The Neural Behavior of Investors *

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Abstract

Risk preferences are known to be heterogeneous, in particular across genders. In this paper we provide striking evidence that brain activity associated with financial decision making differs between males and females. Using Electroencephalogram technology in an investment trading simulation we capture participants' brain electric activity during the investment process and find that men use different parts of the brain to make the same financial investment decisions than women. Furthermore we separately analyse decisions to buy, sell, and hold stocks, and find that whilst men use the same set of neural circuits to make all three types of investment decisions, women use multiple areas. The results provide evidence of why the decision making process for investment decisions is significantly different between men and women. The findings help towards understanding the heterogeneity of risk preferences when making financial decisions and sheds light on some recent empirical findings in behavioral finance.

JEL Classification: G11; G12.
Keywords: Neurofinance; Risk; Gender; Financial Decision-Making.

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1 Introduction

There is a wealth of evidence that documents gender issues. A body of literature associates gender differences relating to discrimination in the workplace (Black and Strahan, 2001; Goldin and Rouse, 2000 and Wenners and Wold, 1997) allocation of high profile jobs (Bertrand and Hallock, 2001) and also higher total compensation (Blau and Kahn, 2000) to men. According to Becker (1957) part of the difference in executive compensation between men and women can be associated with differences in education. Given that the difference in education has been diminishing over recent decades between men and women across the world; women having made remarkable progress in receiving education in last decades, we would expect these differences naturally to decrease further in future.

Recently, a group of researchers (Brody, 1985; McClure et al., 2004 and Schneider et al., 2011), generally in the field of neuroscience, have provided evidence that men and women differ in their abilities and preferences (Polachek, 1981) leading to different behavioural attitudes across the life cycle. In the area of finance, researchers have paid much less attention to gender differences in decision making. The research field has focused on overconfidence, excessive optimism, confirmation biases, and heuristics with men tending to exhibit greater overconfidence, trading more than their female counterparts (Barber and Odean, 2001) and investing more into mutual funds and equity portfolios (Koedijk et al., 2013 and Jacobsen et al., 2014).

Prior work in decision making has found that risk taking behaviour in finance differs between men and women. Men are more tolerant to risk than women (Croson and Gneezy, 2009, among several others). Women normally see risk as a threat, whereas men prefer to see risk as a challenge (Arch, 1993). Even after controlling for many socio-economic factors, the reason why this occurs remain unclear.

Some literature argues that risk aversion differences between men and women are associated with differences in financial education. For example Atkinson et al. (2003) find that male and female fund managers do not handle their funds in a significantly different manner; and Koedijk et al. (2013) argues that young single males are more likely to invest in stocks than females, and the likelihood of investing in individual stocks and mutual funds increases, as education increases. A strand of literature from Psychology also describes gender differences in risk aversion related with emotions with women experiencing emotions more strongly than men (Harshman and Paivio, 1987). Women tend to feel fear whilst men tend to feel anger (Grossman and Wood, 1993) and according to Lerner et al. (2003) anger normally leads to evaluating gambles as less risky choices, which can help explain why women behave in a more risk averse manner. However, all these empirical studies, do not allow us to distinguish whether the neural response of men and women differ, when facing risky decisions.

In this paper we propose and experimentally test the inherent nature of gender differences during risky investment decisions (buy, hold and selling) using advanced technology from neuroscience to observe brain activity for males and females during simulated financial investment decisions. The use of neuroscience techniques to map the brain during the process of financial decision making is a highly promising area that can provide important advances in finance, which we hope will pave the way to understanding how emotions and neural behavior influence the theory of choice behavior under risk.

Our Electroencephalogram measurements reveal patterns of neural activity that are consistently different for males and females proving that men and women use different parts of the brain to make financial investment decisions.

The paper is organized as follows: Section 2 discusses the literature. Section 3 describes the experimental design and data. Section 4 explains the data and the results from the experimental research. Section 5 concludes.

2 Literature Review

2.1 Neuroscience and Finance

Neurofinance is an emerging field of investigation that merges knowledge from neuroscience and finance. It is still in its infancy. The high costs associated with undertaking research in this area, especially with functional magnetic resonance imaging (fMRI), positron emission tomography (PET), single photon emission computed tomography (SPECT), structural magnetic resonance imaging (MRI) explain, in part, why the number of publication in the area remains low. Frydman et al. (2013) define the field of Neurofinace as 'seeking to characterize the computations undertaken by the brain to make financial decisions, and to understand how these computations map to behavior'. Their seminal paper in the finance field using fMRI is an important milestone in the finance literature.

To our knowledge, the first prior investigation in the area of finance using advanced technology to map the brain was developed by Gehring and Willoughby (2002) using Electroencephalogram (EEG) technology and a finance game simulation found that brain activity was indeed related to results from final game outcomes. McClure et al. (2004) and Rocha and Rocha (2011) complement the information describing that a wide network of neural circuits is involved in risk assessment, benefits, conflicts, and the intent to make a purchase or to sell. Understanding the functionality of these circuits is very important in discovering the dynamics of investment in financial markets.

Also in a financial decision making setting, Kuhnen and Knutson (2005) find that the brain area called the nucleus accumbens is activated before investors make risky choices as well as risk-seeking mistakes, and the anterior insula activation proceeds riskless choices as well as mistakes in assessing risk-aversion and concludes that emotions play an important role when people make decisions under risk. An important early study to understand how emotions influence trading was undertaken by Lo and Repin (2002) measuring the skin conductance response and blood pressure level of traders. Also Caplin and Leahy (2001) discuss how suspense and anxiety influence portfolio choice and LeDoux (1993) the important role that the amygdala plays in the preconscious evaluation of a stimulus as representing a potential threat.

Kuhnen and Knutson (2011) found that a positive emotional state induces people to take risk and to be confident to evaluate investment options, whereas negative emotions, like anxiety, reduce the propensity to take risk. Frydman et al. (2014) complement all this information arguing that brain activity increases at exactly the moment at which subjects issue orders to sell stocks knowingly realizing a gain and Samanez-Larkin et al. (2010) that the financial decision process changes over lifetime and older adults make more suboptimal choices, in terms of risk-seeking mistakes, than younger adults when choosing between risky assets.

2.2 Neuroscience, Gender and Risk

Literature in Neuroscience describes several differences between men and women in terms of brain organization. Kelly et al. (2008) argue that, on average, male brain volume is higher than for women, but when controlling for total volume, women have a higher percentage of gray matter, and men a higher percentage of white matter. They also found that women have a higher global cerebral blood flow than men. Men tend to perform better on tasks related to spatial and inhibition settings, and women perform better on more verbal tasks (Halari et al., 2005) and are more efficient in the visual event-categorization process (Jausovec and Jausovec, 2009) and exhibit greater signal intensity changes in middle, inferior, and orbital prefrontal cortices (Goldstein et al., 2005). Gur et al. (2002a) also argue that, after correcting for cranial volume, men and women have identical volumes of amygdala and hippocampus, as well as dorsal prefrontal cortex, but women have larger orbital frontal cortices than men.

Several authors also describe women and men differently in terms of emotions. In the case of Brody (1985) and McClure et al. (2004) they both find differences between men and women in several areas of emotional functioning; including nonverbal sensitivity, expressiveness, self-reported anger, fear, and sadness. Using short videos that present angry and neutral faces, Schneider et al. (2011) found that the right amygdala was more strongly activated than the left amygdala in males but not in females and this happened in adults and not in adolescents. Gur et al. (2002b) complement this information describing that brain frontal and temporal regions change with the age of the person with men having a higher volume decrease across life. According to these authors, the larger volume of cortex related with emotional modulation can, in part, explain the fact why men and women behave differently in emotion processing. Rocha et al. (2011) show that men and women with similar coefficients are likely to use different neural circuits to solve the same task or to process the same perception.

