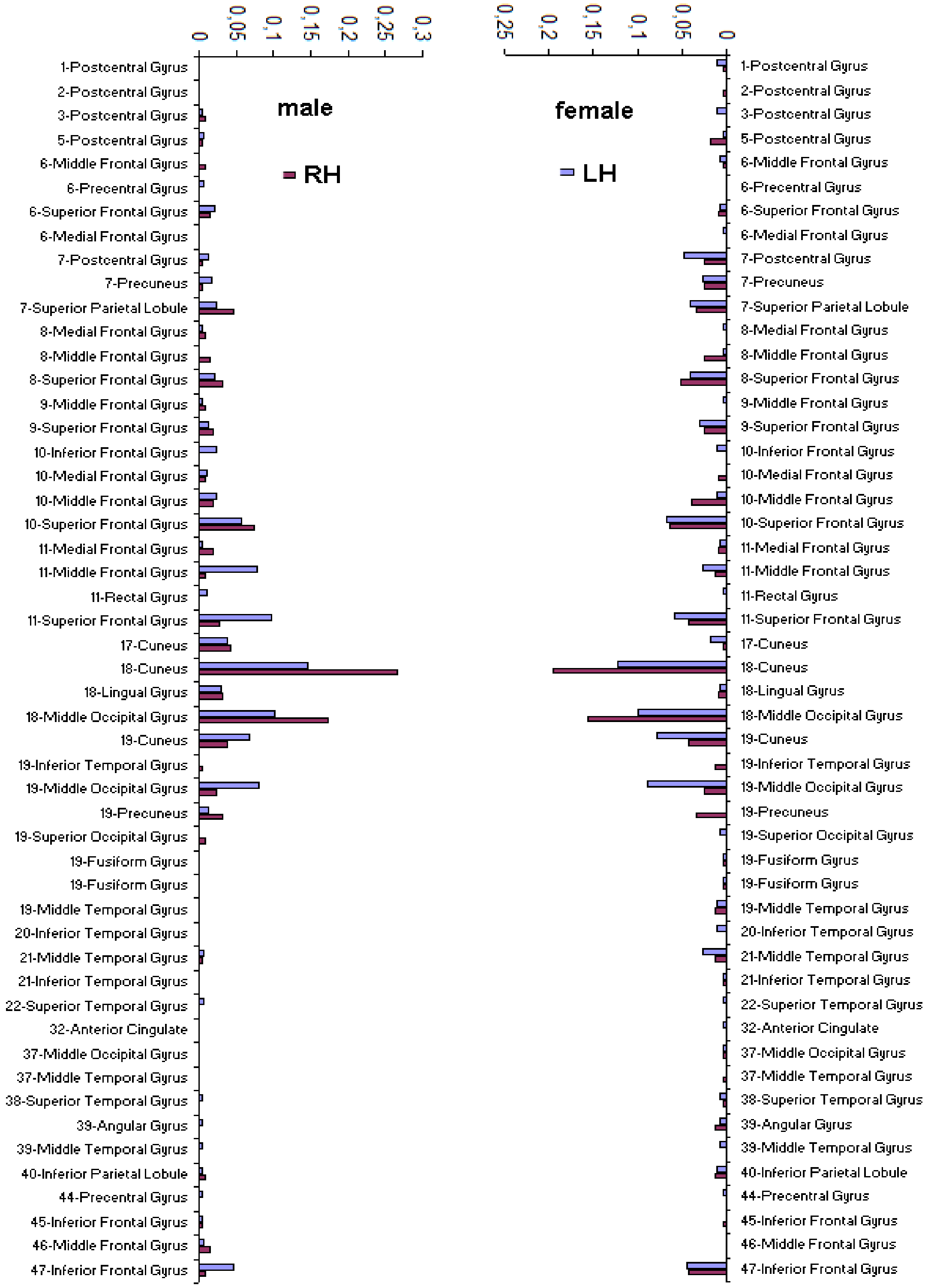


**Figure 6** – Identified LORETA sources for ERA

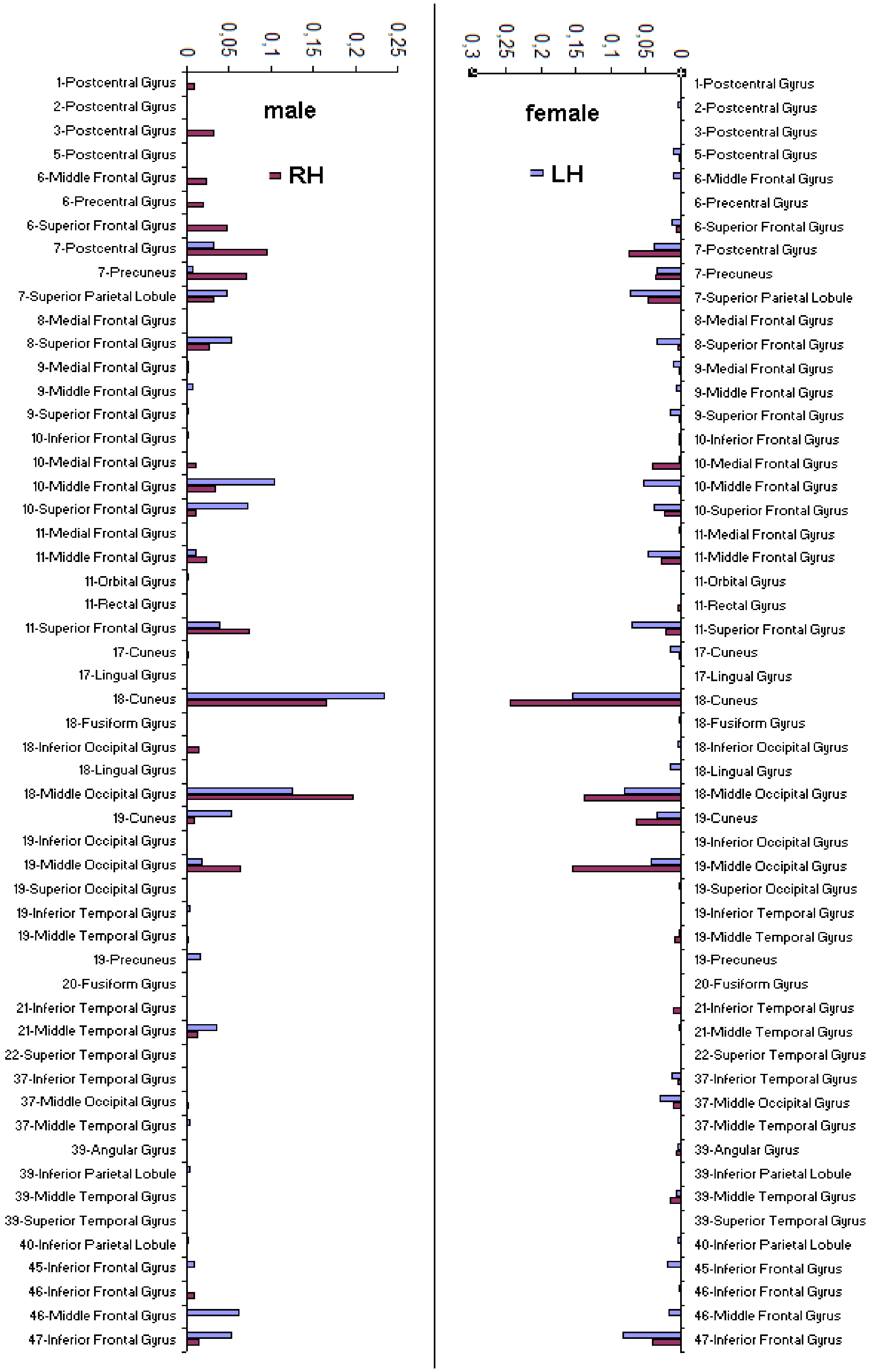


**Figura 7** –LORETA source identification for TVCS

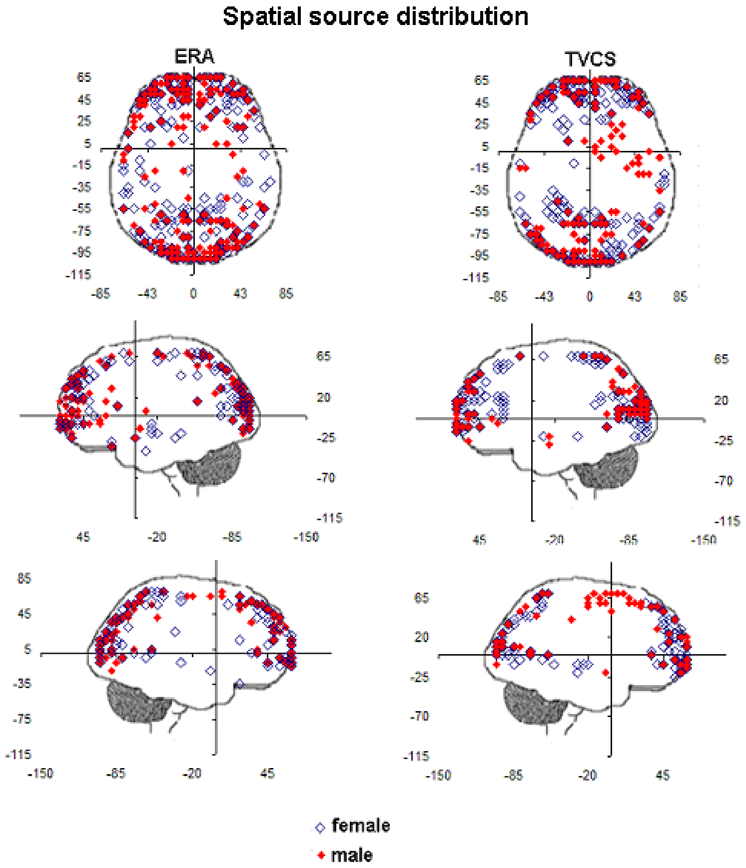


Figure 8 – LORETA source location for ERA and TVCS

LORETA source spatial location was also different for male and females for both TVCS and ERA as observed in Figure 8. One of the most evident differences is the male predomination of source location at right hemisphere in comparison to female when BAs 7 and 8 are taken into consideration.

### 4.2.2 Principal Component Analysis

To better understand if male and female use different part of the brain to make financial decisions, we use another complementary methodology already used by other authors (Rocha et al., 2010, 2011 and discussed by Rocha and Rocha 2011). The authors calculated the amount of information $H(e_i)$ by each electrode $e_i$ about the EEG sources $s_l$ and used Principal Component Analysis (PCA) to reveal pattern of activation of these sources.

