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A neurofeminist approach to gender: results from an fMRI language task

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ABSTRACT

Little is known about which evidence neuroscientific results show when categorizing sex/gender groups beyond the usual F and M alternatives. Here, a fMRI language task was conducted with a group of women with different histories of gender identity and with different performance of gender behaviour. Language processing in the brain was investigated, trying to link stereotypical gendered behaviour to performance in an analogy task. A sample of 26 people, consisting in both trans and cisgender women, was examined. Participants completed questionnaires assessing aspects of gender, one of which was the Gender Role Behaviour Scale (GBRS), evaluating the presence of stereotypical feminine (Fbehav) or masculine (Mbehav) behaviour. All subjects were scanned using functional magnetic resonance imaging (fMRI), while completing a verbal analogy task, contrasted using a semantic decision task. In accordance to the most recent literature, activation was expected to be left lateralized and located in specific regions of interest (BA 10, BA 7 and BA 22). More strategies were adopted to analyse fMRI data, using two different correction methods. Results showed activation in all considered ROIs at individual level, when using one correction method, as well as a left-lateralized pattern. Interestingly, not all the areas were active when the other correction was applied. No significant correlation was observed between the results of GBRS and the scores of the analogy task, the LI or the ROIs activation. In summary, results showed no link between stereotypical gender behaviour and performance in analogy task or the left-lateralization of language processing in the brain. The fact of considering social gendered experience and gender identity related variables, as well as taking into regard the different impact of statistical correction methods used, could be fundamental in showing evidence for the gender similarity hypothesis, also in brain imaging studies. Additionally, this work offers an example of research in which first person gender identities of participants are included and simplifying approaches on sex/gender are expanded.

Keywords: sex/gender, language, analogy, fMRI, trans*

PREFACE

Differences between men’s and women’s mind have always been in the spotlight. Are they real or just a social construction? Does a male and a female brain exist? Are women more sensible because of their hormones? Are men performing better in mathematic because of a special part of their brain?

Nowadays these debates are far from over. Neuroscience may help in this matter: one of its fascinating virtues is that it can provide empirical data that can be used to prove the existence -or the absence- of neurobiological differences. It is crucial to understand the decisive role of neuroscience in contemporary debates, as Western Countries are actually expecting to solve social and political issues through its findings.

The process of recording information and giving it a meaning may look plain, but sometimes it is forgotten that science itself, although its struggle to be completely objective, replicable, and based on facts, is a product of the humankind, and therefore vulnerable to specific social contexts and influences. It is clear how dangerous and contentious this process can be. In fact, in the second paragraph of this chapter we will describe how science has always been enslaved to ideologies, often becoming a political instrument. For a matter of concision, this thesis will focus only on feminist issues, comprehending women rights and the problem of gender, but let’s not forget that over the centuries the empirical knowledge has been used against many minorities, disadvantaging ethnicities and religions.

Considering these first forewords, it emerges how science can lead to justify taking away as well as giving rights. In the next pages, we begin taking a closer look to its entanglement with the theme of gender studies.

Definitions of sex and gender

To start this thesis, some terms whose meaning is often given for granted should be clarified. First, it is important to be clear about the definition of “sex”. It is usually affirmed steadily that, genetically speaking, there is a straightforward distinction between a male and a female body, generated by a clear-cut binary choice, dictated by genes:

feminine chromosomes XX will correspond to feminine genitalia, and masculine chromosomes XY will correspond to masculine genitalia.
This clear-cut distinction was challenged by many. For the field of genetics, we can name Sarah S. Richardson, professor of History of Science and of Studies of Women, Gender, and Sexuality at Harvard University. She examined the interactions between cultural norms, gender and genetic theories, getting to the conclusion that even at a genomic level the binarity is not fixed and unchangeable as we usually assume.
A more precise definition of sex in the field of neuroscience was introduced by Daphna Joel (2014), a neurologist from Tel Aviv University. She suggested the term "3G sex", that refers to the three main characteristics of biological sex: *genetics*, *genitalia* and *gonads*. This expression is useful as it emphasizes the possibility of a more accurate distinction. An evidence of the importance of this divergence can be given by the existence of *intersex* people, which are often forgotten and mistreated. To give an example, an intersex person can have masculine chromosomes in his/her body, but without receptors sensitive to androgens, that are fundamental for the development of masculine genitalia. Therefore, this hypothetical person will have testicles but also external feminine genitalia. Trying to "correct" these conformations with surgeries is not a solution. In the past (and sometimes even nowadays) medical interventions on intersex people were primarily dictated by the need to remove what looks atypical, instead of acting to promote their mental and physical health. In fact, they went for surgeries on young children, often without their consents. It is reported that this kind of procedures were «causing severe mental suffering» (Mendèz, 2013). One may argue that the percentage of intersex people is irrelevant and should not be considered while giving a definition of sex, but this people are just "hidden". As a matter of fact, in 1,7% of births the external genitalia are ambiguous (Fausto-Stearling, 1993).
In conclusion, even what may look simple as the biological sex distinction, is not always so obvious, and a black-and-white point of view should be avoided, as it would mean oversimplifying a complicated theme.

Furthermore, is necessary to give a clear explanation of the term "gender", that is often perceived as controversial.

Nowadays it is common to use the word "sex" to indicate biological characteristics, as said, and the word "gender" to refer to social attributions. It was the French philosopher

Simone de Beauvoir who separated the concepts of sex and gender. We can summarize this concept with one of her best-known quotations: «one is not born, but rather becomes, a woman». Her ideas have been revised, criticized or updated by many posterior scholars, like Judith Butler (1986), who tried to reconnect the two definitions, arguing that Simone de Beauvoir's statement makes it uncertain if sex is bound with gender, coming to the conclusion that «to "choose" a gender (…) is not to move in upon gender from a disembodied locale, but to reinterpret the cultural history which the body already wears». At the end of the Seventies the expression "gender" started to be used to signify a distinction between biological sex and characteristics that society imposes to feminine and masculine identities. The use of the term rapidly changed, as in the Eighties it was used as a synonym of "sex", referring to both humans' and animals' biology.

Moving on to more recent developments, it is important to remind that a fundamental property of gender is that it is *intersected* (Krenshaw, 1991), which means its connotations changes with the changes of other social identities, such as particular ethnicities, disabilities or social classes.

It is also noticeable that some researchers (to name few: Hines Melissa, McCharty Margaret M., Swaab Dick), use the expression "sex/gender" or "gender/sex" to point out that when talking about a person's features, it is impossible to distinguish what is a social product and what is biological product. In other words, it is a way to underline that there is no clear-cut distinction between biological sex and social gender. From now on, the expression "sex/gender" will be adopted in this thesis.

Sex/Gender in Neuroscience

In experimental neuropsychology the variable sex is usually recorded as a binary choice (female, male). This option is common and recommended, because it is considered necessary to describe precisely the sample, so that one can replicate the exact same experiment over and over, a characteristic recognized as fundamental to a proper research. In this attempt, unfortunately, many facts are lost, for instance no distinction between sex and gender is made. This causes the existence of defaults in many domains including the paradigmatic, methodological and statistical ones. We can name a few just regarding the sphere of functional magnetic resonance imaging (fMRI) studies, such as the use of contrast analyses, the significance of thresholding when detecting sex/gender related lateralization, the function of the variable sex/gender as a co-item, the confirmation bias, and the publication bias (Kaiser, 2009). These shortcomings can interfere with finding evidences of the presence or absence of sex/gender differentiations.

These mistakes also have their own outcomes, of which neuroscientists and scientists in general are often unaware. As gender is a deeply social and cultural concept, people working in research are themselves subjected to the beliefs they were taught, taking part in confirming conventional constructions of what is usually called feminine or masculine behaviour. These mechanisms are the base for the idea of a feminine and masculine brain, that is supposed to cause "gender appropriate" habits. Considering the statements given above, it is no surprise that the brain is described as «the most important sexual organ» (Dennis 2004).

Despite of the actual knowledge, neuroscience is still based on rigid distinctions and the most evident of them all is probably the division between male and female brain (Baron-Cohen 2002, Cahill 2005) as stated above. Why is this idea so hard to change? Maybe because the main reason supporting this point of view is the evidence that, given the fact that men and women have different bodies and produce different hormones, their brains will be affected by these chemicals in a way that is inevitably divergent. One will be influenced by the presence of higher levels of testosterone and the other one by higher levels of estrogen. This argument is trivial and in line with the *status quo*, so that it is easily accepted by the most. But to deny this idea, we just have to take a closer look at the endocrine system. Even though some hormones are considered "sex hormones" (we are referring in particular to testosterone and estrogen, albeit they are not the only ones) they have different effects on different people, and this variation is not based only on biological sex. To be specific, is a well-known fact that behaviour and social context have consequences on both circulating level of testosterone and receptor responsivity. Also, many common assumptions, as the link between high levels of testosterone and a masculine appearance and comportment, are not always supported by the empirical research results. Another claim regarding the gender difference generated by the hormones is that they have a role in differentiating the brain during the prenatal period, giving structure to a permanent separation between sexes. A great deal has been written about the non-persistency of the changes operated by early hormonal effects. We can take as an example among others the study conducted by the epidemiologist and gender scientist Jordan-Young and the neuroscientist Rumiati (2012). They examined the neuroscientific paradigm implying that sex/gender differences in the brain are hardwired because of the prenatal hormones and found out that this assumption is both unscientific and unethical. To sum up, even this last claim should not be considered convincing as an evidence.

Also, research on female/male difference and sex hormones tends to be correlational (Fine, 2019), which means it implies that the hormonal level is the only cause to every variant. This approach is completely missing an appropriate view of gender and oversimplifies all the possible influences and entanglements of the social context with the hormonal level and therefore the cognitive system. Once these concepts are understood, a new idea of gender takes form, an idea in which gender (and not sex) works as a “shaper” of the endocrine system and the brain.

The role of cerebral plasticity in current neuroscience is undoubtedly fundamental. We would like to approach this theme with a concrete example, that shows perfectly the entanglement between brain, sex and environment. In doing so we cite Joel’s observation (2012) on studies conducted on cavies by the neuroscientist Shors. Joel stated that some environmental factors, such as prenatal or postnatal stress, exposition to drugs or maternal deprivation, interact with sexual modulation of the brain, in complex and non-linear ways. It is possible to confirm this instance by taking a look to Shors’ work. At the beginning of the experiment a sexual difference in the superior dendritic spines of the rodent, located in a small area of the hippocampus, was present. If the life of the cavies was peaceful, the dendritic spines of the female were denser. If the rodent were stressed (even for only fifteen minutes), this sexual difference disappeared. More precisely, the dendritic spines of the stressed male rodent, were equivalent in density to the ones of the non-stressed female. On the opposite, the dendritic spines of stressed female were identical to the ones of non-stressed males. Regardless of these first facts, changes do not follow precise rules: for example, if we examine only the inferior part of the dendritic spines, we cannot detect a sexual difference in a non-stressful condition. But if the environment becomes stressful, we observe an increase in density. This happens only in the males’ brain, while the females’ one remains the same.

The objective of Shors' study was to detect environment-generated differences in extremely small parts of the brain. It is difficult to imagine what the social context can do to the human brain, if we consider that only fifteen minutes of stress can cause a change in cavies' dendritic spines. Every experience can change specific parts of the brain, in different ways for each sex. Since the interactions between sex and environment are countless, the combinations in the brain are probably unique for every individual. Taking this into account, one might start thinking that it is easier and more correct to stop focusing on the study of a "female brain" and a "male brain". Joel and colleagues used the metaphor of a "mosaic" of different characteristics, some of them more common in women, other more common in men.

A confirmation of this idea came from a research conducted by Joel with the help of Tel Aviv University, Max Planck Institute and Zurich University, during which 14000 images of human brain were analysed. The researcher isolated ten main sexual differences in the samples. None of these differences were particularly significant, and even for the most evident ones the overlapping of shapes indicates that one woman out of five is "more similar to men" on the average.

In conclusion, we can affirm that even though there are sexual differences in the cognitive system, biological sex is not a fundamental variable for the development of the brain.

Overcoming binarity

The two-sex model of society, that consist of the categories of men and women, is not unchangeable as one might think. We probably grew up in a modern Western nation, so it is likely that the most of us feel like this division is immutable and maybe even "natural". As a matter of fact, it is not. Many populations have different ideas of sexual categories, for example certain societies located in South and Southwest Asia (Blackwood, 2005; Morris, 1995) believe there are more than two sexes, and in other cultures genitals are not considered important to assign people to one or another gender.

It is plausible that Western societies have fully interiorized the two-sex model also because of its institutionalization, happened in many fields as law or religion.

Anyway, our community is rapidly changing, in fact it is common to see people not satisfied with the *status quo,* and often groups are rising to ask for the right to have a more fluid identity. In the next two paragraphs we will provide a brief summary, explaining who these *gender non-conforming* people are, focusing on the description of trans* and non-binary identities. For both these profiles the concept of intersectionality is fundamental, as their experiences may vary drastically depending on age, class, cultural background, ethnicity and other attributes. It happens frequently that terms describing trans* and non-binary people change, with the aim to be more inclusive, respecting this concept of intersectionality. Sometimes these changes can be also caused by the need to update old expressions, now considered offensive. These rapid language transformations are not always supported by all the people of the community, because they can be cause of ambiguity. Even though it is no doubt that many names can be confusing, this process should be considered normal, as it derives from our struggle in trying to describe in an academic way what is effectively a bottom-up movement. It is clear that if a group of people around the world attempt to define itself, many answers will be given. All of them should be heard.

As a premise it is fundamental to keep in mind that gender identity, sex and sexual orientation are three separate properties. For instance, it is not true that people uncomfortable with their own gender identity are always homosexual (because gender identity is not connected with sexual orientation), nor homosexuality is a sign of an inner desire of having a sex different from the one assigned at birth (because sexual orientation is not connected with being uncomfortable with the assigned sex).