Based on all these differences in terms of the brains functional network organization

Tian et al. (2011) defends that this can lead to gender differences in terms of behavior and cognition. A large literature in experimental economics finds risk aversion to be higher for females than males, hence evidence in the neuroscience field to investigate these differences arising from gender are worth investigating. A group of authors defend that risk differences are essentially related to testosterone levels (Coates and Herbert, 2008). Testosterone was found to be related with the male tendency toward aggressive behavior (Archer, 1996), hostility (Hartgens and Kuipers, 2004) and dominance (Mazur and Booth, 1998). Preuschoff et al. (2006) complement this information describing that dopaminergic systems are correlated with the mathematical expectation conditioned reward and risk, showing that the expectation of reward responses are immediate while the risk is related to later.

Finally Overman (2004) found that males and females have a different response pattern. Females tended to choose cards associated with immediate wins and males tended to choose cards related with long-term outcome meaning that women prefer investments that produce short terms outcomes. This finding is prominent in Jacobsen et al. (2014) who find that differences in optimism across gender can explain differences in asset allocation across gender.

The literature suggests that decision-making is different across gender. In particular we are interested in investigating investment decisions under uncertainty involving risk, and test if men and women use different parts of the brain to make these decisions; we also test if this situation changes when they buy, sell or hold stocks.

3 Experimental Design

3.1 Data and Experiment

The investigation was conducted, based on a sample composed of 40 undergraduate students of the School of Business Studies from Polytechnic Institute of Viana do Castelo, Portugal. Our sample is composed of 20 women and 20 men, aged 20 to 45, with a mean average age of 27. In terms of financial knowledge the sample is homogenous. Each volunteer played the following investment game (described below), with a portfolio composed by 200 stocks of seven different companies trading on the Portuguese Sock Market: Banif, Portugal Telecom, Energias de Portugal, Banco Comercial Portugues, BRISA, Cimentos de Portugal and Futebol Clube do Porto. Each participant made a total of 100 investment decisions (50 decisions in Market Scenario 1 and 50 decisions in Market Scenario 2). They were asked to buy, sell or hold these seven stocks. Based on EEG technology during the investment simulation of 100 decisions we captured brain electrical activity to identify which areas of the brain are activated when each investment decision was made how much activity takes place. Furthermore test if these areas are different for men and women.

In the trading simulation the stock price changed during the experiment according to the two different market scenarios: market 1 (m1) and market 2 (m2). Both market scenarios are simulated as a random process with drift. The drift in market 2 is higher and the volatility in market 1 is greater. The simulated stock market prices are shown in Figure 1. We provided two treatments with half of the participants (in this case 10 females and 10 males) making 50 trading decisions first in market scenario m1 in session one, followed by and another 50 trading decisions in market scenario m2 in session two.

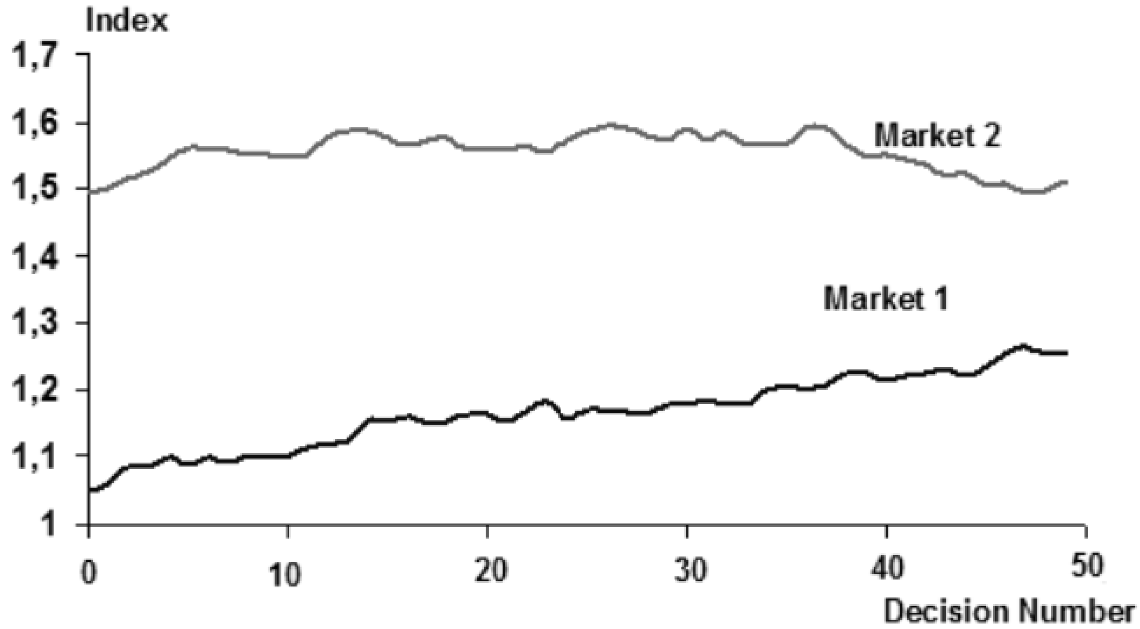

Figure 1: Stock relative price evolution (price on day (d)/price on day (1)) of the companies traded in the simulation

This ensures that we can control for the more volatile declining market prices occurring before and after a period of normal market activity. The other half of the participants reversed the trading order, initially trading in market scenario m2 and then in market m1 for the second session two. Is possible to see also from Figure 1 that market one shows a tendency for the stock index value to decrease essentially after investment decision 40 is made until decision 50. In market two the index shows a positive upward drift with a growth in prices from the start of the first decision up until the final decision. Using two different markets means that we can capture any difference in behavior between men and women when trading and making investment decisions when the market has a tendancy to be growing (bullish) or decreasing (bearish). Our two market scenarios m1 and m2 therefore generate portfolio values with different values. Participants were restricted to 50,000 Euros with which to trade on each market.

Is also important to note that none of the volunteers were given any information about the data generating process and the way each of the stock will behave across the investment simulation process. Table 1 presents the image of the information given on the computer screen presented to the participants when making the investment decisions. The Trading simulation progressed using the screen shown for each new decision. With the EGG mechanism on the scalp of the brain, the participants digitalized the number and the price of the stock to trade each time by selecting the trading option V to sell, or C to buy. The OK Enter key was pressed in order to maintain the current portfolio unaltered. If the price offer was within 5% variation of the next stock price, the offer was accepted and the corresponding number of stocks adjusted; otherwise the offer was rejected and the corresponding number of stocks was maintained unaltered.

Table 2 describes the univariate statistics of the seven stocks that composes the index depicted in Figure 1. The information given on the simulated distributions shows the Portugal Telecom had the highest standard deviation in both markets and hence the most risky stock. Whilst Cimentos de Portugal was the least risky with the lowest standard deviation. Futebol Clube do Porto had the highest average return during market one, whilst Portugal Telecom had the highest average return during the second market simulation.

Table 1: The initial portfolios for markets.

Index	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/ENTER	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 buying.

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				

Table 2: Univariate Statistics

	Market 1				Market 2			
	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev
Banif	22.81	24.13	20.32	0.72	30.90	34.20	25.06	2.04
Portugal Telecom	37.17	41.41	31.87	2.50	50.27	56.31	44.65	3.17
Energias de Portugal	22.77	25.44	19.86	1.51	36.59	39.18	33.40	1.62
Energias de Portugal	7.95	9.27	7.27	0.61	11.32	12.31	9.96	0.58
BRISA	33.06	35.52	31.10	1.07	42.77	44.00	41.15	0.78
Cimentos de Portugal	8.38	8.94	7.77	0.22	9.84	10.28	8.89	0.28
Futebol Clube do Porto	38.40	44.01	34.82	2.20	42.81	45.65	40.45	1.48

3.2 The EEG Process of Mapping the Brain

The electroencephalogram (EEG) is used to measure brain activity from the electrical charge which neurons maintain on the scalp. The EEG is performed while the volunteer undertakes the investment simulation. EEG records changes in the electrical potential using electrodes. The higher the density of the electrodes the better the inference about the spatial distribution of the electrical activity. The wires from the electrodes feed into an amplifier that allows a very rapid sampling of the electrical signal. We use a sampling frequency of 256Hz. Specifically; the recording will be 10/20 with the protocol; impedance below 10 Kohm; low-pass filter 50Hz, sampling frequency of 256 Hz and 10 bits of resolution.