For example, applying PCA to the amount of information $H(e_i)$, provided by each electrode $e_i$ about the $s_l$ involved in a vote decision making experiment (Rocha et al, 2010), the authors found 3 different principal components ($P_1$, $P_2$ and $P_3$ patterns ) that explained more than 80% of data covariance and were associated with different neural circuits involved in evaluating the benefit and risk of each type of vote; in using these evaluation to calculate vote intention and in controlling decision making.

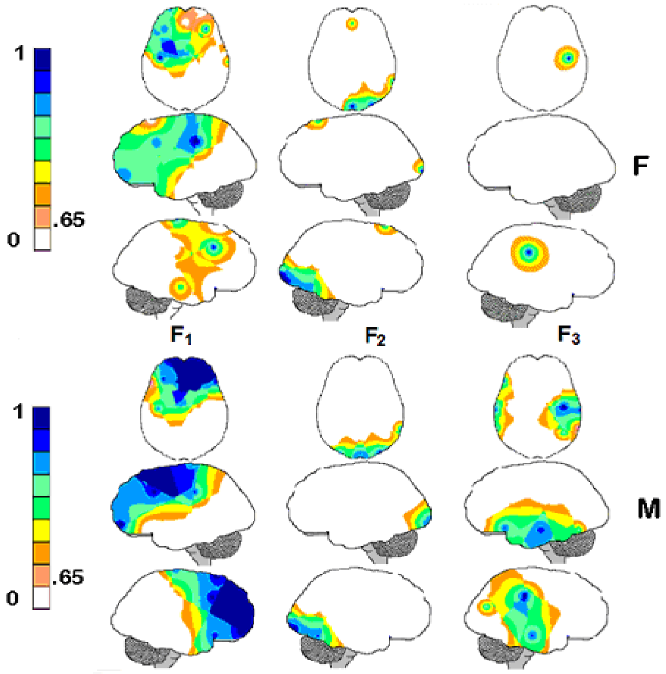


**Figure 7** – Principal Component Analysis mappings for Females (F) and Males (M) calculated from the results on table 1. Values on table I were normalized and color encoded such that loading factor greater than .6 are colored from green (.65) to dark blue (1).

**Table 4– Principal Component Analysis (PCA) Results**

| | Female | | | Male | | |
|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | F1 | F2 | F3 |
| C3 | **0.86** | 0.10 | 0.18 | **0.79** | 0.15 | 0.21 |
| C4 | 0.56 | 0.21 | 0.66 | 0.25 | 0.09 | **0.89** |
| CZ | **0.71** | 0.21 | 0.30 | **0.76** | 0.28 | 0.30 |
| F3 | **0.73** | 0.45 | 0.03 | **0.83** | 0.24 | 0.23 |
| F4 | **0.86** | -0.07 | 0.12 | **0.82** | -0.11 | 0.34 |
| F7 | **0.71** | 0.41 | 0.24 | 0.23 | 0.27 | **0.83** |
| F8 | 0.58 | 0.47 | 0.00 | **0.80** | 0.34 | 0.30 |
| FP1 | **0.72** | 0.52 | -0.02 | **0.85** | 0.29 | 0.19 |
| FP2 | **0.62** | 0.51 | 0.03 | **0.86** | 0.26 | 0.21 |
| FZ | 0.38 | **0.69** | 0.19 | **0.83** | 0.24 | 0.23 |
| O1 | 0.23 | 0.52 | -0.47 | 0.09 | 0.7 | 0.32 |
| O2 | 0.09 | **0.83** | 0.18 | 0.33 | 0.82 | 0.11 |
| OZ | 0.10 | **0.88** | 0.05 | 0.38 | 0.72 | 0.16 |
| P3 | 0.29 | 0.39 | 0.52 | 0.26 | 0.44 | 0.38 |
| P4 | 0.55 | 0.37 | **0.44** | 0.31 | 0.2 | **0.80** |
| PZ | 0.36 | 0.62 | 0.33 | 0.35 | 0.35 | 0.60 |
| T3 | 0.21 | 0.47 | 0.58 | 0.29 | 0.22 | **0.82** |
| T4 | 0.66 | 0.01 | 0.53 | 0.36 | -0.15 | **0.81** |
| T5 | 0.14 | 0.49 | 0.46 | 0.08 | 0.42 | **0.76** |
| T6 | 0.19 | **0.75** | 0.23 | 0.38 | 0.73 | 0.22 |
| Expl.Var | 5.82 | 5.12 | 2.33 | 6.40 | 3.39 | 5.23 |
| Prp.Totl | 0.29 | 0.26 | 0.12 | 0.32 | 0.17 | 0.26 |

Here, PCA also revealed 3 different patterns of brain activity explaining more than 80% of $H(e_i)$ covariance (Figure 7).

The first principal component for female (**$F_1$**) is composed by electrodes C3, C4, CZ, F3, F4, F8, FP1 and T4, whereas male **$F_1$** mapping is composed by electrodes C3, CZ, F3, F4, F8, FP1, FP2 and FZ. To better understand the location of each electrodes please see figure 1.

Female **$F_2$** mapping is composed by electrodes FZ, O2, OZ and T6, whereas male **$F_2$** mapping is composed by electrodes O1, O2, OZ and T6. Finally, female **$F_3$** mapping is composed only by C4 whereas male **$F_3$** mapping is composed by electrodes F7, P4, T3, T4 and T5. This way, we can conclude that patterns **$F_1$** and **$F_3$** clearly distinguishes male from female.