A. Who is a trans person.*

The generic explanation of who a trans* person is, is that he/she is not comfortable with the given gender role; therefore he/she will experience what is called “gender dissonance” or “gender incongruence”. In other words, the assigned sex does not match the affirmed gender.

Anyway, giving an inclusive definition of what being trans* means is not an easy task, as people who identifies as trans* may prefer diverse descriptions, as mentioned in the previous paragraph. Some of them may even be unwilling to be classified at all. Many obsolete terminologies are now changed, for instance because they are perceived as offensive or because they do not include some people of the community. To give an example, the term *Bio-Female/Male* is not considered inclusive of intersex people, therefore expressions like *assigned female at birth* (AFAB) or *assigned male at birth* (AMAB) are preferred.

The expressions *trans and gender non-conforming* (TGNC) or *trans** are used as umbrella terms to identify different people, such as:

- *Trans males* or *trans men* (*trans boys* if young), people whose sex assigned at birth was feminine
- *Trans females* or *trans women* (*trans girls* if young), people whose sex assigned at birth was male
- *Female-to-men* (*FTM/F2M*) (same definition of trans males)
- *Male-to-female* (*MTF/M2F*) (same definition of trans female)
- *Transsexual*, for the most -but not for everyone- is a term indicating a person who is willing to have a sex reassignment surgery (SRS) or who has already had one
- *Transgender*, this world is perceived as offensive by some. Usually it refers only to trans* people who are medically or legally transitioning/transitioned
- *Cross-dressers*, *dressers* or *transvestite* (this last term is outdated and considered offensive) are those who like to wear the clothes of the opposite gender, living most of their lives in the birth-assigned gender.

One may be wondering if there is a definition for those whose gender is coherent with the one assigned at birth. The term used for these people is *cisgender*, which derives from the Latin word *cis*, meaning “on the same side”. Also, the term transgender is derived from Latin, as *trans* means “on the opposite side”.

One of the most discussed part of a trans* person’s life is probably the transition from one sex to another. The transition can be done in different ways, by acquiring the behaviour of the affirmed gender, by dressing in a certain way, by taking hormones or having surgeries. It is important not to presume that every trans* person wants to take medical interventions for sex reassignment. In fact, a transition through surgeries is not always perceived as necessary from the person involved, or he/she can be comfortable with doing only certain surgeries and not others. On the other side, a trans* person may be willing to change sex through surgeries, but he/she may not have enough money to proceed with the intervention. None of these cases are making people “more or less trans*" than the others, even though these choices may be cause of exclusion inside and outside the community.

A sign of respect for the identity of a trans* person is to use his/her chosen name and the correct pronouns. *Misgendering* or *mispronuning* a trans* person can be considered a form of harassment, if intentional.

It is notable that movements for the rights of trans* and intersex people may benefit from the idea of a "sexed" brain. This comes with no surprises, as a medical and biological difference between a female and a male brain would provide evidences for their stances. Also, first studies on trans* people's brain tried to bring them back to a binary vision, tracing similarities between FtM people and heterosexual cis men's brains, and between MtF and heterosexual cis woman's brains. Anyway, the trans* rights movement nowadays is not promoting a mere binary distinction in brains, on the contrary it claims for the existence of a peculiar brain for trans* people, as well as a distinct brain for intersex people (different from the trans' one). Recent fMRI studies confirmed their stances, showing that trans* brains have a sex/gender on their own (with a distinction for FtM and MtF) (Kranz, 2014). Infact, philosopher and gender studies scholar Cynthia Kraus (2010, 2012) who studied the trans* movement and its connection with neuroscience, affirmed that it has many characteristics that make it fit into the *neurodiversity* discourse. This last concept refers to the assumption of the existence of a natural variation amongst brains, which is good for humanity and hence should be respected and valued.

B. Non-binary, not just labels, an identity

In the last years there was an increase of people not identifying with none of the classical genders (female or male). These people usually call themselves "non-binary", but some may prefer other definitions, more coherent with the way they feel. In UK literature non-binary is defined as «an umbrella term for any gender (or lack of gender) that would not adequately represent by an either/or choice between men or woman» (Titman, 2014). Some of the representant of this community may not identify with any gender at all, and in these cases, they may be called *agender*, *gender neutral* or *neutrois*. Others may feel the concept of gender like a fluctuating idea, that can change during time or in different contexts, so that they are called *genderfluid*, *bigender*, *trigender* or *pangender*. Some may also identify almost, but not completely, with one gender, and these are *demi-boys/men* or *demi-girls/women*. Furthermore, the existence of additional genders is underlined by *thirdgender* or *pangender people.* Finally, some like to add a political element to their identity, such as *gender queer*. *Figure 1* provides a summary for all these different definitions

It is important not to mix the definition of trans* and non-binary, as a non-binary person is not necessarily uncomfortable with his/her sex assigned at birth and a trans* person may not identify as non-binary. One may ask how non-binary people express their identity, if being unsatisfied with their body and therefore changing it with hormones and surgeries is not what always happen. According to Twist and de Graaf's study (2018) young non-binary people in UK have many ways to express their genders, for instance by using their chosen names and their chosen pronouns, or by taking care of their appearance. Additionally, they reported that they understood their identity through many experiences, for example using social media, watching TV programs, meeting with other queer people, getting to know their own body or through the help and support of family and friends.

As for the case of the trans community, it is important to not misgender non-binary people. They may choose to be called with the pronouns of a preferred gender, or they may use the pronoun "they" in a new singular form, indicating a neutral person.

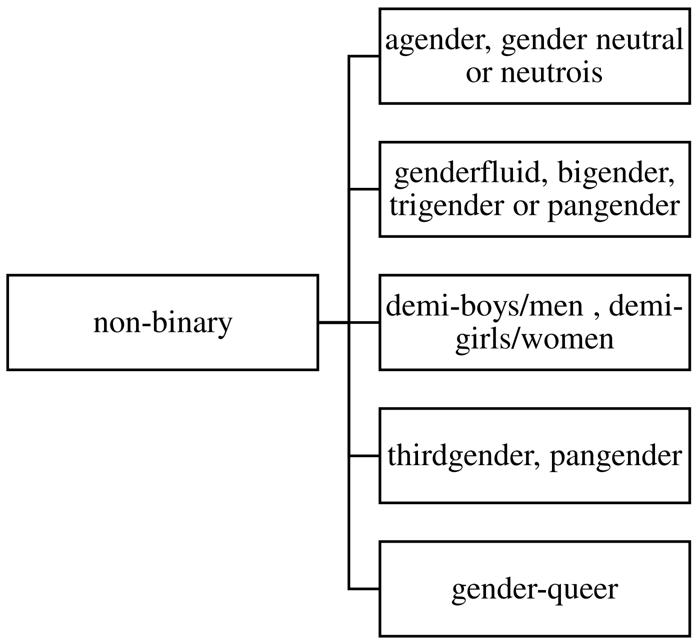

Figure 1, Summary of the various definition included in the term "non-binary".

Neurofeminism

The well-known anthropologist, neurologist and surgeon Paul Broca was the first one to look for differences between male and female brain. In 1861 he found out that the male brain is bigger in size. His explanation for this discovery was deeply influenced by the beliefs of his era and as a matter of fact he assumed that this diversity was correlated to a deficit in cognition, favouring men. This is an example of how empirical data can be manipulated to prove arbitrary instances, and how science can be used as a shield against every possible criticism. Luckily, there were some contestants to these ideas: for example, philosopher John Stuart Mill pointed out that, according to Broca's theory on the correlation between brain size and intelligence, whales must be far smarter than men. Even if we take the proportions into consideration, Broca's argument still comes out contradictory, giving life to what is humorously call "the Chihuahua paradox": if proportion between brain and body are what matter in defining intellect, Chihuahuas should be the smartest dogs.

It is true that Paul Broca lived in a period where the state of the arts of neuroscience was incomparable with the actual knowledge, so that we can consider his speculations naïve and sometimes mixed with pure imagination. It is comprehensible to feel like this example is outdated, but surprisingly, it is not. Psychologist Cordelia Fine introduced the term *neurosexism* to address this kind of phenomena. More precisely, this world indicates either the use of neuroscientific facts and factoids to assume that men and women are different because of their brains, and the use of a neuroscientific vocabulary to support old gender related stereotypes. This last deception is particularly tricky, as most of the people feel like those who uses a scientific language should spread only accurate information.

We have explained what neurosexism is, but nothing was mentioned about the way to overcome the problem. To address this argument, it is necessary to refer to the Feminist Movement. In the neuroscientific context, it assumes a role of *defence* of science, for example by analysing the methods in which research is carried out, not only preventing stretched conclusions, but also taking into account numerous biases that are not usually considered. In other worlds, the aim of neurofeminism is not primarily to deny the existence of a difference between female and male brain, which would certainly be a mistake that would be able to diminish the progress in the field, nor to prevent the acquisition of data regarding sex/gender. This would mean attacking science itself and therefore the right to an appropriate knowledge.

To establish a more appropriate way to carry out scientific research, innovative approaches and paradigms are suggested. The *psycho-bio-social* approach, for example, is one of these possible paradigms, as it is based on interdisciplinary work, that gives value to many parts of the individual and does not attribute biological sex a predominant role.

Researchers Dussauge and Kaiser (2015) define the three major endeavours of the feminist and queer approach of neuroscience:

I. *Destabilization*, a process began during the second-wave feminism, that consists in criticizing the main approaches to neuroscientific research. As pointed out in the article “a main point (…) is that biological science reflected, naturalized and thus also justified the social norms and hierarchies of its time” and so it is important to take part in “exposing the tendency in mainstream sciences to naturalize inequalities based on gender, sexuality, race and class”. Regarding neurofeminism, one of its main targets it is to destabilize the dichotomous and the heteronormative methodology, distinguishing the different roles of sex, gender and sexuality in the brain. Just to name a few representatives of the destabilization, Ruth Bleier and Anne Fausto-Stearling contributed to the feminist critique with their works about the hypothalamus and the corpus callosum, respectively. Without doubt the critic approach must never stop, in order to not fall back into usual mistakes.

II. *Reconstruction,* means finding convergences between feminist agenda and neuroscience, by using concepts of gender studies in the field of neuroscience and vice versa. For instance, norms such as the dichotomous variable of sex should be reconsidered, as it cannot be addressed as a “hard variable”. This does not mean deleting diversities between men and women but rather learning to detect them in a more appropriate way. To achieve this Roy (2011) suggests to “re-multiply differences”, not only between people but also within people. This would be important to create new ontologies of sex and gender. Unfortunately, it is not easy to complete a process of reconstruction, as the interdisciplinary research has many limits, which include the difficulty in finding bridges between theory and methods, and the significantly lower power of the gender studies on a financial and cultural perspective.

III. *Recontextualization*, focuses on the way social movements use scientific knowledge. As mentioned in the introduction of this thesis, neuroscience has a privileged position, as it can empower or disempower groups. Consequently, we must ask ourselves some questions, like how social movements used findings about the brain to advocate their causes and what are the costs of this use. In fact, politicizing the brain can reinforce neurocentrism and the consequent risk to not generate new scientific knowledge. Among others we can cite the problem of brain plasticity. Feminists movements often described plasticity as an infinite and flexible changing in the brain, that implies a complete loss of significance for the brain itself, creating a paradoxical situation. A possible resolution to this matter is to accept that the plasticity is possible "only to a certain extent, in certain areas, under certain conditions, and more during certain moments of life than others". It is still to be debated how to decide the precise extension of these boundaries.

The measures suggested by neurofeminism are not influencing only the neuroscientific field. Knowledge about the brain effectively has an impact on everyone's everyday life. As noted by Fine, the cultural conviction of hardwired sex/gender differences is a constant activator of gender stereotypes. In such environment, it is sure the *status quo* will be maintained forever.

INTRODUCTION

Sex/gender differences in the brain and society

For years neuropsychologists and neuroscientists have been looking for differences in female and male brain. Their focus was usually on biological sex, in order to find dissimilarities. No attention was given to possible variables that can correlate with sex/gender. The performance in many cognitive tasks, for example verbal, spatial and mathematical ones, is nowadays expected to be different in men and women.

In this research we target sex/gender differences in language processing, which are usually accepted as true. There is a general consensus about this theme, reflected in textbooks of introductory psychology and developmental psychology (e.g. Atkinson, Atkinson, and Hilgard, 1983; Gleitman, 1981; Hetherington and Parke 1986; Mussen, Conger, Kagan and Huston, 1984) with the effect of discouraging people to further investigate. The need to re-examine this topic is clear when we considered meta-analysis as the one conducted by Hyde and Linn (1988). Their findings were concerning: the main researcher's sex was correlated with the mean effect size on a statically significant level. This suggests that a neurofeminist approach is necessary to address this problem in a more effective way, for example overcoming the biases caused by the author's sex/gender. According to Hyde and Linn metanalysis (1988), the linguistic processes in which male seems to perform better, is analogy. Analogy is a fundamental process for cognition, in fact it is involved in problem-solving (Glick and Holyoak, 1983), reasoning (Gentner, 2003), understanding of figurative language (Gentner, Bowdle, Wolff and Boronat, 2001) and many others ability directly or indirectly connected with logic. This is not notable, because in history men have always been linked with these peculiar characteristics, and they are reinforced by the social context in which they grow up. It is foreseeable that men perform better than women in analogy task, and again, a neurofeminist approach seems essential to distinguish what is an actual difference in biology between men's and women's brain, from what is a social construct.