Using source localization software we combine the data from these EEG channels and are able to estimate the location of the likely neural generators of the observed signals. We analyze the brain activity data at the precise time when the participants activate the keys on the keyboard for the task. The process is non-invasive and allows us to study the dynamics of financial decision-making. By combining many financial decisions we are able to combine the data from many decisions and observe the average response. Due to the spatial localization, we must infer the brain region that co-occurs with the function of interest. These types of measurement techniques in neuroscience are referred to as correlational.

To clarify the link between the information that the EEG captures from the 20 electrodes situated in different points of the brain and how this has been attributed in the neuroscience literature about main function of brain areas, we first give some more detail on this. Brodmann in 1909 divided the human cortex is 52 different areas and gave a specific name to each area. Figure 2 graphically highlights the location of these 52 areas. Our EEG technology captures information using electrodes in 20 different points of the brain. In Figure 2 we can see both where the 52 brain areas are located alongside the 20 electrodes from the EEG used in the experiment.

Table 3 provides an overview of what the neuroscience literature knows about the main functions of the 52 Brodmann areas of the brain. This information is important when interpreting our findings.

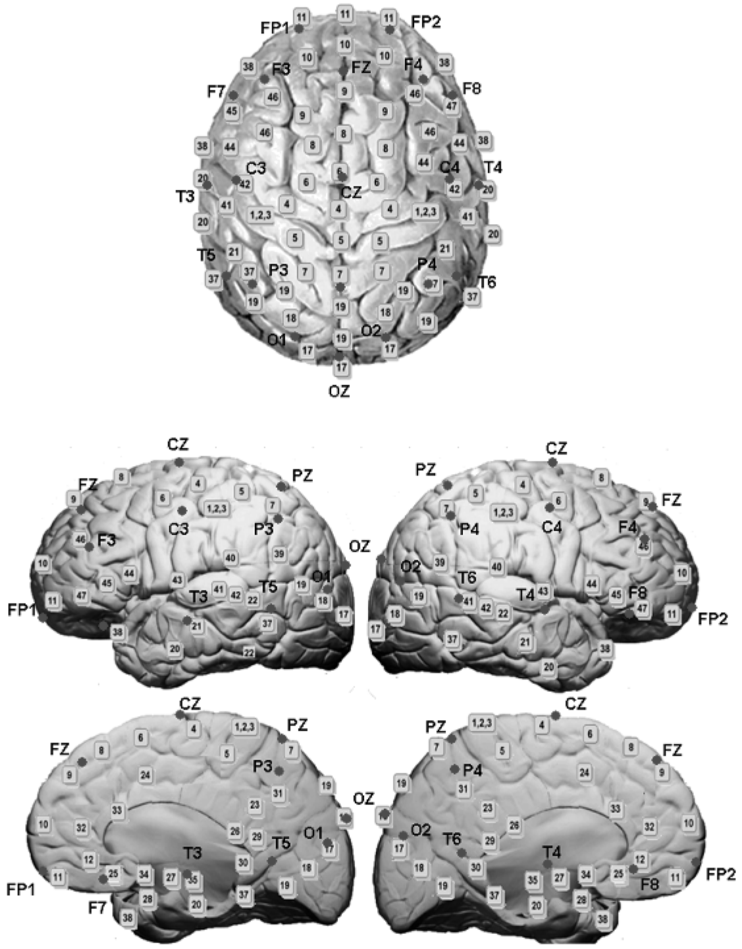

Figure 2: The Spatial Relation between the 10/20 Electrodes and the Brodmann Area Locations

Table 3: EEG Electrods, Brodmann Areas and Brain Functions

Electrode	Brodmann Areas	Function	References
C3, C4, Cz	1,2,3	Somatosensorial crtex	Strominger et al. (2012)
C3, C4, Cz	4	Primary motor crtex	Strominger et al. (2012)
C3, C4, Cz	5	Sensory association area	Strominger et al. (2012)
F3, F4	6	Time processing;	Coull et al. (2011), Rubia and Smith (2004),
F3, F4	6	Motor and sequential	Halsband and Lange (2006),
		Learning	Petersen et al. (1998)
		Language	Fiez and Petersen (1998)
		Working memory	Smith et al. (1998)
		Mirror neuron,	Rizzolatti et al. (1981),
		mentalizing	Van Overwalle and Baetens (2009)
C3, C4, Cz	7	Arithmetic	Budgen et al (2012),
			Rocha et al (2005a), (2005b)
C3, C4, Cz	7 (Precuneus)	Goal directed actions	Cavanna and Trimble (2006)
C3, C4, Cz	7 (Precuneus)	Episodic memory	Cavanna and Trimble (2006),
			Zhang and Li (2012)
C3, C4, Cz	7 (Precuneus)	Episodic retrieval	Kwok, Shallice and Macaluso (2012)
F3, F4, Fz	8	Frontal eye field	Luna et al. (1998)
		(eye movement control)	
		Uncertainty processing	Volz, and van Cramon (2005).
F3, F4, Fp1, Fp2	9	Working memory;	Leung et al. (2002)
FP1, FP2, F3, F7, F4, F8	10	Goal formation	Ramnani and Owen (2004),
			Tsujimoto and Wise (2011)
	10	Risk processing	Rogers et al. (1999)
		Benefit assessment	Cho et al (2013),
			Knutson et al (2003) and (2007)
		Prospective memory	Burgess et al. (2009),
			Krueger et al (2007), Volle et al (2011)
	11	Benefit assessment	Ernst et al (2004),
			Goldapple et al (2004), Knutson et al (2007)
FP1, FP2, F3, F7, F4, F8	11	Risk processing	Ernst et al (2004),
			Goldapple et al (2004), Knutson et al (2007)
		Value	Gottfried et al (2007),
			Padoa-Schioppa and Assad (2006)
FP1, FP2, F3, F4	13	Risk processing	Bossaerts (2010), Kuhnen and Knuston (2005),
			Paulus et al (2003), (2005)
		Episodic memory	Burianov et al (2012),
			Kim (2009)
P3,P4, Pz, T5, T6	BA 18, BA 19 (Lingual Gyrus)	Language	Campbell et al. (2008),
	BA 19 (Lingual Gyrus)		Friederici (2011),
			Price (2012), Vitacco et al (2002)
P3,P4, Pz, T5, T6	BA 18,	Language	Adorni and Proverbio (2012),
	BA 19 (Fusiform Gyrus)		Friederici (2011), Price (2012)
P3,P4, Pz	BA 18, BA 19 (Precuneus)	Goal directed actions	Cavanna and Trimble (2006)

Table 3: EEG Electrods, Brodmann Areas and Brain Functions Continued.

Electrode	Brodmann Areas	Function	References
T3, T4, T5, T6	BA 21, BA 20, BA 21 (Temporal Lobe)	Language	Dien et al (2013), Grindrod et al (2008), Price (2012)
T3, T4, T5, T6	BA 21, BA 20, BA 21 (Temporal Lobe)	Arithmetic	Grabner et al (2009), Fehr et al. (2007), Rocha et al (2005a), (2005b)
T3, T4, T5, T6	BA 22 (Wernick's Area)	Language	Campbell et al. (2008), Friederici (2011), Price (2012)
Fp1, Fp2, F3, F4, Fz	BA 32	Conflict	Bush et al. (2000)
	BA 32	Error detection	Bush et al. (2000), Perianez et al (2012)
T3, T4, T5, T6	BA 37 (Angular Gyrus)	Language	Campbell et al. (2008), Friederici (2011), Price (2012)
T3, T4, T5, T6	BA 38 (Temporal Pole)	Emotion	Blaizoet al (2010), Koelsch (2014), Smith et al (2005)
P3, P4, PZ	BA 39 (Angular Gyrus)	Arithmetic	Grabner et al (2009), Fehr et al. (2007), Rocha et al (2005a), (2005b)
C3, C4, P3, P4, T3, T5, T4, T6	BA 40 (Supramarginal Gyrus)	Language	Campbell et al. (2008), Friederici (2011), Price (2012)
C3, C4, P3, P4, T3, T5, T4, T6	BA 40 (Supramarginal Gyrus)	Emotion	Morelli et al. (2014), (2013)
P3, P4, T3, T5, T4, T6	BA 41	Language	Friederici (2011), Price (2012)
P3, P4, T3, T5, T4, T6	BA 42	Language	Friederici (2011), Price (2012)
C3, C4, Cz, F3, F4, Fz, F7, F8	BA 43	Arithmetic	Kaufmann et al (2008), Mayhew et al (2012)
	BA 43	Language	Vingerhoets et al. (2003)
		Learning	Mayhew et al (2012)
F3, F7, T3, T4, C3, C4, Cz	BA44 , BA 45	Language	Campbell et al. (2008), Friederici (2011), Price (2012)
F3, F7, T3, T4, Fp1, Fp2	BA46	Working memory	Leung et al. (2002), Ranganath and D'Esposito (2003)
F3, F7, T3, T4, Fp1, Fp2	BA46	Decision making	Deppe et al (2005)
F3, F7, T3, T4, Fp1, Fp2	BA47	Decision making	Rogers et (1999)
F3, F7, T3, T4, Fp1, Fp2	BA47	Reasoning	Rogers et (1999)
F3, F7, T3, T4, Fp1, Fp2	BA47	Inhibitory control	Hampshire et al (2010), Obeso et al (2013), Watson and Chatterjee (2012)