### 4.2.3 Combining LORETA and Principal Component Analysis

In this part we join the information from all the past analysis (ERA, TVCS and PCA) to identify the areas of the brain activated by men and women when the make financial investment decisions.

Because the electrical activity recorded by each electrode is determined by the sum of the electrical currents generated by each $s_l$, Figures 9, 10 and 11 show those $s_l$ at the nearest location $l_l$ to the electrodes composing each PCA mapping **$F_1$**, **$F_2$** and **$F_3$**, respectively. Figures 12 and 13 shows the cortical areas and frequency at which those $s_l$ associated with **$F_1$**, **$F_2$** and **$F_3$** were located.

Figures 8 to 10 show that 3 different sets of sources $s_l$ can be distinguished by the proximity of their location to the recording electrodes defining factors **$F_1$**, **$F_2$** and **$F_3$**, respectively. The cortical location of the sources $s_l$ composing these different sets with the respective frequency, are shown in Figures 12 and 13 for ERA and TVCS, respectively.

Sources $s_l$ located at BAs 8, 10, 11, 45, 46 and 47 are predominately associated with **$F_1$** whereas $s_l$ located at BAs 20, 21, 23, 37, 38, 39 and 40 are predominately associated with **$F_2$**. Finally, $s_l$ located at BAs 18 and 19 are predominately associated with **$F_3$**. It can be observed in all figures, that $s_l$ composition, as well as their temporal and spatial distributions are different when ERA, TVCS or gender is considered.

The most important differences between male and female it is observed for **$F_1$** and **$F_3$** when TVCS sources $s_l$ are considered. The most distinctive difference t is characterized by a clearly frequency predominance of $s_l$ located at the right BAs 3, 6, 7 and 8 and in males compared to females for **$F_1$** (Figures 11 and 12). Locations at these areas predominated for man and right hemisphere. Another difference consists on frequency predominance of $s_l$ located at the BAs 45, 46 and 47 in females compared to males (Figures 11 and 12) for both **$F_1$** and **$F_3$**. A predominance of $s_l$ frequency is also observed for BAs 3, 5, 6 and 40 in males compared to females concerning sources associated with ERA **$F_3$** (Figures 12 and 13).