Looking at nowadays social notions of gender roles, many evidences are suggesting that men are more likely to be encouraged in developing analytical skills than women. There is stereotype, for instance, women are usually depicted as victims of their own feeling, and therefore more likely to take nonsensical decisions. This belief appears also in scientific papers, in which women are reported to think less analytically and more intuitively than men (Lieberman, 2000; Pacini and Epstein, 1999). It is highly likely that a social context which supports these stereotypical ideas will influence people's self-perception, for example making women underestimate their own analytical abilities, hence neglecting them. As a matter of fact, gender as a binary classification of behaviour and appearance is one of the first categories children learn, and the effect of gender stereotypes enforced by media and socialization can be therefore visible from the early life (Steffens and Viladot, 2015). Also, adolescents and students from college have been shown to construct their vision of themselves according to the gender stereotypes they have internalized (Nosek, 2002; Steffens, 2010) This may be a possible reason for the significantly low number of women with carriers in fields such as science, technology, engineering and mathematic (STEM). Even if we consider only data from countries such as Finland, Norway and Sweden -where gender equality is usually not considered a problem- the result is still concerning, as fewer than 25% of the STEM graduates are women (Stoet and Geary, 2018).

In this thesis the relation between people's internalized gender stereotypes and their performance in a gendered cognitive, specifically an analogy, task will be examined. By using this approach, we aim to relate the subjective experience of gender with cognitive processes and behavioural performance. Additionally, we give more value to the personal point of view of each participant.

Sex/gender differences in language

Many studies address the theme of sex/gender differences in linguistic task performance and in language processing in the brain (Hier, 1994; Weiss, 2003; Hirnstein, 2013). We can divide them by the different methodologies used, for instance behavioural, PET or fMRI.

A great amount of papers was based on behavioural approaches, suggesting that women have better performance than men (Halpern, 1992; Kimura, 1992), especially for the tasks of verbal fluency and speech production (Halpern, 1992; Capitani et al. 1998; Kimura, 1992). According to Hyde and Linn's metanalysis (1988), in which they compared 165 studied regarding gender differences in verbal abilities, there is a slight difference in performance favouring woman, but the effect size is so small that authors conclude that the magnitude of the gender difference in verbal ability can be considered as non-existing.

Despite of the small effect sizes, some differences are reported, for example women seem to do better in tasks such as verbal fluency and language production while the performance of analogy tasks appears to be better in men (Hyde and Linn, 1988). This last result about analogy, that will be the focus of this work, is also consistent with other domains published after the cited metanalysis (Lim, 1994; Halpern, 2000; Colom, 2004; Hyde, 2016). It is fundamental to keep in mind that sex/gender differences in language is still very small, and for all the tasks men's and women's performance is overlapping (Hyde, 2005).

PET studies showed contradictory results, as some researchers were able to find differences sex/gender differences in cortical language regions (Wood and Flowers, 1991; Jager at al., 1998) while others found little or no difference (Price, 1996; Buckner, 1995).

Several fMRI studies have been conducted to approach the question whether women and men differ in functional activation when they process language. The first study, Shaywitz (1995) investigated language differences using orthographic, phonologic and semantic fMRI tasks. They reported sex differences only for the phonologic task, but she also found a divergence in hemispheric lateralization. According to her findings, men show a more left lateralized activation, while women have a bilateral activation pattern. Years later, also Der Kallen (1998) and Frost (1999) investigated gender differences using a fMRI paradigm. They reported no difference between men and women in both word generation and semantic decision tasks.

More recent studies like the one by Harrington and Tomaszewski (2008) further investigated this matter. They used fMRI to analyse many linguistic tasks such as semantic decision, reading sentence comprehension, auditory sentence comprehension or verb generation. The results were inconsistent. If men and women were compared at a group level, men showed a stronger activation in the left part orbitalis, while women showed a stronger activation in the right insula, but with individual analysis all the significant differences disappeared. The study also examined small specific ROIs, discovering that changing the methodology drastically changed the outcomes, even if the task was constant, meaning that sex/gender differences could either be found or not.

Analogical reasoning

Analogical reasoning is the ability to find correspondences between the structures of distinct mental representations, using commonalities, and generate inferences by these commonalities (Gentner, 1983; Hummel and Holyoak, 1997). This is central to the ability of learning and to abstractly thinking (Holyoak and Thagard, 1995). Analogies differ in appearance, content or usage, but their development can still be generalized. A computational model (Gentner, 1983; Hummel and Holyoak, 1997; Gentner and Smith, 2012) has been created to explain the mechanism beyond analogies. This model involves three fundamental steps:

1. *Semantic retrieval.* In this first part of the process, the person, given a topic in working memory, connects it with an analogous situation stored in long-term memory;
2. *Mapping.* This is the core part of the analogy. It consists in two steps. The first one is about finding the similarities between two given situations. This process is called alignment and is implemented on the basis of a communal structure between two instances, one of them takes the name of *source* (the more familiar one) the other is the *target* (the less familiar). The second part of the mapping consists in projecting inferences;
3. *Evaluation.* In this last part, analogies and their inferences are judged, using three evaluation factors. One factor is the *correctness*, that also comprehends the *adaptability*, which is a measure of how easy it is to produce inferences confronting source and target. It has been proven that people are more likely to develop analogies if they are highly compatible with the target. Another factor is called *goal relevance*. People are more likely to choose analogies if they are useful for their personal goals. One last factor taken into account is the amount of new knowledge that an analogy can provide.

Analogy in the brain

In fMRI research, the analogy task has been typically explored through four term analogies, that can be both developed with words or pictures. Therefore, the analogies are already shown in the experimental setting, and the role of the participants is simply to indicate the correct answer (Gentner and Smith, 2012).

Up until now, studies agree that analogical reasoning involves areas within left prefrontal cortex. As summarized by Schmidt (2012) several areas, both parietal and frontotemporal, appear to be include in verbal four term analogy tasks:

- The left and/or right rostral prefrontal cortex (BA10) (Bunge, Wendelken, Baldre & Wagner, 2005; Green, Fugelsang, Kraemer, Shamosh & Dunbar, 2006; Green, Kraemer, Fugelsang, Gray & Dunbar, 2010; Morrison *et al*., 2004; Wendelken *et al.*, 2008);
- The left and/or right inferior frontal gyrus (BA44, 45, 47) (Bunge *et al*., 2005; Green *et al*., 2006: Green *et al*., 2010; Luo *et al*. 2003; Wendelken *et al*., 2008);
- The left superior parietal lobule (BA7) (Green *et al*. 2006; Wendelken *et al*., 2008)
- The left and/or right posterior middle temporal gyrus (BA22) (Green *et al*., 2010; Luo *et al*. 2003).

A stronger attention has been given on the rostral prefrontal cortex since it is considered important in higher cognitive function in humans, although its precise role is still not clear (Ramnani and Owen, 2004). This area was central in the study of Bunge (2005) who used fMRI to investigate a relational integration task. She found out that the right rostro lateral prefrontal cortex (RPLPFC) (right lateral BA10) is sensible to the increase in difficulty of the task of relation processing. On the other hand, the right RLPFC was only used when participants had to deal with high order relationships, suggesting that this part may be fundamental for high level cognition too.

As the literature shows, the regions of interest (ROIs) responsible for analogy are many and widely distributed across the brain. Hence, it is no surprise that they can be aggregated into networks. Regarding these neural networks, is particularly important to cite Pulvermüller and Fadiga's review (2016) on language processing in the brain. They point out the existence of a semantic hub, which has the role of giving the words a meaning. This hub's location is not completely clear. Researchers disagree on its lateralization too: some claim it is right lateralized (Paivio, 1991), but most of them suggests that is left lateralized. Many areas in the left hemisphere are suggested to be part of this semantic hub, for example inferior-frontal (Bookheimer, 2002), inferior-parietal (Binder and Desai, 2011), posterior-middle-temporal (Hickok and Poeppel, 2007), or anterior-temporal regions (Patterson, 2007). Both functional studies and research on lesions provided strong evidence that all these areas are involved in the semantic hub, however none of them can be considered independent.

To sum up, according to the actual knowledge, it emerges that the verbal analogy task is implemented by a complex fronto temporo-parietal network that involves many areas. We decided to select one area for each of these three main brain lobes regions that have been shown to be of crucial impact in previous functional imaging:

- As for frontal regions the left and/or right rostral prefrontal cortex (BA10) was chosen (Bunge, Wendelken, Baldre & Wagner, 2005; Green, Fugelsang, Kraemer, Shamosh & Dunbar, 2006; Green, Kraemer, Fugelsang, Gray & Dunbar, 2010; Morrison *et al*., 2004; Wendelken *et al.*, 2008);
- As for temporal regions, the left and/or right posterior middle temporal gyrus (BA22) was selected (Green *et al*., 2010; Luo *et al*. 2003);
- As for parietal regions the left superior parietal lobule (BA7) (Green *et al*. 2006; Wendelken *et al*., 2008).

Language lateralization in the brain

The process of analogical reasoning is studied not only by targeting ROIs, but also analysing the hemispheric lateralization. We say that a brain function is lateralized when a hemisphere is more involved in its implementation than the other. The phenomenon of hemispheric lateralization has been relevant for what concerns language for a long time, in fact from Broca (1861) and Wernicke (1911) language functions have always been considered left lateralized. Also in more recent years, studies find that the left hemisphere shows typically more involvement during language tasks (Binder, 1996; Desmond, 1995; Leblanc, 1992; Springer, 1999). The language lateralization on the left hemisphere has been linked to a strong asymmetry of the planum temporale, which is also left lateralized in right-handed people. This suggest planum temporale's possible involvement in linguistic tasks (Foundas, 1994).

The contribution of hemispheres in function is expressed using the lateralization index (LI), calculated with the following formula:

$$LI = \frac{Al - Ar}{Al + Ar}$$

In which *Al* and *Ar* stand respectively for the activity of the same ROIs measured through fMRI in the left hemisphere (LH) and in the right hemisphere (RH). The LI has been used in many fMRI studies, but it is still not clear how robust this measurement is and how much it is influenced by the difference between methodological paradigms (Bradshaw, 2017). It can describe both the degree of lateralization and the dominance. Positive values indicate LH dominance, while negative values indicate RH dominance (e.g., Hinke et al., 1993; Binder et al., 1995). Springer (1999) tried to introduce a third category for bilateral dominance, but Jansen (2006) proved that the 90% of the results claiming a bilateral dominance were not reproducible.

Sex/gender and language lateralization

In the last years, the approach to language lateralization started to take in consideration many variables, such as difference in age, gender or native language. Two main hypotheses have been formulated in the attempt to explain gender difference in lateralization:

- Buffery and Gray hypothesis (1972), according to which girls develop the left hemisphere before boys, leading to a better performance in language as well as a worst performance in spatial processing;
- Levy hypothesis (1976), stating that women are more likely to be bilateral for verbal functions, consequently impairing the spatial processing abilities.

Studies have been conducted to investigate sex/gender differences in the brain lateralization. For instance, Phillips (2001) used a passive listening task, and found out that men apparently have a more asymmetric activation if compared with women. This activation regards anterior and posterior volumes of interest in the temporal lobe. His result is in line with Shaywitz's (1995) results, cited above.

These differences in lateralization, have often been used to justify other cognitive sex/gender differences. As both Buffery and Grey's and Levy's hypotheses suggest, good verbal abilities apparently lead to bad spatial processing performance. In other words, women's bilateralism is "damaging" to the network supposed to implement visuo-spatial skills.

Many studies (Hickok nd Poeppel, 2007; Peelle, 2012; Poeppel, 2014; Price, 2012) pointed out that not all the language processing is left lateralized, but there is a difference between different language tasks. This indicates that the question is a complex one and the functional activity of language as a left lateralized process need further scrutinization. For example, acoustic processing of speech and speech articulation are considered bilateral, while processes like comprehension and generation of meaningful language are usually considered lateralized. As reported in Friederici's review (2003) the segmental, lexical and syntactic information, according to the dynamic dual pathway model, are processed in a left hemispheric temporo-frontal pathway. Circuits for semantic and syntactic information are also located mainly in a left-lateralized temporo-frontal network, while the analysis of the prosodic processing appears to be more complicated as the pitch in isolation is processed in a right hemispheric temporo-frontal pathway (consisting in frontal operculum and areas in the STG). However, citing Federici: «the more linguistic the nature of either the stimulus or the task, the larger the involvement of LH». This idea is supported by a single case study regarding a subject with a lesion in the anterior part of the corpus callosum (Klouda, 1988) as well as by studies on tonal languages, like Thai, in which the pitch patterns are used to distinguish lexical meaning and are hence processed in the LH.

It can be concluded that the lateralization of language processing is related to the stimulus properties (Pannekamp, Toepel, Hane and Friederici, 2003) and to task demands (Plante, 2002), and can therefore change. This evidence is hinting to the possibility of a dynamic interplay between the two hemispheres. Overall it appears that trying to distinguish lateralization patterns based only on sex/gender may be reductive.

Lateralization in analogy task

Semantic judgement tasks are often used as a control to study analogical reasoning and its lateralization (Bunge, 2004). Semantic decision requires the knowledge about the word semantic meaning and about the relationship between words (Bradshaw, 2017). There is general consensus that semantic judgement is processed in a distributed network, involving different brain areas that take different parts in the objects' representation (Warrington and McCarthy, 1983; Warrington and McCarthy, 1987; Warrington and Shallice, 1984). Based on the results from Seghier (2004), it is possible to affirm that the semantic decision task is left lateralized, and the frontal region is particularly involved, with significant activations also in the temporal, occipitoparietal and motor areas. This result is in line with Friederici's review (2011). As already mentioned above, both syntactic and semantic information are supported by a temporo-frontal network. The activation is lateralized to the LH for both these functions -more for the syntactic information processes. The area involved for the semantic network are the middle and posterior superior temporal gyrus (STG)/middle temporal gyrus (MTG) and BA45 in the frontal cortex.

For what concerns research about analogy task and lateralization, Bunge (2004) performed an event-related fMRI experiment, in which the participants had to execute both analogy and semantic decision tasks. She concluded that the verbal analogical reasoning is dependent on multiple PFC mediated computations, involving both left frontopolar cortex, sensitive to the associative strength of the words, and anterior left inferior PFC (aLIPC), sensitive to the integration process. The activation is observed only in the left PFC, in line with other studies (Goel 1997; Wharton, 2000; Kroger, 2002).