In terms of EEG any cognitive task is supported by activation of sets of neurons located in many different cortical areas over the entire cortex, each of these taking charge of handling specific aspects of cognition (see table 1 and Rocha et al, 2005, 2010). Activation of these neurons generated electrical currents that give rise to electrical fields that are sensed by electrodes placed in the scalp. The temporal recordings of brain activity by sets of electrodes (e.g., 20 electrodes as in this paper) is called electroencephalogram (EEG).

The 20 electrodes of the EEG are named according to the brain lobes (Frontal or F electrodes, Temporal or T electrodes, Occiptal or O electrodes and Parietal or C and P electrodes) they are supposed to monitor. Electrodes in the left hemisphere are even-numbered and in the right hemisphere they are odd-numbered.

The currents generated by different sets of neurons located in different areas of the brain sum up to produce the electrical fields that are sensed by the different electrodes. The electrical field sensed by each electrode depends on the distance of the electrode to the sets of neurons acting as current sources. This way, the frontal electrodes (denoted as Fx in Figure 3) are able to measure the activity of neurons located in the anterior brain.

Because EEG data are assumed to be a weighted sum of the electrical activity of different sources s_i, correlation analysis of the electrical activity $v(e_i, t)$ recorded by the different electrodes e_i may be used to summarize information provided by each electrode e_i about all involved sources s_i into a single variable as proposed by Rocha et al (2010; 2011, 2013). Correlation estimates capture the degree of linear dependence between the electrodes.

In our investigation we also use Principal Component Analysis (PCA) to determine if information may be condensed into small sets of these variables called principal components. This transformation is defined in such a way that the first principal component is the one that accounts for as much of the variability in the data as possible, and each succeeding component in turn explains the subsequent amount of variance possible under the constraint that it is orthogonal to the preceding components. Based on this information we create brain maps to represent the activity of the neural circuits involved in a cognitive task. We condense the information provided by the electrodes sampling this neural activity. Factorial analysis does not map brain areas activated by a cognitive task, but rather, measures the amount of information provided by about the spatial and temporal distribution of the neurons. Factorial analysis provides information to disclose the activity of circuits composed by neurons distributed on different areas of the brain recruited by the cognitive task. PCA is therefore first applied here to study the covariation during each of the selected epochs.

Furthermore, regression analysis studies the association between the financial numerical variables and the discrete numerical variables from a questionnaire to collect demographic information on age and gender; and $H(e_i)$ is calculated for each of the electrodes (independent variables) and controlled for by the variable expertise (potential confounder). Given $H(e_i)$ as the mean $H(e_i)$ for each group, the normalized values of the $\beta_i(e_i)H(e_i)$ will be used to build the color-coded brain mapping images to display the results of the regression analysis. Statistically positive betas will be coded from green (normalized $\beta_i(e_i)H(e_i)$ tending to 0) to dark blue (normalized $\beta_i(e_i)H(e_i)$ tending to +1). Statistically negative $\beta_i(e_i)H(e_i)$ will be coded from rose (normalized $\beta_i(e_i)H(e_i)$ tending to 0) to dark red. Hence the greater the brain activity the darker the blue in the brain maps.

4 Experiment Results

The psychology literature describes that men and woman, although having similar IQs may use different neural circuits to solve the same task or to process the same perception (e.g. Bell et al, 2006; Jaušovec and Jaušovec 2009; Rocha, Rocha and Massad, 2011), but according to our knowledge no investigation until now has analyzed what happens in terms of gender differentials and brain electrical activity when a large number of financial investment decisions are made. This way, this investigation is among the first to analyse if women and men brains work in different ways when making the same investment decisions. We also test if these differences exist when they make particular decisions related to buying, selling or holding stocks.

4.1 Gender Differences in Brain Activity

Table 4 and Figures 3 display the electrodes and the zones of the brain activated in men and women when they make the same investment decisions. The table has three different columns that represent the image of the brain with the information capture from Principal Component Analysis (Factor 1, Factor 2 and Factor 3). Each factor has three different groups of images that display the view of the brain in three different perspectives. To build these images we use a loading factor higher than 0.65 until 1 like Rocha et al. (2011). For example, the highest loading value of female factor 1 is the value of 0.85 and is associated with the brain area related with the electrode C3. In the male case the electrodes with high loading values are FP2 (0.86) and FP1 (0.85). In figure 4, the higher loading values appear with more intense color. The white colours areas of the brain mean that loading factors are smaller than 0.65, meaning that brain electrical frequency activity captured by the electrodes located in this area is low.

Table 4: Principal Component Analysis Results

	Female				Male		
Electrod	Factor 1	Factor 2	Factor 3	Electraod	Factor 1	Factor 2	Factor 3
C3	0.85	0.06	0.23	C3	0.79	0.14	0.21
C4	0.49	0.14	0.73	C4	0.25	0.09	0.88
CZ	0.74	0.18	0.26	CZ	0.76	0.28	0.31
F3	0.78	0.43	0.10	F3	0.83	0.24	0.24
F4	0.84	-0.10	0.23	F4	0.83	-0.12	0.34
F7	0.68	0.40	0.33	F7	0.22	0.30	0.83
F8	0.54	0.49	0.18	F8	0.80	0.34	0.31
FP1	0.76	0.50	0.02	FP1	0.85	0.30	0.20
FP2	0.63	0.51	0.05	FP2	0.86	0.26	0.22
FZ	0.36	0.68	0.21	FZ	0.84	0.24	0.22
O1	0.27	0.55	-0.31	O1	0.09	0.71	0.30
O2	0.05	0.86	0.15	O2	0.33	0.82	0.10
OZ	0.11	0.90	0.13	OZ	0.37	0.73	0.16
P3	0.30	0.41	0.41	P3	0.26	0.43	0.43
P4	0.47	0.33	0.65	P4	0.36	0.22	0.78
PZ	0.33	0.60	0.43	PZ	0.39	0.37	0.58
T3	0.18	0.44	0.58	T3	0.27	0.23	0.84
T4	0.65	-0.07	0.55	T4	0.36	-0.16	0.83
T5	0.02	0.44	0.59	T5	0.09	0.44	0.74
T6	0.20	0.76	0.32	T6	0.39	0.73	0.24
Expl.Var	5.70	5.09	2.91	Expl.Var	0.79	0.14	0.21
Prp.Totl	0.28	0.25	0.15	Prp.Totl	0.25	0.09	0.88
Eigenvalue	Variance	Eigenvalue	Variance				
F1	9.75	48.76	1	11.06	55.29		
F1	2.27	11.34	2	2.31	11.54		
F3	1.36	6.78	3	1.81	9.03		
	F1	F2	F3				
R (F/M)	0.52	0.75	0.53				

Note: R (F/M) - Pearson's correlation coefficient among female and male loading factors equal or greater than 0.65.