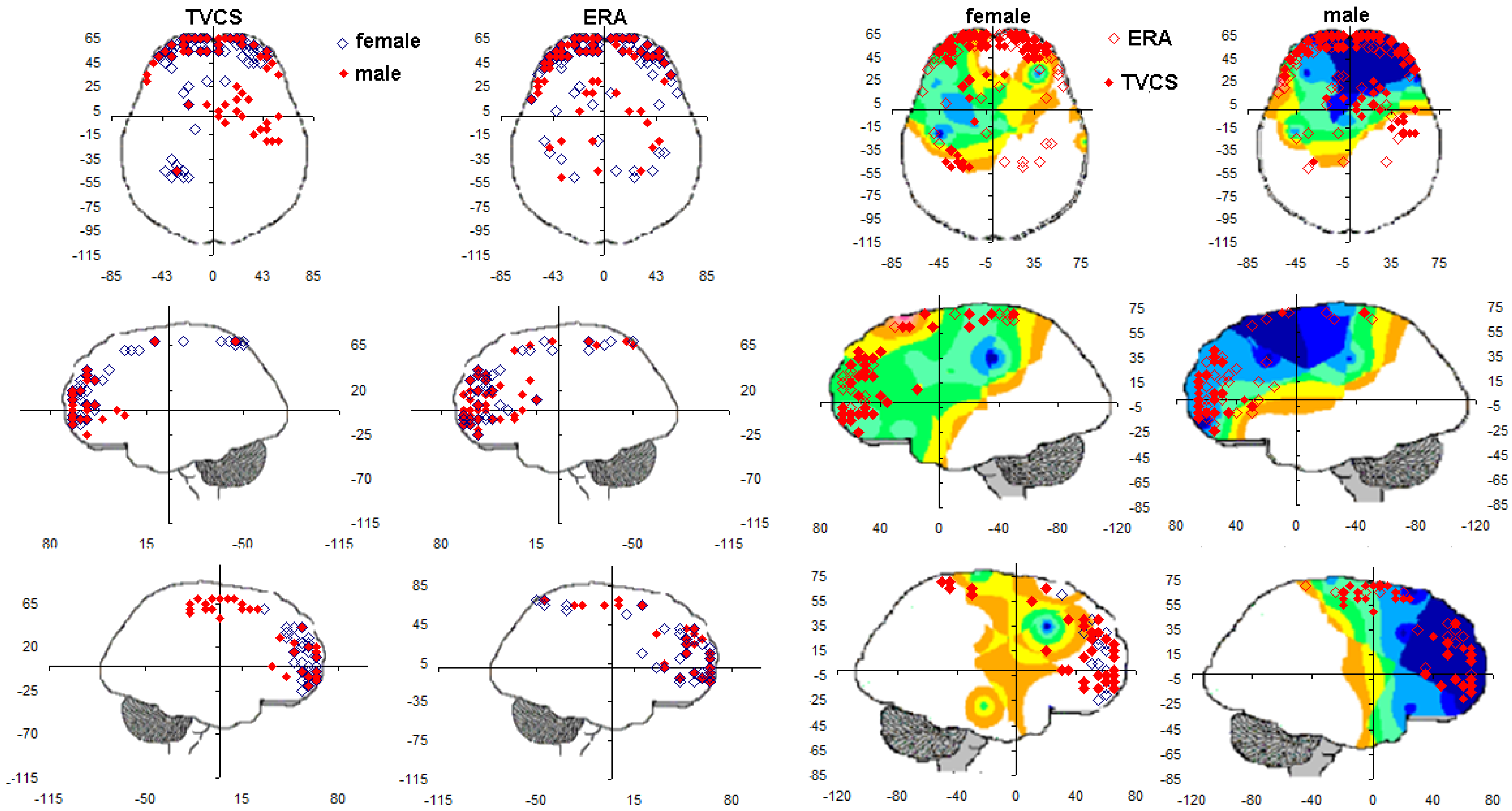


**Figure 9** – Spatial distribution of ERA and TVCS sources $s_l$ associated with PCA factor F1 for male and female. At right spatial plotting of those $s_l$ nearest to the electrodes composing $\mathbf{F_1}$, at left superposition these sources of over the factorial mapping $\mathbf{F_1}$.

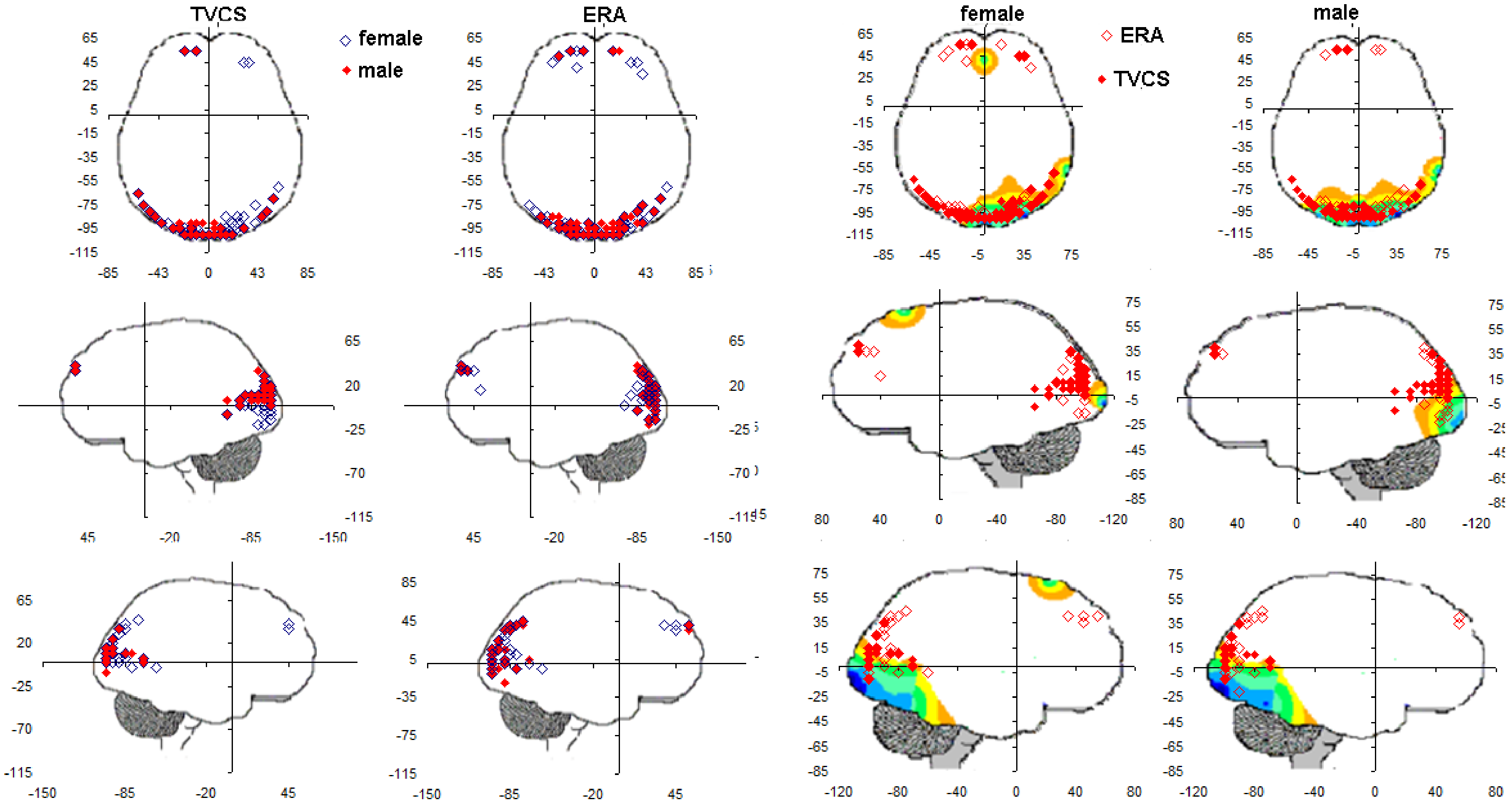


**Figure 10** – Spatial distribution of ERA and TVCS sources $s_l$ associated with PCA factor $\mathbf{F_2}$ for male and female. At right spatial plotting of those $s_l$ nearest to the electrodes composing $\mathbf{F_2}$, at left superposition these sources of over the factorial mapping $\mathbf{F_2}$.