Luo (2003) provides another example of fMRI study on analogical reasoning, in which linguistic stimuli are used. Also, in this study the semantic judgement task was used as a control, to find the pure analogical reasoning activation. Across the two hemispheres the following areas presented differences between the tasks : right middle/inferior frontal gyri (BA11/47), left inferior frontal gyrus (BA45), left postero-superior temporal gyrus (BA22) bilateral fusiform gyrus (BA37/19) and left parahippocampal gyrus, bilateral basal ganglia (left lateral globus pallidus and the right putman). The process was also left lateralized for some areas such as the left postero-superior temporal gyrus (BA22) and the parahippocampal region. Also, right lateralization was observed, concerning the anterior cingulate.

In conclusion, the state of the art suggest that the network involved in analogical reasoning is mainly left lateralized, although results are clearly highly dependent on the decision of which ROIs to take into account.

Research has also shown tendencies in the lateralization of language processing related to sex/gender, demonstrating less bilateralized patterns in women and more lateralized patterns in men (Phillips, 2001; Shaywitz, 2009). In all these studies, sex/gender has been examined by classifying participants into groups of F and M without any further background of sex/gender related data such as sex/gender, identity, behaviour, gendered socialization, and other important variables. Thus sex/gender was approached as "sex" not considering the interplay of society on these participants.

Hypotheses

With this work we want to overcome the classical approach to sex/gender -in which biology alone is taken into account- in order to contribute to a fairer and more inclusive view on sex/gender and how this variable is related to language processing in the brain. Based on the literature discussed above, the following hypotheses were developed.

Hypothesis 1 Verbal analogical reasoning involves abilities like logical thinking that seem more common in stereotypical masculine behaviours and less common in stereotypical feminine behaviour. Therefore, cis and trans women's masculine stereotypical behaviour is expected to have a positive correlation with the number of correct answers and the accuracy in a four-term verbal analogy task and a negative correlation with the reaction time of such task, while feminine stereotypical behaviour is expected to have a negative correlation with the number of correct answers and the accuracy and a negative correlation with the reaction time.

Hypothesis 2 According to the most up to date research available (Jansen 2006; Schmidt 2012) analogical reasoning is most strongly associated with activity in parietal and frontotemporal areas. Areas highly involved, as claimed by the actual literature, are the left superior parietal lobule (BA7), the left and/or right rostral prefrontal cortex (BA10) and the left and/or right posterior middle temporal gyrus (BA22). In accordance with these findings the second hypothesis is that, in a verbal analogy condition minus semantic judgement condition contrast, activation is awaited in BA7, BA10 and BA22.

Hypothesis 3 Combining the predictions above, the third hypothesis is that during the verbal analogy task, the activation of the areas *a priori* defined as regions of interest (ROIs), would be higher in subjects with higher stereotypical masculine behaviour, and lower in subjects with higher stereotypical feminine behaviour.

Hypothesis 4 The most updated studies converge on the idea that the left hemisphere is active during analogical reasoning and the lateralization is stronger in analogy task, compared with semantic task. In accordance with this finding the fourth hypothesis is that, in a verbal analogy condition minus semantic judgement condition, the performance is expected to be left lateralized.

Hypothesis 5 Combining the behavioural and the fMRI data, the last prediction formulated was that the stereotypical masculine behaviour scores would be positively correlated with the values of the lateralization index, while the stereotypical feminine behaviour would be negatively correlated with the values of the lateralization index.

MATERIAL AND METHODS

Participants

This study is based on the data previously collected[1]. The project involved 53 healthy German speaking volunteers. All of them were categorized as being right-handed, using Oldfield's test (1971). Two people had to be excluded, one because of technical problems and the other because of hearing deficits.

The remaining group (51 people) was composed by 6 people who transitioned from female to men (FtM) (aged 24-43, mean=30, SD=6,8), 6 people who transitioned from men to female (MtF) (aged 21-58, mean=39, SD=11,9), 20 cisgender woman (aged 21-52, mean=35, SD=9,7) and 18 cisgender man (aged 22-64, mean=36, SD=10,7). No intersex person took part in this project.

The present thesis considers only data from women (both cis and trans), creating a new group of 26 people that can simply be called "women" (aged 21-58, mean=36, SD=10,31) due to relying the understanding of what sex/gender and gender identity is on the perspective of the participants who denominated themselves as "women". Many ways of subdividing gender groups were previously investigated, as explained in Table 1.

Table 1.

Subdivision of Gender Groups, N=26.

[1] Marie Heim-Voegtlin Fellow Project PMPDP1_145452/1, funded by the Swiss National Foundation, 2013-2016 (Title of project: "Multi-Scale Battery of Femaleness and Maleness to Examine Language Processing and its Plasticity in Structure and Function of the Brain", head: Anelis Kaiser.

	Number of Groups	Name of Groups (N)	Definition
Sex/Gender Self-Designation	3	F (21), M (0), Rest *(In between (1), Genderqueer Transwoman (1), Genderqueer (1), Transwoman (2))*	Indicated by participants, filling a blank box
Sex/Gender as Recruited	3	F (18), Trans* (8)	Name, appearance
"Tick the Box" Sex/Gender	5	F (22), M (0), Trans (4) Genderqueer (0), Undefined (0)	Indicated by participants, using close answers
Cis and Trans*	2	Cis (19), Trans (7)	Social norm
Cis and Trans-Sex/Gender	4	Cis-f (19), FtM (7)	Social norm

All the people recruited in the main study completed a multi-dimensional battery consisting of several scales to assess different aspects of sex/gender. This assessment was preceded by socio-demographic questions and by the C-Test (a language test). In this thesis, only data from one of the scales used in the multi-dimensional battery, the Gender Role Behaviour Scale, was considered.

Subsequently subjects took part in a block-design fMRI experiment, consisting of a verbal fluency, a verbal analogy and a language comprehension task. In this work only the verbal analogy task is examined.

The participants were given an informed consent to fill out before taking part at the experiment. The entire process was previously approved by the Swiss Ethics Committee on research involving humans. As compensation for taking part in the study, subjects were given credits for a university course or a remuneration of Sfr. 50.-,

Gender Role Behaviour Scale

A gender role behaviour scale was used to measure sex/gender role and behaviour. Participants had to complete it at home online and before the fMRI session. The gender role behaviour scale is a self-report regarding the conception of sex/gender roles. One of the first scales of that type were originally developed by Kerr and Holden (1996). The scale used in the present study is Gender Role Behaviour Scale (GRBS) in German language (Athenstaedt, 2003).

Its internal consistency is strong, with a Cronbach's α of 0.89 (Brown, 2012) as well as the test-retest variability. The GRBS has two subscales, one measures stereotypical masculine behaviours, further referred as MBehav scale, with a Cronbach's α of 0.695 (Brown, 2012), and the other measures stereotypical feminine behaviours, further referred as FBehav scale, which has a Cronbach's α of 0.764 (Brown, 2012). The MBehav scale contains 10 items (example: "view sport programs"), while the FBehav scale contains 14 items (example: "decorate the workplace with flowers").

The rating system used in the GRBS is a 7-point scale (from "almost never" to "very often").

Stimuli fMRI task

The verbal task consisted of a baseline condition, an experimental and a control condition. For the baseline condition, eight quadruplets of letter strings were created, according to the principles used by Gutbrod (2012).

For the experimental task, the analogical reasoning condition, quadruplets from the subtest Verbal Analogies of the Intelligenz-Struktur-Test-Screening (Liepmann, 2012) were created. Those quadruplets were adapted to result into 40 new quadruplets with an analogous relationship between two-word pairs (e.g., white: black, yes: no), as well as other 40 quadruplets with word with a different relationship between them (e.g., mirror: glass, book: cup).

For the control condition, a total of 120 quadruplets were created, 16 of them containing an animal word. When choosing these quadruplets, the characteristics of the quadruplets of the analogical reasoning condition were taken into account. The characteristics considered were the frequency and the concreteness of the nouns, the specificity of the nouns regarding their function (e.g. “beginner”) and the frequency of adjectives, foreign words and verbs.

Every word was used only once, in order to avoid repetition confounds. Also, the word used in the analogical reasoning condition were not the same used in the reading control condition.

Procedure fMRI task

The scanning session consisted in an eight-steps block design. Each of the eight blocks contained in order: a baseline run, an analogical reasoning run and, finally, a semantic judgement run.

In the baseline condition, subjects were shown for two seconds the word “relax”. Then, a quadruplet of letter strings was presented for 22 seconds. In this condition, participants had only to focus on the letter strings.

In the analogical reasoning condition, subjects were shown for two seconds the words “decision word pair” in green colour. Then, quadruplets of words were presented for 22 seconds. Participants had to evaluate if the lower word pair of the quadruplet was linked by the same relationship as the upper word pair of the quadruplet. To do so, they had to press the right button of the response pad with the right hand - meaning “yes/correct”- or the left button with the left hand - meaning “no/incorrect”.

Finally, in the semantic judgement condition, subjects were shown for two seconds the words “decision animal”. Then again, quadruplets of words were presented for 22 seconds. Participants had to evaluate whether one of the four words was an animal. The answering method was the same that was used for the analogical reasoning run.

The baseline run was used as basic control condition, with the aim of being able to differentiate the general activation, like the activation caused by the resting state attention or the visual activity, from the specific activation caused by the experimental task.

The semantic judgement condition was built to provide a more specific control condition than the baseline condition. In this way, it was possible to subtract the functional activation consequent to simple language processing from the analogical reasoning task. With this procedure it is possible to capture the specific and “pure” activation caused by the analytical part of verbal processing.

The same stimulus material was presented in the same randomized order to all the participants. In both the analogical reasoning and the reading control runs, the quadruplets were presented until the subjects had given an answer. Only the last quadruplets were shown for a restricted period, because their presentation was limited by the 22 seconds duration of each run. Since the reaction times were different for each participant, some of them were able to give more responses than the others. Considering all the trials, subjects were able to give their answers for an average of 50 quadruplets in the analogical reasoning condition and for 106 quadruplets in the semantic judgement condition. The total duration of the fMRI task was 9 minutes and 36 seconds, forasmuch as each of the 8 blocks was rigorously timed to finish after 1 minute and 12 seconds, regardless the number of given answers.

Before entering the scanner, all subjects underwent a training of the three conditions to ensure that the task was fully understood.

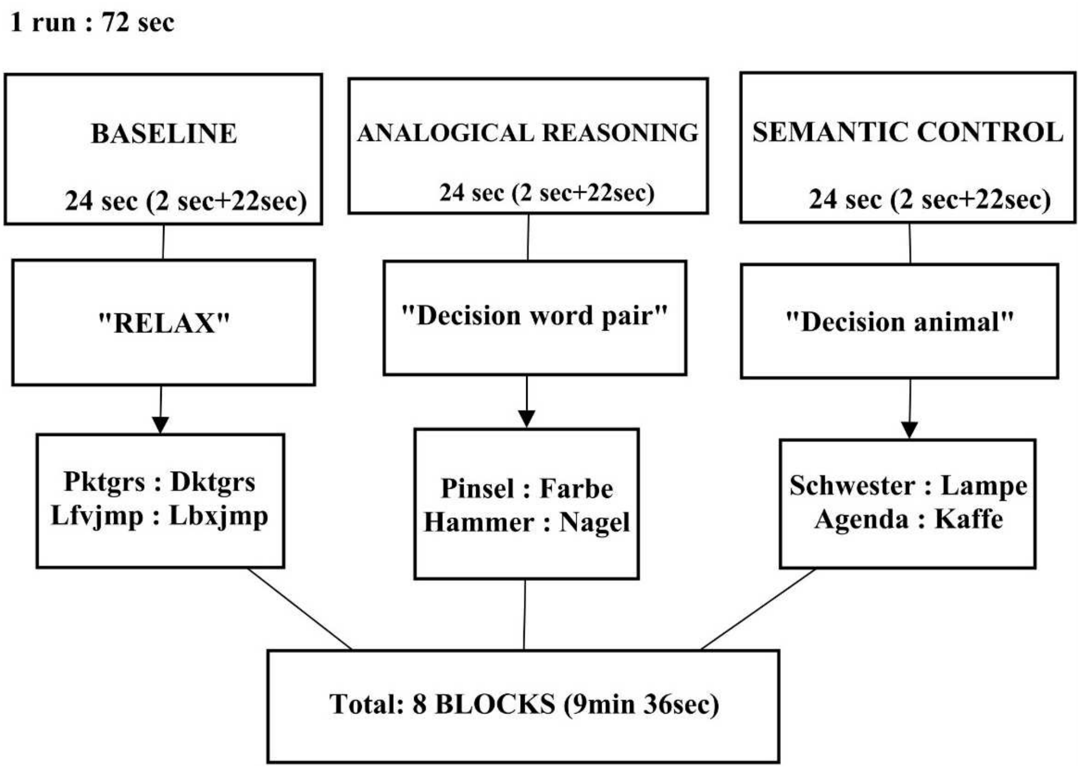

Figure 2, example of one run of the block design.

Image acquisition

A 3.0-Tesla Siemens Trio Tim MRI scanner (Siemens Medical, Germany) was used to acquire images. At first T1-weighted (resolution: 1 x 1 x 1 mm) anatomical images were obtained using MP-RAGE (magnetization prepared rapid acquisition gradient echo) sequence. Then, while participants were doing the verbal analogy task, functional images were acquired using a gradient-echo echo-planar pulse sequence (TR= 3 s, TE = 93 ms, 32 axial slices, 3 x 3 x 3 mm, 0.75 mm inter-slice gap, 192 volumes per run).