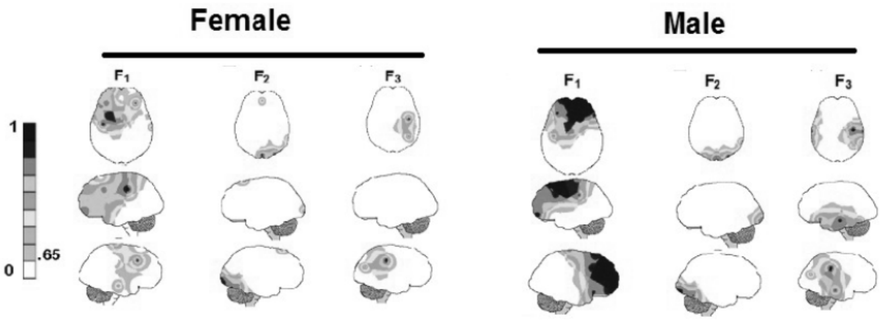

Figure 3: Principal Component Analysis mappings for Females (F) and Males (M) calculated from the results in table 4. Values in table 4 were normalized and color encoded such that loading factor greater than .6 are colored from green (.65) to dark blue (1).

We can see that in the case of factor 1, 48.76% of brain activity for female participants and 55.29% of the variance for males is explained. It is possible to see large differences in brain activity between men and women when they make the same financial investment decisions. Females activate areas C3 (0.85), CZ (0.74), F3(0.78), F4 (0.84), F7 (0.68) and FP1 (0.75) more than men. Men activate more the brain areas C3(0.79), CZ (0.76), F3(0.83), F4(0.83), F8(0.80), FP1(0.85), FP2(0.86), FZ(0.84) than women. Comparing the results from both cases we can conclude that brain areas monitored by electrodes F8, F7, FP2 and FZ have different contributions when men and women make the same decisions. Analysing the second factor, that explains 11.34% (female) and 11.54% (male) of the variance of the activity, we can conclude that female areas of the brain with more than 0.65 activity are FZ (0.68), O2 (0.86), OZ (0.90) and T6(0.76). For males the brain area activity occurs in O1 (0.71) O2 (0.82), OZ (0.73) and T6(0.73). Areas monitored by FZ and O1, FZ have different contributions when men and women make the same decisions. Finally, in the case of factor 3 females only activate two brain areas: C4 (0.73) and P4 (0.65) but males activate C4 (0.88), F4(0.83), P4(0.78), T3 (0.84), T4 (0,83) and T5 (0.74). It is interesting to see that similar regions of the brain are activated, but that males use more areas in the case of factor 3. Overall from our results we find strong evidence that that men and women use different parts of the brain to make investment decisions. Using the information of table 4 we also compile the results in figure 4, highlighting the location of the electrodes activated when neural activity corresponds to values greater than 0.65. We do this for Factors 1, 2 and 3.

4.2 Gender Differences in Buy, Sell, and Hold Decisions

We extend our analysis to investigate if there are gender differences in terms of brain activity when different types of investment decisions are made. In particular we split the sample into decisions to buy, sell and to hold (maintain the stock position). Table 5 displays information related to brain electrical activity for male and female investment decisions. Figure 5 displays the results graphically. We see that for males, the areas of the brain more activated during investment process are on average relatively similar when they make the decisions to buy, sell or to hold stocks. However, for females the areas are different. Females appear to use different neural circuits to make these three different decisions investment decisions. Figure 6 graphically presents the electrodes activated (values higher than 0.65) for decisions to buy, sell or maintain share holdings.

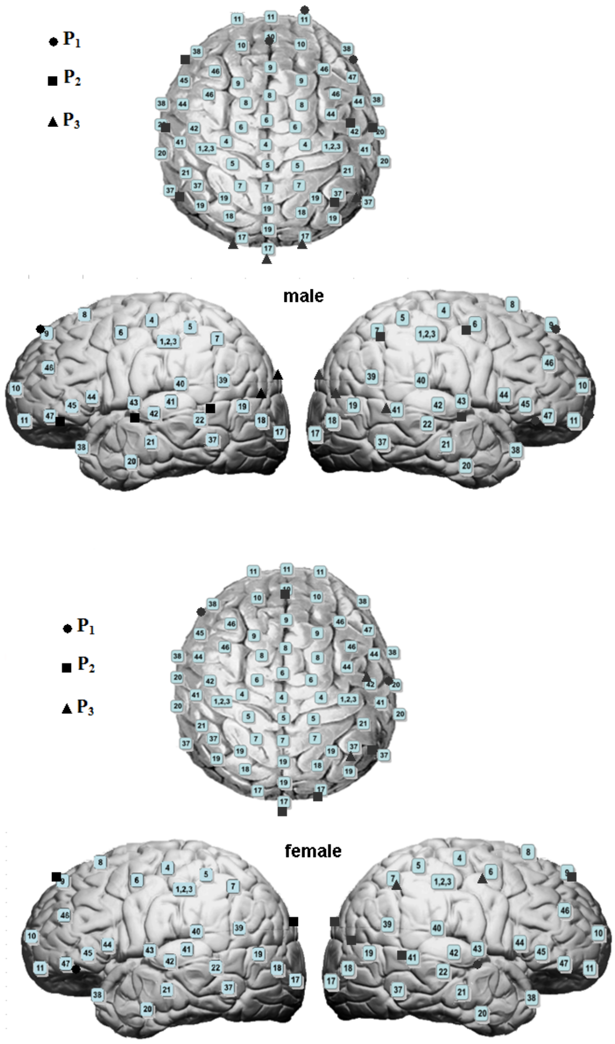

Figure 4: Electrodes that differentiate male and female PCA mappings provided in figure 3

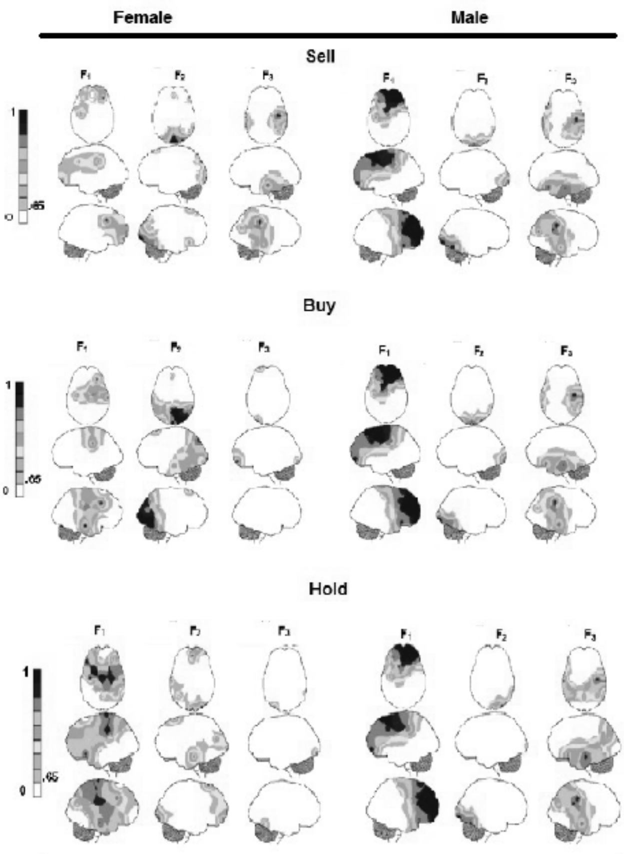

Figure 5: Buy, Sell and Maintain Decisions - Principal Component Analysis mappings for Females and Males calculated from the results in Table 5