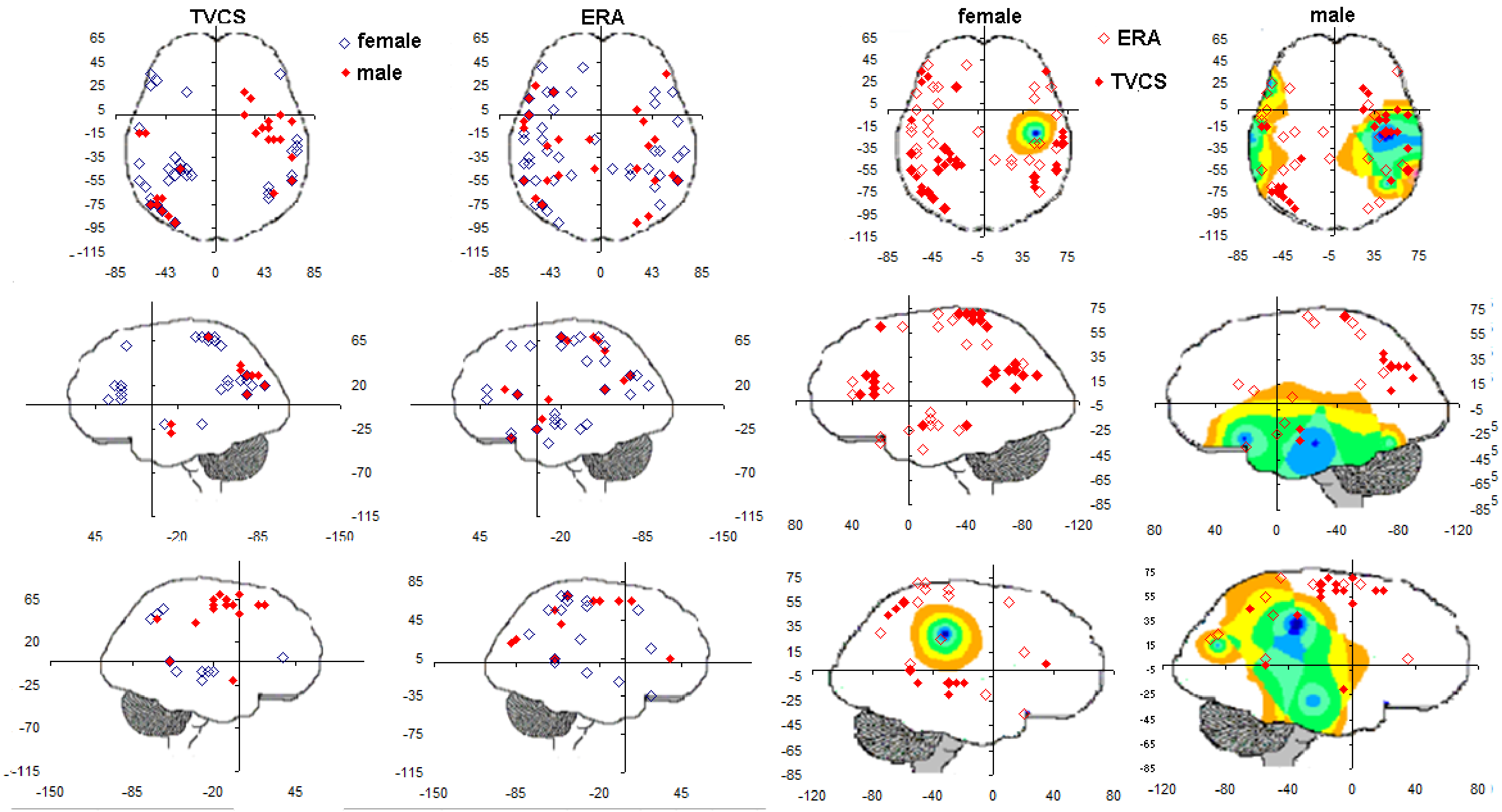


**Figure 11** – Spatial distribution of ERA and TVCS sources $s_l$ associated with PCA factor $\mathbf{F_2}$ for male and female. At right spatial plotting of those $s_l$ nearest to the electrodes composing $\mathbf{F_3}$, at left superposition these sources of over the factorial mapping $\mathbf{F_3}$.