The experimental stimuli were projected onto a screen and the subjects were able to see them reflected by a mirror that was installed in the head coil of the MRI scanner. Foam inserts were placed around the head to prevent movements.

Behavioural analysis

The results of the fMRI analogy task for the mean percentage of correct answers, the reaction time and the percentage of correct answers (accuracy) were already calculated for the whole sample, therefore the data of the experimental group (trans and cis women) could be extracted. The same procedure was followed for the scores of the subscales Mbehav and Fbehav.

To test the first hypothesis, six linear regression analysis were performed, with the total number of correct answers, the reaction time and the accuracy as dependent variables, and with the results of Mbehav and the results of Fbehav as independent variables. Means and standard deviations are displayed in Table 2 (Appendix). When Mbehav is used as independent variable, the correlation is expected to be positive for the accuracy and for the total number of correct answers, while it is expected to be negative for the reaction time. For the other subscale, the correlations are expected to be negative for what concerns total number of correct answers and accuracy, while it is expected to be positive for reaction time.

Software IBM SPSS Statistics 23 was used to conduct the analysis of behavioural data.

Image analysis

For the fMRI data's analysis Brain Voyager QX 3.6.2 software (http://www.brainvoyager.com) was used.

Once the scanning session was finished, raw data were pre-processed (slice scan time correction, 3D motion correction, spatial smoothing and temporal filtering), with the aim of excluding confounds, such as effects of the subject's movements. Images were also normalized into Talairach and Tournoux's space, resulting in a volume time course file (*.vtc*).

After that, further statistical analysis was conducted to distinguish the actual activation from random fluctuations. To do so, the general linear model (GLM) was used. The GLM consist in adapting the data into a matrix which comprehends the time-course, the fMRI signal from each region of interest as well as the residuals. The final result is a statistical parametric map (SPM) in which hot colours indicate the magnitude of the effect (*r*).

To test Hypothesis 2, which states that activation for analogical reasoning is awaited in BA 7, BA 10 and BA 22, a contrast was applied subtracting the control condition from the experimental condition. Before extracting the data for the ROIs activation, other parameters where adjusted: only positive values were overlaid, and the option to enable the creation of cluster threshold was selected.

The procedure for image analysis diverges at this point, depending on the thresholding method chosen. In this work, the significance level was assessed using both a false discovery rate (FDR) and Bonferroni correction methods. To apply FDR correction (p(corr) <0,05) Brain Voyager provides a default option, which was selected. For the Bonferroni correction, the method "Bonferroni" was used, and the p-value was adjusted at 0.001 uncorrected.

The last step was the region of interest analysis, in which only significantly activated voxels in the selected brain regions were considered. In order to show the time course in these regions, the *.vtc* file was selected, and every ROI was individually examined. Finally, the ROI's details for all the participants were saved in a text file. The peak activation for each BA was also assessed, as well as its coordinates that were converted into Talairach's system afterwards.

Hypothesis 2 was also examined on a group level. For this purpose, a random effect (RFX) GLM was used. More precisely, a *.glm* file was created aligning all the 26 subjects' activation. The contrast applied was the same used on individual level (analogy condition minus semantic condition).

For what concerns Hypothesis 4, according to which in the analogy task minus semantic judgement condition the activation is expected to be left lateralized, the LI had to be calculated for all the different combination of participants, ROIs and thresholding methods. To compute the LI, using the formula (L-R)/(R+L), Python programming language was used (https://www.python.org/).

Analysis of functional and behavioural data combined

To test the third hypothesis linear regressions analysis were done, for the purpose of finding a positive correlation between the ROIs activation and the score of the subtest Mbehav, and a negative correlation between the ROIs activation and the score of the subtest Fbehav. In detail, the comparison was then developed between Mbehav and Fbehav (independent variables) and the number of active voxels respectively for BA7, BA10 and BA22. As explained in the previous paragraph, the number of active voxels was computed using two different threshold levels, the False Discovery Rate (FDR) and the Bonferroni correction. For this reason, a total of twelve regression analysis were performed, one for each of the dependent variables. To sum up, the dependent variables are the following:

- Number of active voxels in BA7 applying FDR Brain Voyager's option
- Number of active voxels in BA10 applying FDR Brain Voyager's option
- Number of active voxels in BA22 applying FDR Brain Voyager's option
- Number of active voxels in BA7 applying Bonferroni at 0,001 uncorrected
- Number of active voxels in BA10 applying Bonferroni at 0,001 uncorrected
- Number of active voxels in BA22 applying Bonferroni at 0,001 uncorrected

A regression analysis was conducted with the aim of testing Hypothesis 5. A positive correlation with the results of Mbehav and the scores of the LI was expected, indicating that the more the behaviour is stereotypically masculine, the more the process of verbal analogy is left lateralized in the brain. A negative correlation was as well expected, when comparing Fbehav scores with the LI. The lateralization was calculated for all the ROIs, with significance levels computed using both the FDR and the Bonferroni correction, so that, as explained for Hypothesis 3, all these cases were used as dependent variables.
With the aim of preventing bias, before starting linear regression analyses, the normal distribution of the data and the distribution of the errors were checked.

RESULTS

Behavioural results

The considered sample of 26 women had a mean score of 3,59 (SD=.93) on the Mbehav scale and a mean of 4.0 (SD=.90) on the Fbehav scale, assessing respectively the stereotypical masculine behaviour and the feminine stereotypical behaviour. The results for the analogy task had a mean of 41.77 out of 50 correct answers (SD=6.81), a mean percentage of 79.86 correct answers (SD=8.44) and mean of 3.24 seconds (SD=.53) for the reaction time.

The prerequisites for linear regression were met, since data was normally distributed, and errors were randomly distributed. To check the error's distribution, a scatterplot was used, and no outliers were detected in all the behavioural variables.

No significant correlation was found between stereotypical masculine behaviour and the total number of correct answers in the analogy nor with the percentage of correct answers (b=-.27, p= .88) or the reaction time (b= -.03, p.= .79). Also for the results of the correlation analysis on FBehav subscale the p-value was below the significance level. In detail, there was no significant correlation between the stereotypical feminine behaviour and the total number of correct answers (b=.23, p=.88) and the percentage of correct answers (b=-3.18, p=.09), while the was a tendency for the reaction time (b=-.03, p=.08).

Individual level ROIs analysis results for analogy minus control condition

The results for analogy minus control condition analysis of the regions of interest was conducted using two different thresholds, False discovery rate (FDR) and Bonferroni correction. According to the correction used, the results changed, both in terms of number of activated voxels and p-values. In detail, using FDR correction led to an activation in all participants for all the areas considered (BA 7: mean=544.88, SD=836.06; BA 10: mean= 724.62, SD= 831.19, BA 22: mean= 264.58, SD= 278.59) while using Bonferroni correction activation was found for 20 people in BA 7 (mean=21.73, SD=42.55), for 12 people in BA 10 (mean=14.46, SD=31.20), and in 10 people for BA 22 (mean=6.92, SD=20.66).

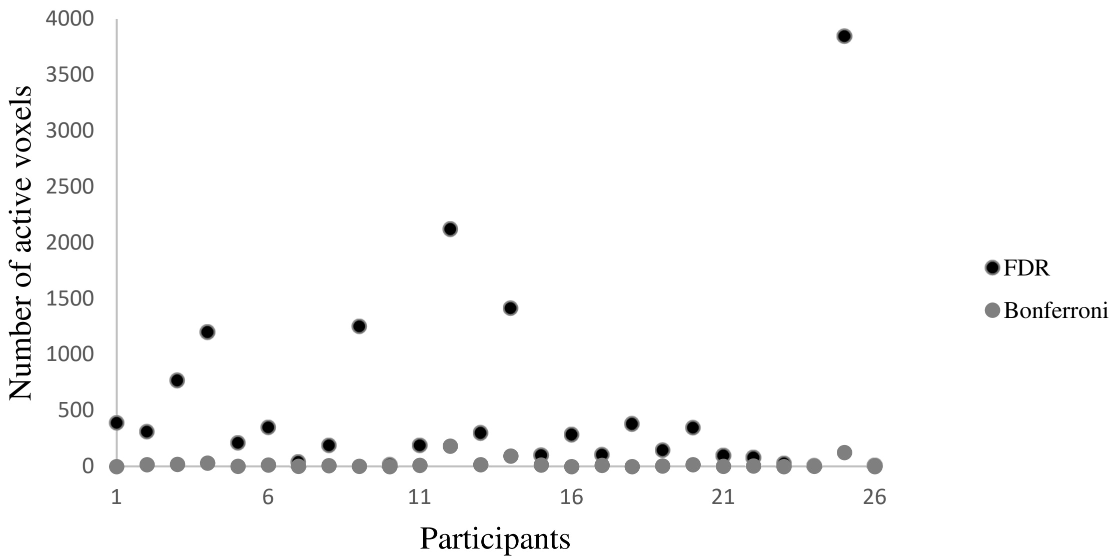

Figure 3, voxel activation for BA 7.

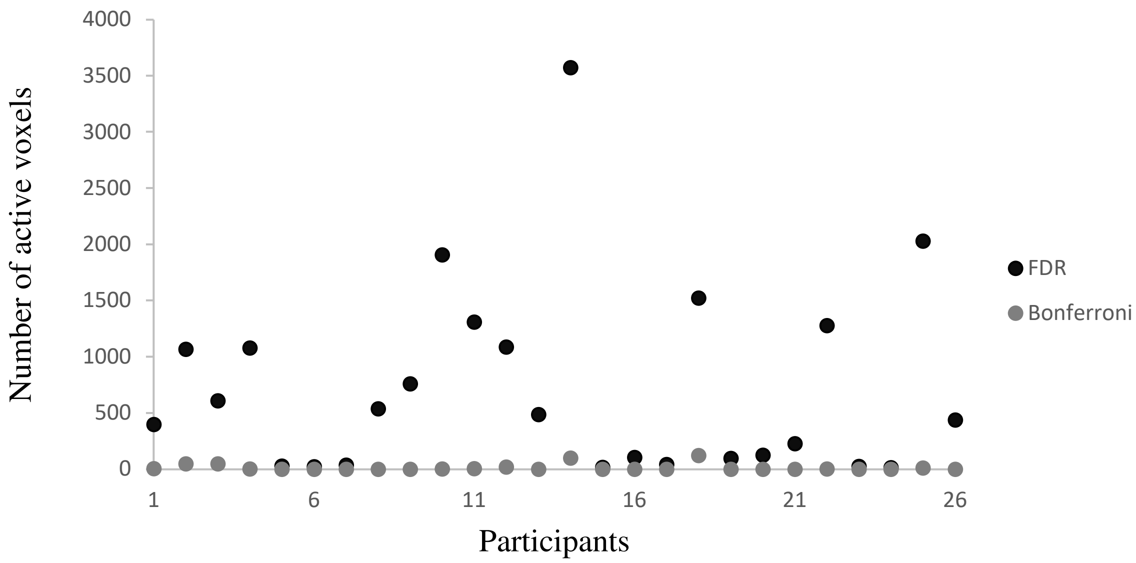

Figure 4, voxel activation for BA 10.

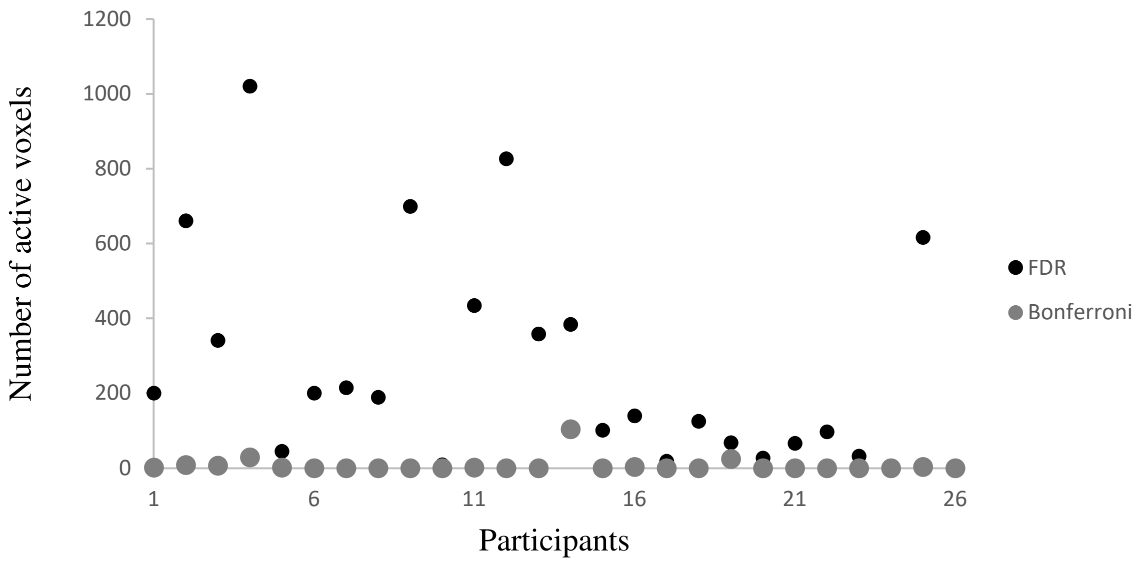

Figure 5, voxel activation for BA 22.