Table 5: Principal Component Analysis results

	Sell						Buy						Hold					
	Male			Female			Male			Female			Male			Female		
Electrode	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
C3	0.80	0.25	0.12	0.79	0.29	0.18	0.77	0.25	0.15	0.74	0.12	0.42	0.80	0.03	0.24	0.92	0.08	-0.12
C4	0.29	0.88	0.09	0.33	0.83	0.18	0.23	0.89	0.09	0.63	0.48	-0.10	0.22	0.89	0.11	0.82	0.13	0.09
CZ	0.75	0.31	0.31	0.53	0.36	0.31	0.76	0.31	0.23	0.63	0.38	0.25	0.72	0.28	0.41	0.88	0.16	-0.04
F3	0.83	0.25	0.23	0.64	0.15	0.55	0.81	0.21	0.25	0.49	0.39	0.59	0.86	0.26	0.26	0.75	0.32	0.10
F4	0.81	0.34	-0.06	0.86	0.26	-0.06	0.81	0.39	-0.16	0.85	-0.09	0.30	0.87	0.24	-0.01	0.83	-0.12	0.14
F7	0.24	0.85	0.22	0.46	0.53	0.45	0.21	0.83	0.32	0.45	0.48	0.47	0.25	0.78	0.19	0.85	0.24	0.13
F8	0.81	0.32	0.30	0.35	0.26	0.64	0.78	0.30	0.38	0.17	0.51	0.54	0.82	0.29	0.30	0.73	-0.07	0.36
FP1	0.85	0.22	0.27	0.67	0.13	0.59	0.83	0.15	0.34	0.41	0.37	0.70	0.89	0.23	0.23	0.74	0.47	0.06
FP2	0.86	0.22	0.23	0.78	0.19	0.41	0.84	0.21	0.34	0.59	0.36	0.56	0.90	0.19	0.14	0.33	0.75	0.02
FZ	0.82	0.25	0.26	0.41	0.35	0.63	0.82	0.24	0.25	0.32	0.63	0.41	0.88	0.20	0.15	0.28	0.82	-0.02
O1	0.09	0.34	0.69	0.24	-0.18	0.62	0.13	0.22	0.77	-0.10	0.13	0.73	0.04	0.56	0.38	-0.04	0.01	0.83
O2	0.36	0.12	0.77	0.19	0.24	0.81	0.31	0.11	0.83	0.08	0.80	0.30	0.26	0.12	0.89	0.00	0.84	0.07
OZ	0.40	0.17	0.70	0.14	0.18	0.84	0.34	0.18	0.73	0.05	0.80	0.40	0.39	0.13	0.77	-0.06	0.77	0.31
P3	0.21	0.27	0.52	0.17	0.52	0.24	0.34	0.33	0.43	0.45	0.61	-0.02	0.19	0.73	0.20	0.41	0.65	0.06
P4	0.30	0.81	0.19	0.30	0.73	0.29	0.33	0.79	0.22	0.45	0.67	0.14	0.31	0.77	0.23	0.76	0.10	0.34
PZ	0.34	0.66	0.32	0.04	0.50	0.68	0.38	0.48	0.48	0.16	0.83	0.25	0.36	0.72	0.08	0.65	0.27	0.40
T3	0.30	0.81	0.19	0.22	0.76	0.31	0.27	0.82	0.27	0.49	0.62	-0.08	0.28	0.85	0.17	0.09	0.75	-0.02
T4	0.41	0.79	-0.12	0.54	0.63	-0.07	0.35	0.82	-0.18	0.82	0.22	-0.07	0.32	0.82	-0.15	0.83	0.16	-0.20
T5	0.10	0.80	0.36	0.09	0.64	0.36	0.10	0.74	0.44	0.10	0.64	0.03	-0.02	0.74	0.49	0.17	0.49	0.31
T6	0.39	0.23	0.71	0.10	0.33	0.74	0.39	0.23	0.72	0.15	0.83	0.23	0.32	0.23	0.81	0.28	0.40	0.63
Expl.Var	6.45	5.36	3.17	4.33	4.18	5.11	6.23	5.06	3.83	4.57	6.06	3.11	6.59	5.79	3.10	7.54	4.48	1.80
Prp.Totl	0.32	0.27	0.16	0.22	0.21	0.26	0.31	0.25	0.19	0.23	0.30	0.16	0.33	0.29	0.15	0.38	0.22	0.09
	Male vs Female						Male vs Female						Male vs Female					
R	0.77	0.81	0.79				0.08	0.35	0.27				0.43	0.16	0.42			

4.3 Brain Activity, Gender and Portfolio Holdings

We now turn to understanding what areas of the male and female brain are related to portfolio holdings, in particular portfolio value and cash holdings. One of the first important conclusions that we can extract from the table is that women manage portfolios with a lower total value and prefer to keep a higher percentage of the portfolio in cash. Is important to mention that each volunteer received 50,000 Euros at the beginning of the investment simulation to invest and they were able to invest all this money in stocks or just a small part and retain the rest in cash.

Table 6: OLS Regression Neural Activity and Value of Equity in the Portfolio

	Dependent Variable: Equity Value											
	Full Market Simulation				Market 1				Market 2			
	(1)		(2)		(1)		(2)		(1)		(2)	
	Coef	T Stat	Coef	T Stat	Coef	T Stat	Coef	T Stat	Coef	T Stat	Coef	T Stat
Constant	2.904	20.483***	3.102	21.615***	2.991	30.831***	3.158	33.568***	2.811	11.287***	2.931	11.794***
Gender	-0.745	-6.552***	-1.002	-8.053***	-0.103	-1.318	-0.251	-3.036***	-1.735	-8.473***	-2.1122	-9.398***
C3	-0.013	-0.244	-0.099	-1.511	-0.048	-1.31	-0.139	-3.061***	-0.047	-0.489	-0.065	-0.561
C4	-0.009	-0.143	-0.180	-2.247***	-0.071	-1.704*	-0.290	-5.172	0.04	0.367	-0.335	-2.383**
CZ	0.008	0.148	0.034	0.449	0.168	4.455***	0.085	1.553	-0.353	-3.769***	-0.216	-1.662*
F3	-0.015	-0.271	0.177	2.599***	-0.212	-5.202***	-0.088	-1.855*	0.069	0.7	0.322	2.794***
F4	0.378	7.219***	0.604	9.330***	-0.114	-3.117***	-0.070	-1.603	0.941	10.242***	1.28	11.487***
F7	0.428	7.432***	0.31	3.770***	0.231	5.743***	0.133	2.311**	0.632	6.192***	0.458	3.135***
F8	0.116	2.157**	0.08	1.102	0.099	2.665***	0.018	0.363	0.168	1.760*	0.084	0.655
FP1	0.356	5.305***	0.541	6.500***	0.167	3.501***	0.137	2.337**	0.634	5.304***	1.052	7.038***
FP2	-0.054	-0.807	-0.144	-1.741*	0.039	0.752	0.201	3.272***	-0.158	-1.386	-0.382	-2.619***
FZ	-0.595	-11.137***	-0.709	-10.818***	0.033	0.857	0.111	2.472**	-1.192	-12.988***	-1.471	-13.343***
O1	0.026	0.574	-0.180	-2.438**	-0.110	-3.592***	-0.211	-4.295***	0.169	2.059**	-0.141	-1.063
O2	0.117	1.840*	0.308	3.826***	-0.208	-4.710***	-0.056	-1.036	0.38	3.302***	0.674	4.638***
OZ	0.368	5.632***	0.542	7.009***	0.122	2.632***	0.268	5.060***	0.777	6.523***	0.987	6.822***
P3	0.056	1.238	0.175	2.654***	0.04	1.372	0.078	1.780*	0.142	1.606	0.317	2.705***
P4	-0.096	-1.785*	0.039	0.566	-0.167	-4.467***	-0.077	-1.607	-0.005	-0.058	0.305	2.468**
PZ	0.0561	1.13	-0.076	-1.08	0.103	2.953***	-0.021	-0.428	0.066	0.743	-0.236	-1.957*
T3	0.158	2.971***	0.064	0.914	-0.084	-2.168***	-0.102	-2.042**	0.409	4.345***	0.291	2.442**
T4	-0.384	-7.949***	-0.702	-11.108***	0.03	0.887	-0.130	-3.053***	-0.747	-8.676***	-1.268	-11.083***
T5	-0.401	-7.990***	-0.335	-4.677***	-0.036	-1.045	0.091	1.902*	-0.841	-9.106***	-0.674	-5.130***
T6	-0.197	-3.504***	-0.091	-1.24	0.072	1.801	0.133	2.682***	-0.450	-4.494***	-0.264	-2.038**
C3*Gender			0.264	2.250**			0.124	1.628			0.319	1.48
C4* Gender			0.237	1.804*			0.38	4.389***			0.609	2.533**
CZ*Gender			-0.097	-0.793			-0.040	-0.488			-0.075	-0.355
F3*Gender			-0.055	-0.405			0.218	2.436**			-0.307	-1.257
F4* Gender			-0.547	-4.599***			0.059	0.762			-1.066	-4.999***
F7* Gender			-0.140	-1.046			-0.022	-0.255			-0.285	-1.208
F8* Gender			-0.109	-0.856			0.149	1.781*			-0.213	-0.936
FP1* Gender			-0.646	-4.400***			-0.250	-2.533**			-1.046	-4.160***
FP2* Gender			0.136	0.881			-0.283	-2.604***			0.433	1.676*
FZ*Gender			0.736	5.254***			-0.141	-1.468			1.496	6.377***
O1*Gender			0.151	1.486			-0.015	-0.235			0.439	2.388**
O2* Gender			-0.436	-2.964***			-0.328	-3.341***			-0.597	-2.340**
OZ* Gender			-0.417	-2.715***			-0.251	-2.381**			-0.776	-2.977***
P3* Gender			-0.245	-2.566**			-0.054	-0.9			-0.480	-2.634***
P4* Gender			-0.319	-2.730***			-0.152	-1.994**			-0.770	-3.687*
PZ* Gender			0.183	1.698*			0.206	2.898***			0.376	1.941
T3* Gender			0.085	0.698			0.08	0.976			0.087	0.412
T4* Gender			0.715	6.357***			0.156	2.090**			1.218	6.16
T5* Gender			0.112	1.021			-0.116	-1.639			0.175	0.883
T6* Gender			0.12	0.847			0.037	0.399			0.226	0.899
R-Squared		16.14%		18.97%		11.98%		26.96%		28.10%		35.11%
Observation		3460		3460		1714		1714		1739		1739