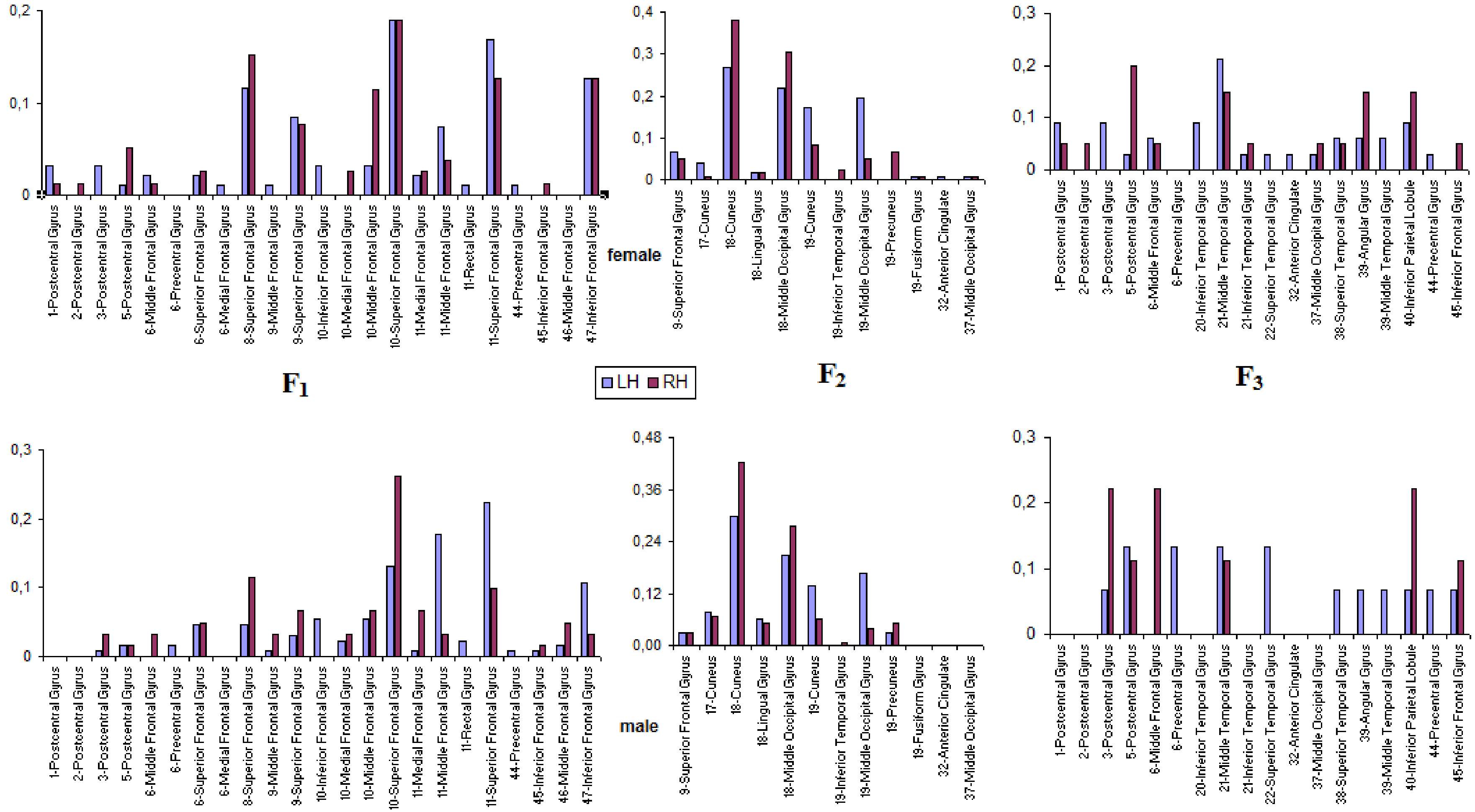


**Figure 12** – Cortical areas at which those ERA $s_l$ associated with the PCA mappings $\mathbf{F_1}$, $\mathbf{F_2}$ and $\mathbf{F_3}$ were located. Blue bars show the frequencies at which $s_l$ were identified at the left cortical areas and red bars show the location frequency at the right cortical areas.