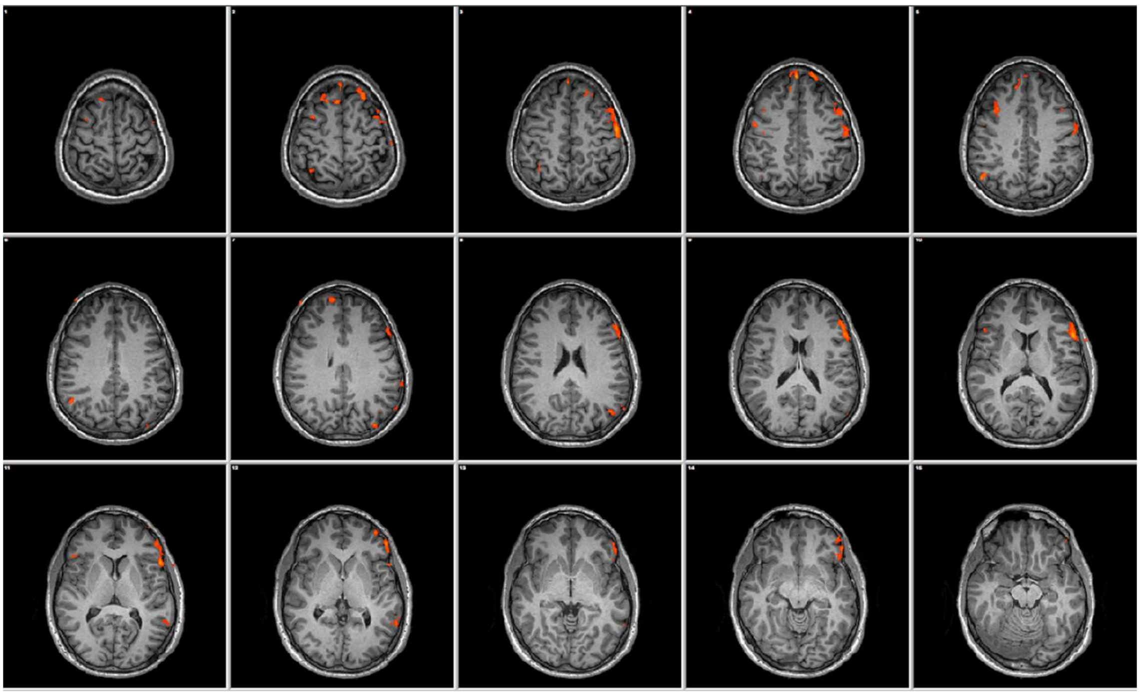

Figure 3 Activation map of analogy minus semantic condition of a participant with number of activated voxel close to the group mean. 15 axial slices, with a slice distance of 5, slice 13 has coordinates x=0, y=0, z=0 (FDR) < 0.05.

The lateralization index of all the ROIs was calculated for the whole sample. The number of people showing a positive lateralization index (LI) for the analogy task minus semantic control condition was constantly bigger than the number of people showing a negative LI (see Table 2). Out of 116 cases analysed, only 21 showed a stronger activation in the right hemisphere. In other words, in 81.9% of the cases the activation was left lateralized. Two participants had a LI of zero which indicates that an equal number of voxels is active in the left and the right hemisphere, but since the most recent literature (Jansen, 2016) claims that bilateral activity is not a robust measurement, it was decided to divide people only in two categories, left and right lateralized, therefore this data was not taken into account.

Interestingly, a shift from a left lateralization to a right one, or vice versa, was observed in 8 cases according to the thresholding method used (see results in bold in Table 3).

Table 2.

Number of participants showing negative or positive lateralization index

	BA 7		BA 10		BA 22	
	FDR	BON	FDR	BON	FDR	BON
Positive	23	17	22	9	20	8
Negative	3	3	4	3	6	2
Total	26	20	26	12	26	10

Table 3.

Left or right lateralization, all participants, all ROIs, all corrections.

	BA 7		BA 10		BA 22	
Subject	FDR	BON	FDR	BON	FDR	BON
1	L	X	L	L	L	L
2	L	L	L	L	L	L
3	L	L	L	L	**L**	**R**
4	**R**	**L**	**L**	**R**	**R**	**L**
5	R	R	L	X	R	R
6	L	L	R	X	R	X
7	L	L	L	X	L	X
8	L	L	R	X	R	X
9	L	L	L	X	L	X
10	L	X	L	L	L	X
11	**L**	**R**	L	L	L	L
12	L	X	L	L	L	X
13	L	X	L	X	L	X
14	L	L	**L**	**R**	L	L
15	L	L	L	X	L	X
16	L	X	R	X	**R**	**L**
17	L	L	L	X	L	X
18	L	X	L	L	L	X
19	L	L	L	X	L	L
20	L	L	L	X	L	X
21	L	L	R	X	L	X
22	L	0	L	L	L	X
23	L	X	0	X	R	X
24	R	R	**L**	**R**	L	X
25	L	L	L	L	L	L
26	L	X	L	X	L	X

Note. FDR=false discovery rate, BON= Bonferroni correction. L= left lateralization, R=right lateralization, X=no activation, 0=LI equal to zero.

Results of GBRS and fMRI combined

No significant correlation was found with the scores of both the GBRS subscales and fMRI data regarding ROIs' activation.

More precisely, the relationships between Mbehav and BA 7 (FDR correction, *b*=-67.69, *p*=.71, Bonferroni correction, *b*=-12.07, *p*=.2) BA 10 (FDR correction, *b*=-283.58, *p*=.12, Bonferroni correction, *b*=-11.35, *p*=.10) and BA 22 (FDR correction, *b*=-58.73, *p*=.36, Bonferroni correction, *b*=.79, *p*=.87) was not significant.

Also considering the correlation of Fbehav scale and the different ROIs, the significance level was never below the threshold, either for FDR's correction (BA 7: *b*=35.88, *p*=.85; BA 10: *b*=182.05, *p*=.34; BA22: *b*=37.78, *p*=.56) or Bonferroni's one (BA 7: *b*=1.52, *p*=.88; BA 10: *b*=5.15, *p*=.48; BA22: *b*=2.82, *p*=.56).

For what concerns LI, no significant correlation was found with the GBRS. The correlations between the scores of Mbehav and the LI of BA 7 (FDR correction: *b*=2.9E+15, *p*=.38; Bonferroni correction: *b*=-9.8E+14, *p*=.12) and the LI of BA 22 (FDR correction: *b*=-1.7E+15, *p*=.25; Bonferroni correction: *b*=3.23E+14, *p*=.62) were not significant. A tendency was observed in the correlation between the LI of BA 10, but only when FDR correction was used (FDR correction: *b*=-5.6E+15, *p*=.09; Bonferroni correction: *b*=-1.2E+15, *p*=.51).

All the correlations between the results of Fbehav and the LI were non-significant. More precisely, the significance level was over the threshold for the results of the correlations between FBehav and the LI of BA 7 (FDR correction: *b*=2.96E+15, *p*=.38; Bonferroni correction: *b*=-7.7E+14, *p*=.26) , the LI of BA 10 (FDR correction: *b*=4.23E+14, *p*=.91; Bonferroni correction: *b*=-1.2E+15, *p*=.46) and the LI of BA22 (FDR correction: -7.5E+14, *p*=.62; Bonferroni correction: *b*=2,52E+14, *p*=.75).

Whole-brain group contrast results for analogy minus baseline condition

The group analysis of RFX-GLM based on $p < 0.05$ corrected for false discovery rate for analogy minus baseline condition resulted in many activation clusters. The minimum cluster size was set at 8, meaning only clusters with a size of at least 8 contiguous voxels are reported. The main areas involved were found in the frontal cortex (left BA 45; right BA 47), in the parietal lobe (left dorsal anterior cingulate area, BA 32; orbitofrontal cortex, BA 11), and in the temporal lobe (left temporopolar area, BA 38).

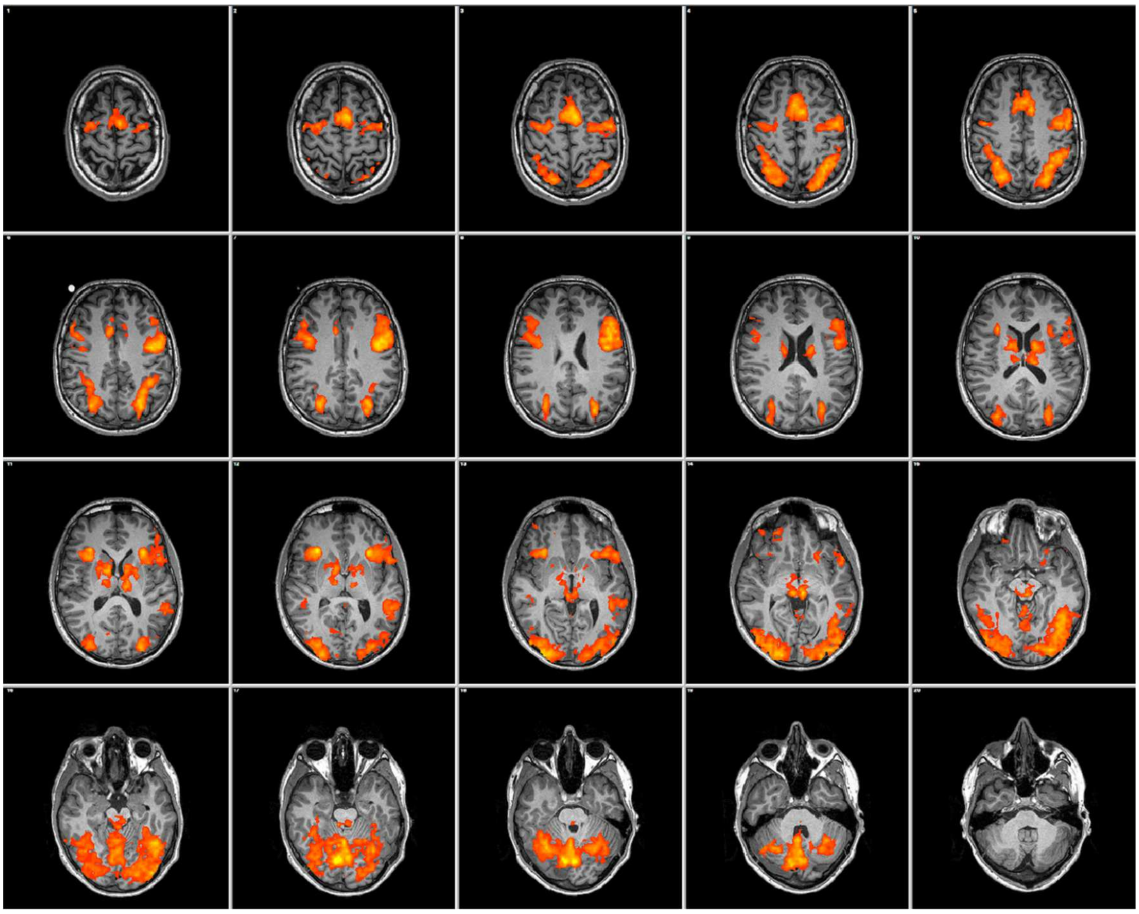

Figure 4 Whole group brain activation map analogy minus baseline condition. 20 axial slices, slice 13 has coordinates x=0, y=0, z=0 (FDR) < 0.05.

Group analysis results for analogy minus semantic condition

The whole-brain (RFX) GLM contrast of all participants, resulted in numerous activation clusters, localized mainly in the left hemisphere. Five activation clusters were found, covering the frontal lobe (orbitofrontal cortex, BA 47; right BA 11), the temporal lobe (left temporopolar area, BA 38), the parietal lobe (left superior parietal cortex, BA 7; left caudate, BA 4; left dorsal posterior cingulate, BA 31), and the left subgenual cingulate area (BA 25).

Table 1

Peak activation of the ROI shown by means of t-values in the given x-y-z coordinates, for analogy minus semantic condition

Area	x	y	z	t-value
Left BA 38	-24	23	-8	3.668587
Left BA 47	-51	38	1	7.151754
Left BA 25	-9	14	-8	4.045371
Left BA 32	3	35	-8	4.307945
Left BA 7	-24	23	-8	3.668587

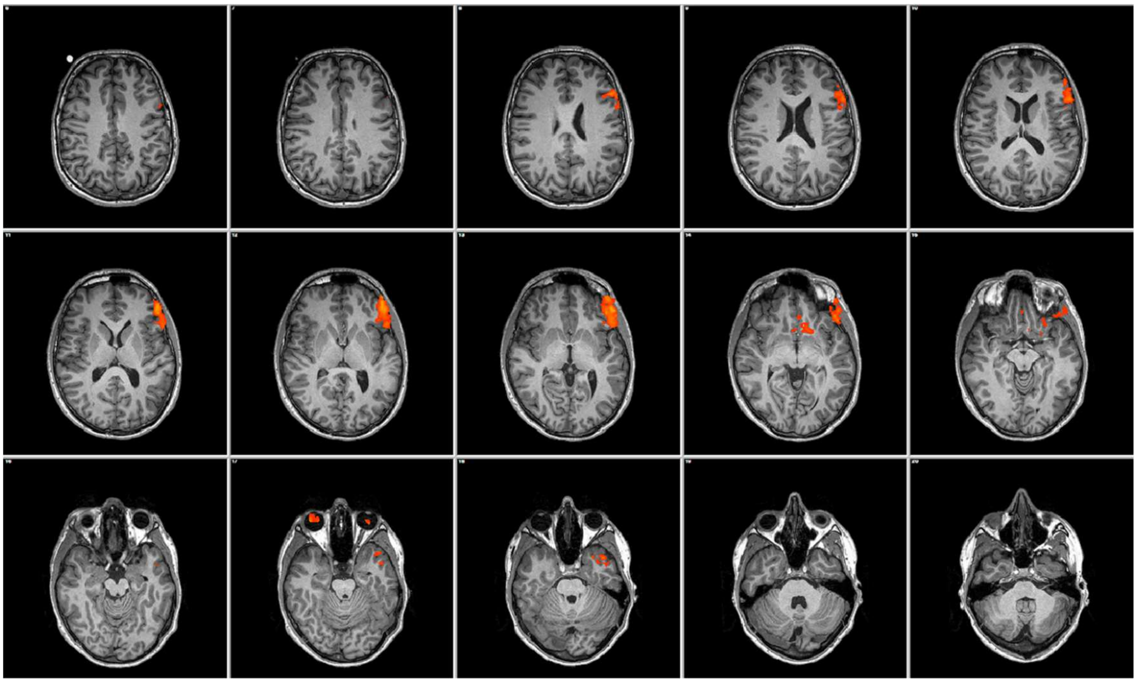

Figure 5 Whole brain activation map analogy minus semantic condition. 15 axial slices, slice 8 has coordinates x=0, y=0, z=0 (FDR) < 0.05.