Table 7: OLS Regression Neural Activity and Cash Holdings

	Dependent Variable: Cash Holding											
	Full Market Simulation				Market 1				Market 2			
	(1)		(2)		(1)		(2)		(1)		(2)	
	Coef	T Stat	Coef	T Stat	Coef	T Stat	Coef	T Stat	Coef	T Stat	Coef	T Stat
Constant	1.442	16.801***	1.221	14.246***	1.478	13.767***	1.232	11.577***	1.423	10.515***	1.269	9.462***
Gender	0.729	10.589***	0.945	12.719***	0.375	4.330***	0.688	7.341***	1.177	10.571***	1.31	10.798***
C3	0.032	0.977	0.131	3.362***	0.03	0.735	0.214	4.156***	0.082	1.543	0.109	1.743*
C4	0.021	0.578	0.004	0.084	0.008	0.181	-0.038	-0.605	-0.033	-0.575	0.1	1.31
CZ	-0.053	-1.670*	0.024	0.521	-0.015	-0.372	0.072	1.164	-0.035	-0.703	-0.0007	-0.011
F3	0.155	4.478***	0.072	1.786*	0.104	2.295**	-0.090	-1.673*	0.22	4.138***	0.199	3.197***
F4	-0.209	-6.605***	-0.310	-8.028***	-0.173	-4.271***	-0.303	-6.098***	-0.268	-5.369***	-0.357	-5.945***
F7	-0.372	-10.701***	-0.264	-5.386***	-0.366	-8.225***	-0.262	-4.048***	-0.386	-6.973***	-0.288	-3.652***
F8	0.076	2.341**	0.071	1.651*	0.041	1.004	0.124	2.245**	0.112	2.150**	0.093	1.334
FP1	-0.284	-7.016***	-0.432	-8.703***	-0.130	-2.467**	-0.203	-3.058***	-0.498	-7.675***	-0.716	-8.887***
FP2	0.084	2.068**	0.154	3.120***	-0.033	-0.594	-0.111	-1.603	0.208	3.347***	0.365	4.629***
FZ	0.087	2.703***	0.076	1.947*	0.042	0.984	-0.082	-1.623	0.109	2.191**	0.179	3.005***
O1	0.064	2.325**	0.32	7.250***	0.147	4.312***	0.397	7.105***	-0.040	-0.921	0.24	3.354***
O2	-0.025	-0.669	-0.023	-0.493	0.017	0.348	-0.088	-1.436	-0.047	-0.765	-0.028	-0.363
OZ	-0.165	-4.192***	-0.383	-8.310***	-0.106	-2.068**	-0.294	-4.919***	-0.236	-3.662***	-0.485	-6.222***
P3	-0.219	-8.059***	-0.454	-11.505***	-0.226	-7.067***	-0.328	-6.610***	-0.256	-5.330***	-0.558	-8.830***
P4	0.045	1.384	-0.039	-0.955	0.052	1.26	-0.097	-1.790*	0.058	1.107	-0.054	-0.814
PZ	-0.030	-1.007	0.005	0.12	0.039	0.996	0.159	2.771***	-0.090	-1.870*	0.02	0.307
T3	0.052	1.618	0.219	5.215***	0.069	1.606	0.096	1.697*	0.022	0.437	0.262	4.070***
T4	0.165	5.650***	0.353	9.362***	0.171	4.630***	0.442	9.168***	0.16	3.409***	0.369	5.978***
T5	0.256	8.427***	0.117	2.737***	0.162	4.240***	0.106	1.970**	0.41	8.156***	0.117	1.650*
T6	-0.015	-0.46	-0.018	-0.414	-0.138	-3.148***	-0.012	-0.228	0.118	2.161**	-0.022	-0.321
C3*Gender			-0.194	-2.781***			-0.293	-3.406***			-0.152	-1.308
C4* Gender			0.062	0.793			0.157	1.609			-0.136	-1.048
CZ*Gender			0.059	0.81			0.069	0.745			0.108	0.946
F3*Gender			-0.097	-1.188			0.195	1.919*			-0.334	-2.538*
F4* Gender			0.156	2.198**			0.131	1.498			0.169	1.469
F7* Gender			-0.014	-0.177			-0.036	-0.366			-0.005	-0.045
F8* Gender			0.011	0.139			-0.116	-1.232			0.041	0.332
FP1* Gender			0.48	5.479***			0.269	2.404**			0.716	5.278***
FP2*Gender			-0.225	-2.449			0.042	0.343			-0.362	-2.598
FZ*Gender			-0.040	-0.479			0.052	0.482			-0.123	-0.978
O1*Gender			-0.284	-4.695***			-0.221	-2.967***			-0.404	-4.083***
O2* Gender			0.008	0.092			0.176	1.586			-0.041	-0.302
OZ* Gender			0.601	6.550***			0.568	4.756***			0.695	4.941***
P3* Gender			0.472	8.283***			0.241	3.503***			0.692	7.025***
P4* Gender			0.227	3.248***			0.26	2.998***			0.336	2.976***
PZ* Gender			-0.137	-2.136**			-0.273	-3.409***			-0.183	-1.756*
T3* Gender			-0.398	-5.494***			-0.094	-1.027			-0.593	-5.199***
T4* Gender			-0.281	-4.196***			-0.470	-5.579***			-0.259	-2.432**
T5* Gender			0.135	2.055**			0.033	0.409			0.292	2.731***
T6* Gender			-0.264	-3.141***			-0.516	-4.864***			-0.140	-1.035
R-Squared		15.39%		22.88%		16.07%		27.31%		19.82%		28.68%
Observations		3550		3550		1714		1714		1738		1738