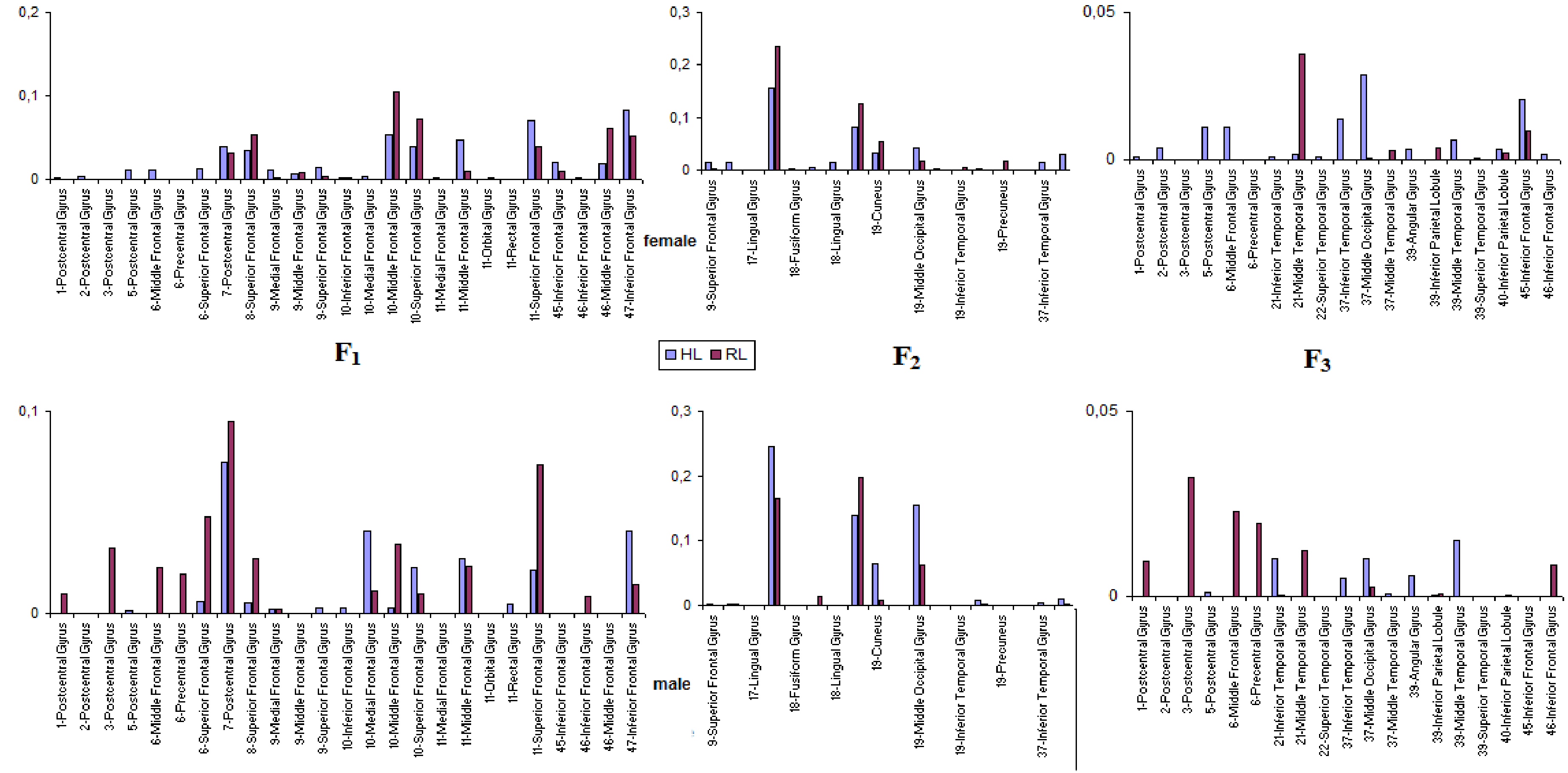


**Figure 13** – Cortical areas at which those TVCS $s_l$ associated with the PCA mappings $\mathbf{F_1}$, $\mathbf{F_2}$ and $\mathbf{F_3}$ were located. Blue bars show the frequencies at which $s_l$ were identified at the left cortical areas and red bars show the location frequency at the right cortical areas.

Clear different patterns of $s_l$ location for male and female in $\mathbf{F_1}$ case are observed (Figure 9). Sources located (see locations between X=45 and X=65 in Figure 9) at Superior Frontal Gyrus (BA 9) and Middle Frontal Gyrus (BA 10) tend to be more clustered for females in comparison to males. In contrast, a clear cluster is observed for male compared to female in case of Precentral, Middel Frontal and Superior Frontal Gyri and Paracentral Lobule, all of them in BA 6 (see region around axe intersection in Figure 9). Finally, locations at Poscentral Gyrus (BA 1, 2, 3 and 5) predominated for females (see locations between X=-35 and X=-55). These findings support the proposition that neural activity of two different neural circuits is disclosed by $\mathbf{F_1}$ and they differentiate financial reasoning used by males and females.

Clear different patterns of $s_l$ location for male and female are also observed in $\mathbf{F_3}$ case (Figure 11). Female $\mathbf{F_3}$ is due to the activity of neurons located at Postcentral Gyrus (BA 1 and 2), Middle Temporal Gyrus (BA 20), Inferior Temporal Gyrus (BA 21) and Middle Temporal Gyrus (BA 21) at the right hemisphere. In contrast, male $\mathbf{F_3}$ is due to the activity of neurons located at Paracentral lobule (BA 5), Middle Frontal Gyrus (BA 6), Fusiform Gyrus (BA 19), Inferior Occipital Gyrus (BA 19), Inferior Temporal Girus (BA 21) and Middle Frontal Gyrus (BA 21) at both hemispheres. These findings support the proposition that neural activity of two different neural circuits is also disclosed by $\mathbf{F_3}$ and they differentiate financial reasoning used by males and females.

## 5. Conclusion

Based on stock investment simulation with 100 decisions, this investigation is among the first to analyze the patterns of brain activity associated with financial decision making in women and men.

The investigation was done based on a sample composed by 40 undergraduate students (20 men and 20 women), with no past experience in real stock trading. This will guarantee that students are homogenous in term of financial knowledge. During all the decision process we use the EEG technology to record the brain electrical activity trying to identify what areas of the brain are activated when they make each investment decision.

We find that men and women use different neural circuits to make finical investment decisions but the average value of male and female portfolio is similar, what is congruent Haier et al. (2005) finds that that human evolution created two different brains but with equally intelligence.

Male activate neurons that are specifically located at Precentral, Middel Frontal and Superior Frontal Gyri and Paracentral Lobule in BA 6 (pattern $\mathbf{F_1}$), as well as located at Paracentral lobule (BA 5), Middle Frontal Gyrus (BA 6), Fusiform Gyrus (BA 19), Inferior Occipital Gyrus (BA 19), Inferior Temporal Girus (BA 21) and Middle Frontal Gyrus (BA 21) at both hemispheres (pattern $\mathbf{F_3}$). Female activate neurons that are specifically located at (pattern $\mathbf{F_1}$) Superior Frontal Gyrus (BA 9), Middle Frontal Gyrus (BA 10) and Poscentral Gyrus (BA 1, 2, 3 and 5) as well as located (pattern $\mathbf{F_3}$) at Postcentral Gyrus (BA 1 and 2).

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