DISCUSSION

In this thesis, a verbal analogy fMRI task is examined using a neurofeminist approach, consisting in sampling participants according to their expressed gender identity. This approach is insofar neurofeminist as it is derived from feminist studies on science, technology and society arguing for a weighting of “subjectivity” in research. By letting participants define themselves which gender identity they belong to, we do not contribute to their “objectification”, but we concentrate on a subjective categorization. Also, attention was not given on subjects’ appearance but on their ordinary habits (assessed using the gender role behaviour scale, GRBS), so the variable of sex/gender was freed from its traditionally causal function. Additionally, this approach is neurofeminist as it investigates the methodological impact on the study of language lateralization in the brain, following the principles of sex/gender scholarship outlined by the latest papers (Dussauge, Kaiser 2015; Rippon, 2014). Findings on lateral (typically masculine) or bilateral (typically feminine) activation in the brain are then questioned, with the goal of obtaining results that are truly objective and independent from the methods. Using this frame, five hypotheses based on behavioural and functional data were examined.

Discussion of results

Imaging results confirmed the second and the fourth hypothesis, thus showing evidence of an activation in the regions of interests as well as of a pronounced left lateralization in the brain during the experimental task.

According to Hypothesis 2 in verbal analogy minus semantic condition, activation was awaited in the left superior parietal lobule, the left and or/right rostral prefrontal cortex, in the left and or/right posterior middle temporal gyrus and in the supramarginal gyrus. The activation was found at single-level analysis, in line with the most recent literature (Jansen 2006; Schmidt 2012), when false discovery rate correction method was used.

Even though this hypothesis was confirmed, the correction method used arises interesting questions. FDR, the most common method of thresholding in imaging analysis, is less restrictive than the other used method (Bonferroni) and revealed an activation for all the ROIs analysed in this work. For what concerns Bonferroni’s correction, as explained before, a conspicuous number of participants showed no activation. This fact is not surprising as this correction method is considered by many too conservative (Perneger, 1998, Goebel, 2016), as it corrects for the family wise error, that would be appropriate only if voxels were independent from each other. Recently, also the FDR correction has been declared as not absolute ideal for depicting the voxel activation or for drawing topographic inferences from statistical parametric map (Chumbley 2009) since this methodology does not consider the activation in the brain. So, many possible sources of mistakes like the multiple comparison problem (Goebel, 2014) remain unsolved and the inflated numbers of false positives is still a central theme in the current discussion (Elkund, 2016). Nowadays the cluster size correction is often suggested for fMRI studies (Chumbley, 2009), as it takes into account the actual voxel activation.

To sum up, considering the divergent results obtained with FDR and Bonferroni correction, it is plausible that using a cluster size level correction would change again the number of activated voxels, confirming or disconfirming brain activity.

Furthermore, Hypothesis 4, which states that the activation during the analogy task is expected to be left lateralized, was accepted, as in most of the cases considered the left hemisphere was more involved. For what concerns the brain lateralization, the results are even more challenging to interpret, since dividing participants into left or right lateralized groups, in accordance with the lateralization index, creates a clear-cut distinction that cannot always be meaningful (a difference of activation in just one voxel can invert the LI) and so appears far too restrictive. Additionally, concerning the different correction types, just switching from a correction to another, the lateralization of the same participant can switch from one hemisphere to the other. These findings are consistent with what the state of the art suggest (Jansen, 2006; Bradshaw, 2017): the LI is closer to zero with less conservative thresholds and closer to 1 with restrictive thresholds[2] (see *Figure 1*). Many studies have also linked the LI with the threshold chosen (Rutten, 2002; Adcock., 2003; Seghier,2004; Abbott, 2010; Nadkarni, 2015), and, in line with our results, found out that changing the threshold caused a switch in the dominance (Jansen, 2006; Suarez, 2008; Wilke and Lidzba, 2007; Ruff, 2008).

[2] Since Bonferroni correction was mostly applied in early fMRI research, it would be interesting to examine lateralization in men (and everybody) detected in early fMRI research as compared to more bilateral language lateralization in women (and everybody) detected in late or today’s FDR-neurolinguistic fMRI designs.

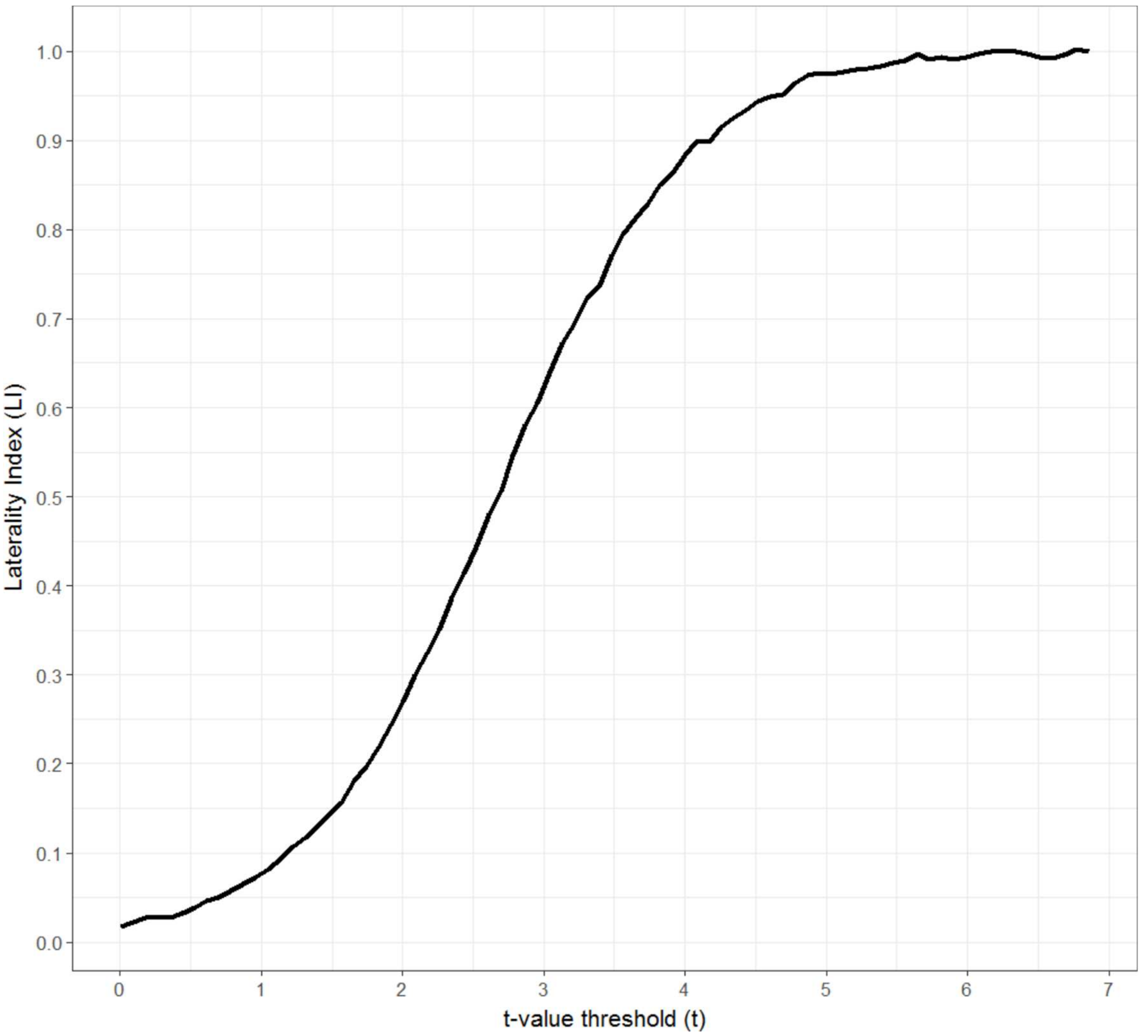

Figure 6 Plot of LI as a function of threshold (t -value). Created by P.A. Thomspon.

Considering this great change in results, it is inevitable to start questioning the assumption of different lateralization for men and women's brain, since these differences may have been enhanced because of the method used, as previously shown (Harrington, 2008; Ihnen, 2009; Kaiser, 2009).

Additionally, when considering ROIs, a clear-cut division between left and right lateralization is difficult to make, both at individual and group level, as a great amount of literature has drawn attention into cases of crossed or dissociated dominance across cortical language areas (Vikingstad, 2000; Thivard, 2005; Jansen, 2006; Bethmann, 2007;

Propper, 2010; Seghier, 2011 a-b; Seghier, 2011; Van der Haegen, Cai and Brysbaert, 2012; Vingerhoets, 2013; Berl, 2014; Häberling, Steinemann and Corballis, 2016).

The question of thresholding directly addresses Hypothesis 2 and 4, that refer both to the brain activation, respectively to the mean of active voxels and to the lateralization index. It is important to be aware that even Hypothesis 3 and 5 will be affected by the same problem, as Hypothesis 3 examines the data from the ROIs activation and correlates them to the results of GRBS, while Hypothesis 5 correlates them with the lateralization index.

According to the first hypothesis, the stereotypical masculine and feminine behaviour, acquired with the GRBS's subscales, were expected to be related to the performance in the analogy task. No significant correlations were found, neither for what concerns subscale Fbehav, which regards feminine stereotypical behaviour, nor for masculine stereotypical behaviours, measured with subscale Mbehav, meaning that "masculine" behaviour detected by the items, such as "assembling furniture", has nothing to do with a good performance in an "male" analytical language task in our sample of women with different gender identity life stories.

Also, the Hypotheses 3 and 5 which aimed to reconnect functional data to the GRBS, resulted in non-significant correlations. Hypothesis 5 was developed to find a correlation between the LI and GRBS. In other words, it was postulated that "male" behaviour is related with "male" functional brain language patterns, here corresponding to a left lateralization, but this assumption was disconfirmed. According to Hypothesis 3, a positive correlation with the number of active voxel and the stereotypical masculine behaviour and a negative correlation with the stereotypical feminine one was awaited.

Summing up, all the variables that had as an objective finding a connection between the behavioural performance or the functional data and the results of GBRS were non-significant. The connection between these data and everyday behaviour was therefore non confirmed. It is particularly difficult to isolate the main factors influencing performance in the analogy task as well as the functional activation, because it requires a detailed analysis of the social environment. Since the correlation were non-significant, it is likely that the GBRS subscales have not captured the source of these differences. In the next paragraphs, many possible variables that can be cause of interference with the significance of these correlations will be examined. Particular attention is given to psychosocial variables. Still, it is important to remember that the absence of a significance, in principle, does not imply the complete absence of correlation. For instance, the lack of results can be simply due to the small sample used. This latter point has been extensively discussed in the frame of neurofeminism (Joel, 2015; Fine, 2019; Sanchis-Segura 2019).

A possible source of mistake can be the way of measuring stereotypical masculine and feminine behaviour. This measure implies recognizing some activities as typical of women or man. It is not possible to give for granted that these clear-cut distinctions are still true. For example, in last years, gender is often debated, and gender fluid or non-binary people are rapidly increasing in number. This makes binary tests such as the GBRS rapidly outdated. It was also demonstrated by literature that scales to assess gender are failing more and more (Sczesny, 2004; Evers and Sieverding, 2014). In particular, traditionally masculine activities lately have become desirable also for women to achieve, leading to a change in the common characteristics possessed by women (Diekman and Eagly, 2000; Spence and Buckner, 2000; Wilde and Diekman, 2005; Ebert *et al*., 2014). This could have introduced a shift in the behavioural results, both from the GBRS scale and from the analogy task, making it impossible to create a clear correlation. Additionally, strictly spoken there is no “female” and “male” behaviour either, only what society classifies as such (Morgenroth, 2018). In this thesis behaviour was classified in female and male’s using the way adopted by western society, that is not natural, but based on the performance of traditional actions and behaviours. Measuring a concept that is both social and subjective can be challenging, and even the decision of measuring it implicitly implies the acceptance of this social norm among a group, fact that is not obvious, as for the case of non-binary people, already stated above.

Another issue regarding the problem of measuring gender is the rapid evolution of the language used to describe it. This can create many problems on sampling level, as it is not obvious that a person who is “mentally” non-binary is aware of what this definition means. Also, this kind of labels assumes the right to give a personal meaning to the chosen identity, leading to the possibility of having people who both describe themselves as non-binary and behave in completely opposite ways. Additionally, it is reported that participants may be unsure about what the researcher wants them to answer, when asked about their gender (Frohard-Dourlent, 2016). To sum up, even though the subjects involved in this study were given many different tests assessing sex/gender, as well as many ways to define themselves, it is not certain that they all were aware of the existence of considered labels, such as non-binary or gender queer. For this reason, in this work it was decided to use a more "traditional" way to distinguish the experimental sample, taking into account only data from women. The focus on the perceived and felt gender of the participant was still guaranteed, disregarding other characteristics such as the gender at birth or the physical appearance, in line with neurofeminism and giving importance to everyone's subjectivity. But, even if the idea of gender was not traditional, the distinction was still based on a binarity, thus creating a paradox, possible source of bias.

As previously stated, participants had to complete many questionnaires regarding gender, and this could have changed their scores at the analogy task. There are many evidences that priming a sample, even implicitly, by making it self-conscious of its gender, can influence the performance, in either a positive or negative way (Shih, 1999). This is an effect not to underestimate, considering that even priming the area of study can have an indirect effect on gender (Hausmann, 2014) and other examinations, also in the neuroscience field, confirmed the role of gender stereotype threat (Wraga, 2006; Krendl, 2008). It is hard to understand how the participants to the present work could be influenced by that, as their past experiences are presumably really divergent, and it would be inappropriate to assume that trans women are more sensible to this threat than cisgender women, leading to a worst performance in the analogy task, or vice versa.