Table 8: OLS Regression Neural Activity and Final Portfolio Balance

	Dependent Variable: Final Portfolio Value											
	Full Market Simulation				Market 1				Market 2			
	(1)		(2)		(1)		(2)		(1)		(2)	
	Coef	T Stat	Coef	T Stat	Coef	T Stat	Coef	T Stat	Coef	T Stat	Coef	T Stat
Constant	14.411	16.803***	12.204	14.243***	14.784	13.767***	12.318	11.577	14.228	10.519***	12.669	9.454***
Gender	7.291	10.597***	9.455	12.733***	3.751	4.330***	6.885	7.341	11.768	10.579***	13.121	10.824***
C3	0.317	0.984	1.317	3.378***	0.303	0.735	2.136	4.156	0.819	1.548	1.11	1.770*
C4	0.213	0.586	0.044	0.091	0.083	0.181	-0.384	-0.605	-0.334	-0.571	1.002	1.319
CZ	-0.534	-1.665*	0.244	0.536	-0.154	-0.372	0.717	1.164	-0.356	-0.7	0.007	0.011
F3	1.546	4.478***	0.724	1.785*	1.037	2.295**	-0.9	-1.673	2.202	4.139***	1.986	3.195***
F4	-2.094	-6.604***	-3.102	-8.032***	-1.731	-4.271***	-3.03	-6.098	-2.681	-5.370***	-3.578	-5.955***
F7	-3.726	-10.700***	-2.636	-5.379***	-3.668	-8.225***	-2.629	-4.048	-3.863	-6.974***	-2.867	-3.636***
F8	0.762	2.342**	0.713	1.650*	0.412	1.004	1.238	2.245	1.116	2.151**	0.922	1.329
FP1	-2.847	-7.015***	-4.324	-8.701***	-1.301	-2.467**	-2.031	-3.058	-4.984	-7.678***	-7.169	-8.892***
FP2	0.839	2.065**	1.539	3.113***	-0.338	-0.594	-1.112	-1.603	2.078	3.347***	3.64	4.616***
FZ	0.872	2.698***	0.757	1.934*	0.418	0.984	-0.826	-1.623	1.092	2.189**	1.774	2.984***
O1	0.637	2.327**	3.198	7.256***	1.468	4.312***	3.966	7.105	-0.408	-0.92	2.411	3.368***
O2	-0.258	-0.674	-0.24	-0.501	0.17	0.348	-0.888	-1.436	-0.48	-0.769	-0.296	-0.378
OZ	-1.656	-4.190***	-3.834	-8.307***	-1.065	-2.068**	-2.946	-4.919	-2.368	-3.662***	-4.849	-6.213***
P3	-2.189	-8.056***	-4.536	-11.500***	-2.269	-7.067***	-3.281	-6.61	-2.561	-5.330***	-5.566	-8.818***
P4	0.447	1.378	-0.401	-0.97	0.523	1.26	-0.978	-1.79	0.577	1.103	-0.564	-0.847
PZ	-0.301	-1.009	0.046	0.11	0.386	0.996	1.593	2.771	-0.908	-1.874*	0.186	0.285
T3	0.518	1.613	2.182	5.205***	0.694	1.606	0.961	1.697	0.222	0.435	2.606	4.053***
T4	1.65	5.648***	3.531	9.359***	1.709	4.630***	4.422	9.168	1.595	3.409***	3.687	5.971***
T5	2.564	8.434***	1.177	2.752***	1.62	4.240***	1.063	1.97	4.099	8.164***	1.19	1.679*
T6	-0.156	-0.459	-0.179	-0.408	-1.384	-3.148***	-0.127	-0.228	1.177	2.164**	-0.213	-0.305
C3*Gender			-1.951	-2.788***			-2.939	-3.406			-1.535	-1.319
C4* Gender			0.62	0.789			1.574	1.609			-1.368	-1.055
CZ*Gender			0.585	0.802			0.693	0.745			1.068	0.935
F3*Gender			-0.972	-1.187			1.947	1.919			-3.344	-2.536**
F4* Gender			1.561	2.201***			1.311	1.498			1.696	1.473
F7* Gender			-0.146	-0.183			-0.369	-0.366			-0.072	-0.057
F8* Gender			0.106	0.139			-1.166	-1.232			0.408	0.332
FP1* Gender			4.801	5.478***			2.693	2.404			7.163	5.279***
FP2* Gender			-2.248	-2.445**			0.423	0.343			-3.61	-2.590***
FZ*Gender			-0.394	-0.472			0.524	0.482			-1.221	-0.966
O1*Gender			-2.85	-4.698***			-2.218	-2.967			-4.055	-4.091***
O2* Gender			0.084	0.096			1.763	1.586			-0.405	-0.295
OZ* Gender			6.012	6.549***			5.678	4.756			6.945	4.937***
P3* Gender			4.719	8.278***			2.41	3.503			6.906	7.013***
P4* Gender			2.274	3.258***			2.596	2.998			3.38	2.999***
PZ* Gender			-1.368	-2.131**			-2.739	-3.409			-1.822	-1.745*
T3* Gender			-3.98	-5.488***			-0.949	-1.027			-5.917	-5.189***
T4* Gender			-2.816	-4.193***			-4.707	-5.579			-2.588	-2.427**
T5* Gender			1.341	2.048**			0.328	0.409			2.903	2.717***
T6* Gender			-2.65	-3.144***			-5.163	-4.864			-1.413	-1.044
R-Squared		15.3%		22.88%		16.07%		27.31%		19.83%		28.68%
Observations		3551		3551		1714		1714		1739		1739

In table 6 we regress the neural activity on the log value of the stocks (risky assets) held in the portfolio. In the first specification (1) we include the 20 electrodes as explanatory variables. We find that gender has a highly significant negative relationship with the value of equity in the portfolio. Females hold significantly less equity in the portfolio. This result does not hold when looking at the data from market 1 only, but is even more pronounced when using the data for market 2 only. From Table 7 we see that there is a highly significant positive effect from gender on the log value held in cash in all three market cases. This helps explain that the insignificant holding in equity for market 1 for females is due to the lower value of equity when the market does not rise by as much as in market 2. Overall we can conclude that females hold a significantly small position in the risk assets during the experiments. The results are congruent with Overman (2004) who finds that males and females have a differing response pattern. Females tended to choose investments associated with immediate wins (or a known outcome) and males tended to choose investments related with long-term outcome (more risk); meaning that women prefer investments that produce short terms outcomes. Turning to the neural activity of the electrodes during the various market simulations. A simple analysis, without interacting gender, we see that electrodes FZ and T4, T5 and T6 are negative related with Portfolio value and F4, F7, FP1, and OZ are positively related with the equity value in the portfolio. When looking at the neural activity related to the value of cash held the tendency is for the sign of the coefficients to be switch, in particular for those which show a statistically significant relation. Electrodes F3 and P3 also become significant for the value held in cash, and T3 is no longer significant.

When splitting the data across the two market scenarios we find that CZ and F4 are both significantly positive for market 1 and negatively significant for market 2, and O1 and O2 are both significantly positive for market 1 and negative for market 2. P4 and PZ also become significant during market 1. The R^2 is also much higher when including the interaction terms and also across each market scenario. The R^2 increases from 18.97% for the full market scenario to 26.96% for the volatile market scenario, market 1, and even higher explanatory power for market 2, with an R^2 of 35.11%.

When controlling for the interaction terms across gender we find that C4 and O1 also become negatively significant, and F3, O2 and P3 become positively significant. The interaction terms of gender with each of these electrodes captures whether women activate more, or less, of these areas of the brain than men. We find significant negative values on the interaction terms of F4, FP1, O2, OZ, P3 and P4, which highlights the difference that females have on neural activity than men. Men therefore have significantly higher activity in these brain areas, which are associated with benefit and risk processing and value estimation.

5 Conclusion

This investigation is among the first to analyze male and female patterns of brain activity associated with financial decision making and to what extent brain activity is different across gender. We further investigate if these differentials also occur for different types of investment decision. In particular we focus on the decisions to to buy, sell or hold stocks. Using 40 participants (20 men and 20 women) who are invited to trade during a simulated investment market with 100 financial decisions, across 50 decisions traded in market with that is growing and 50 in market which has a tendency to decline.

During the decision process we use Electroencephalogram technology to capture the brain electric activity. Our results describe that males and female use different parts of the brain to make investment financial decision. In the case of investment decisions of buying, selling or holding stocks we find that males activate similar parts of the brain when making all three different types of investment decisions. Whereas females appear to use different neural circuits. Our results highlight the importance of understanding exactly how risk is interpreted by individuals and that whilst many see risk as an opportunity others see it as a threat. In line with empirical findings in the behavioural finance literature, we also find that men trade more stocks and women buy more and sell less. Moreover women prefer to hold a larger proportion of the portfolio in cash and men more stocks.

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