Other variables, such as the hormones' level, could be cause of interference with the result of the analogy task, making it impossible to confirm Hypothesis 1. Endocrinological data has gained more and more attention in the last years, especially in the sex/gender differences discourse. Interesting results emerged from this new field, for instance, in an fMRI study, by testing women during their period and during the 11th or 12th day of their menstrual cycle (Dietrich, 2011) it was discovered that levels of estrogen were influencing the level of cerebral hemodynamic. The difference in performance of tasks which usually favours males, such as spatial task, was erased, when the estrogen levels of women were low. Also, it was demonstrated that the hormones' level is influenced by the priming of gender, as shown in Hausman's study (2009), in which the male superiority in mental rotation was present only in the stereotyped active group -

compared with a non-primed control group – which also had an increase of testosterone of the 60% for what concerns male participants. Considering these two cited studies, it may be possible that the hormones had a heavy influence on our results, as a part of the sample had a menstrual cycle, and others were taking hormones supplements. Also the effect of priming the gender on the hormones should not be underestimated.

Data regarding the process of development of sex/gender differences as results of gender socialization, like parent's attitude or culture, was not considered in this work. Then, it is not possible to know if subjects participated in activities that could have an indirect outcome on the analogy task results. As Hines (2019) and Fausto-Sterling (2019) underline, experiences in early life are particularly relevant as they have an enormous impact on future development. It was also demonstrated that sex/gender differences in performance can depend indirectly by other factors such as experience in other related fields, therefore changing the results of the experimental condition. This is in line with the Gender Stratification Hypothesis (Hyde, 2016) which states that the difference in gender emerge in association with other variables, for example gender difference in math performance emerges in cultures in which girls are not given the same opportunities to study as boys. In videogames playing we find a typical example of how experience positively influences certain cognitive abilities, such as spatial cognition. Taking part in activities typically masculine, like gaming, is often not socially accepted by the mainstream society. It may look excessive to claim that society would influence apparently neutral hobbies, but it was not long ago that the Gamergate[3] controversy raised, showing that sexism has a huge role also in supposedly irrelevant leisure interests. Activities connected indirectly with logic may have undergone through the same processes, and finally they can have influenced women's ability in analogy.

In conclusion, the outcomes of Hypothesis 1, 3 and 5 could have been influenced by the improper measurement of gender and gender stereotypical behaviour, the level of hormones, the priming of gender or by culturally and socially induced experience.

For what concerns Hypothesis 5, many non-considered interfering variables could have a role in the absence of significance of the outcomes, because of their influence on the LI. Hypothesis 5 was previously discussed using a statistical point of view, referring

[3] Controversy started in August 2014 regarding sexism in videogame culture.

to the problem of thresholding and its influence on LI. In this paragraph only the sociodemographic characteristic of the sample will be taken into account: many characteristics are confirmed to have influence on the lateralization such as age (Chee, 2001; Jäncke, 2018), multilingualism (Kaiser 2007), mother tongue (Chee, 2001) or structural differences in language areas (Amunts, 1999; Steinmetz and Seitz, 1991). Particularly interesting are the interactions with age pointed out by Jäncke (2018), according to which the level of structural asymmetry during cognitive performance decreases with age, independently by people's gender. Again, this idea challenges the typical clear-cut assumption that the "female" brain has got more symmetric activation, while also raises new questions about how appropriate may be to try to connect a specific task with the index of lateralization, if there is this great amount of interfering variables. This method may be over simplistic, and, as in the past the research interest switched from linking brain areas to functions to linking networks, maybe even the approach to brain lateralization deserves such a change, leading to a broader vision.

To sum up, Hypothesis 5 would need further investigations, as, basing on this work's results, it is still not possible to affirm that there is no connection between the lateralization index and performance, since the sample used presented interfering variables such as a large age gap and bilingual participants.

Limitations

First, the results of this study may have been influenced by some characteristics of the sample, followingly presented.

To include trans* people, researchers have recruited them via the Transgender-Network Switzerland (Section Bern), via the LGBT-students group of the University of Bern, through personal contacts to trans*-friendly activists' groups or through personal contacts in general. Many of this recruitment methods comprehend association involved in political action; therefore, it is likely for the people involved to be more socially aware, and maybe more open minded than the average population. Thus, this sampling method can introduce uncontrolled factors to the population studied, that can influence the results as well as restrain the possibility of replicating successfully the research.

Moreover, the sample studied had a high variability in languages spoken. For most of the people involved, German was their mother tongue, although German language has many differences across countries, so it can be distinguished in German talked in Austria, in Germany or in Switzerland. People familiar with all these dialects were present, so it is plausible that cross-linguistic variability in brain networks may have influenced the result of the study (Kroll and Chiarello, 2015). Also, there was a consistent number of people speaking more than one language, comprehending languages such as English, French, Greek, Italian, Turkish and Hungarian. Bilingualism has been demonstrated to be the origin of different brain organization, so this characteristic as well may have been cause of confounds (Ojemann and Whitaker, 1978).

The sample is also small, with the 26 people used for this thesis, there is a chance that small inter-subject variables have influenced heavily the overall results.

Second, possible limitations are due to the way used to assess the performance in analogy. As said in the introduction chapter, in research it is usual to study analogies by giving subjects four predetermined option to let them combine them in the right way. From a sociolinguistic point of view, this is also unnatural and almost impossible to happen in every day's life (Gentner and Smith, 2012). So, a possible limitation of the study design could be that it does not reflect the spontaneous language behaviour. Additionally, the analogies presented were considered trivial, and they may not have been the more suitable way to induce a possible difference in the scores.
Finally, for what concerns the methods used, the brain data of this study where acquired using the BOLD signal of fMRI. This signal does not correspond to the actual activation of the neurons but is just a reconstruction of what is really happening in the brain – the real relation between blood flow and (electrical) activation of the neurons, is still under scrutinization (Logothetis 2001).

Similarly, it is important to notify that even the anatomical images are just a reconstruction of what the brain is expected to look like and are consequently vulnerable to all the usual inferences normally present in fMRI studies.

CONCLUSION

The aim of this thesis was to address the theme of sex/gender in research from a neurofeminist point of view. To do so, an analogy task, claimed to be a task in which men perform better, was examined. The sex/gender of the experimental group was assessed considering both the perceived/felt gender of the participants (creating a sample composed of cis and trans women with no distinction based on the gender assigned at birth) and the gender stereotypical behaviour they pursue. The decision to include the study of the gender role behaviour scale (GBRS) was taken to have a broader vision on the concept of sex/gender, which comprehends not only the gender identity but also the everyday habits, which play an important role in shaping a person's experiences, and therefore his or hers brain. Only data from woman were considered, to demonstrate what nurture, and especially gender stereotypes, can provoke in a homogenous group, creating differences.

It may be disputed that trans women have experienced less years of being treated as women, and therefore they could have had less exposure to the gender stereotyping traditions imposed by society. This aspect was noticed, but it was also considered that usually trans woman, with the aim of affirming their identity, stress the feminine gendered behaviour. So, the sample was assumed to be comparable.

It was awaited that performance in the analogy task would have been correlated to the results of GBRS subscale, showing an advantage in the analogy task for participants with high stereotypical masculine behaviour and a disadvantage for the subjects with high stereotypical feminine behaviour. The source of the difference in performance was expected to be found in the usual behaviour of the sample. This was because a masculine stereotypical behaviour was considered to be evidence of an inclination in activities that are traditionally associated with masculine identities, such as logic and analytical thinking, that are necessary to execute analogic tasks. Since the correlation was non-significant, other interfering variables may have taken place into creating the differences, for example the level of hormones or other possible past experiences of the participants, that could have enhanced the scores.

The investigation confirmed an activation in left superior parietal lobule, rostral prefrontal cortex and posterior middle temporal gyrus at single level, FDR corrected, for all participants. Surprisingly, at a group level, activation was found in other different clusters, except of left superior parietal lobule that was the only region found to be activated at individual level too.

The lateralization index attested a pronounced left lateralization, in line with the hypothesis. Differences in the results were observed when analysing the same data applying Bonferroni correction instead of False discovery rate correction method, suggesting that the correction used may have a fundamental role in confirming or disconfirming differences. It is proved by literature (Bradshaw, 2017) that using only one thresholding method while assessing the LI is insufficient. A future challenge may be to try to start distinguishing what of the sex/gender differences in lateralization is real and what is the by-product of statistical analysis.

Data of the regions of interest and the lateralization index, both obtained during the analogy task, were linked to the results of the GBRS in order to gain an integrated view on people’s brain, overcoming simplistic perspectives in which sex/gender is strictly binary divided according to sex assigned at birth. In other words, the effects caused by the nurture, here reflected in scores of female and male behaviour, were examined, taking distance from the standard approach in which only biology , i.e. checking the F and M box, is taken into account, with the risk of linking nature to the evolutionism discourse, and therefore sex/gender differences to a compulsory and predetermined path.

Interestingly, no significant correlation was found. This findings may be due to psychosocial reasons, for example the inability of the GBRS to capture behavioural differences, the lack of consideration for the non-binary identities and the priming of subjects with questions about gender, as well as for demographic characteristics of the sample that could have an influence on the level of neuronal activation and in consequence also on the lateralization index. A possible way to improve the future research would be to find a more homogenous sample for what regards bilingualism, age, or gender identity, and to give the questionnaires about gender after the fMRI session, avoiding the effect of priming. Also, further investigation should be conducted on past and present experiences of the participants, for example regarding education, work or hobbies.

Even though some of the correlations calculated in this thesis did not showed significant outcomes, it should be acknowledged that a good research should not only be focused on finding dissimilarities, but also on demonstrating their absence, which is fundamental not to make emerge the "publication bias" (Dickersin and Min, 1993). This matter is particularly important in the field of neurofeminism as such bias reinforces the perceived sex/gender difference in cognition (Kaiser, 2009). The proper study of sex/gender difference in language processing have many consequences, not only for what concerns the broad political theme of the difference in female and male brain, but also for the need of providing correct information useful in the medical field, such as in neurosurgical planning. Therefore, also the absence of such difference should be considered (Detre, 2006), in order not to create distinctions that can possibly be harmful. Therefore, it becomes clear that sex/gender similarities in the brain should be systematically investigated.

A last notable aspect of this work is the way in which research on trans* people is carried, not only shifting away from pathologizing, but also using the correct pronouns, as suggested by American Psychological Association guidelines (2010) report, and therefore the perceived categorization, by considering them simply women and non-isolating them in a second group.

To conclude, this thesis provides an example on how to conduct analysis on sex/gender similarities and differences, without including biases, and considering all the possible variables before implicitly and explicitly postulating the essential or "natural" existence of brain differences.

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APPENDIX

SPSS outputs.

Table 4.

Descriptive Statistics for GRBS.

	Minimum	Maximum	Mean	Standard Deviation
Mbehav	1,60	5,30	3,5923	,93420
Fbehav	2,43	5,79	4,0495	,90006
N	26	26	26	26

Note. N= number of participants.

Table 5

Descriptive for ROI activation FDR corrected

	Minimum	Maximum	Mean	Standard Deviation
BA 7	7	3849	544,8846	852.61857
BA 10	15	3573	724,6154	847,64719
BA22	0	1020	264,3846	284,28747

Table 6.

Descriptive for ROI activation Bonferroni corrected

	Minimum	Maximum	Mean	Standard Deviation
BA 7	0	181	21,7308	43,38899
BA 10	0	124	14,4615	31,81978
BA22	0	104	7	21,06751

Table 7.

Descriptive for LI, FDR corrected

	Minimum	Maximum	Mean	Standard Deviation
BA 7	-2,57525E+16	4,55E+16	8,42E+15	1,5E+16
BA 10	-3,5E+16	4,99E+16	6,93E+15	1,56561E+15
BA22	-8,9E+15	1,85E+16	4,51423E+15	6,67E+15

Table 8.

Descriptive for LI, Bonferroni corrected

	Minimum	Maximum	Mean	Standard Deviation
BA 7	-6	7,79E+15	9,33E+14	2,32E+15
BA 10	4,99E+16	9,18E+15	9,601111E+14	4,6E+15
BA22	-3,3E+15	2,41E+15	-1E+14	1,45E+15

Table 9.

Descriptive Statistics for analogy condition variables.

	Minimum	Maximum	Mean	Standard Deviation
Total score	29	55	41,77	6,819
Percentage correct answers	58	98	79,86	8,449
Reaction time	2,3421	2,3421	3,245399	,5349317
N	26	26	26	26

Note. N= number of participants.

Table 10.

Hypothesis 1.

		Total score	Percentage correct answers	Reaction Time
Mbehav	Pearson's correlation	,093	-,058	-,030
	Sig.	,650	,885	,778
	B Value	,681	-,269	-,033
	N	26	26	26
Fbeahv	Pearson's correlation	,031	-,338	-342
	Sig.	,881	,091	,088
	B Value	,233	-3,177	-,203
	N	26	26	26

Note. N= number of participants. Correlation <0.05 is significant.

Table 11.

Hypothesis 3, FDR correction.

		BA 7	BA 10	BA 22
Mbehav	Pearson's correlation	-,074	-,313	-,193
	Sig.	,719	,120	,345
	B Value	-67,691	-283,575	-58,727
	N	26	26	26
Fbeahv	Pearson's correlation	,038	,193	,120
	Sig.	,854	,344	,561

	B Value	35,883	182,046	37,776
	N	26	26	26

Note. N= number of participants. Correlation <0.05 is significant.

Table 12.

Hypothesis 3, Bonferroni correction.

		BA 7	BA 10	BA 22
Mbehav	Pearson's correlation	-,260	-,333	,035
	Sig.	,200	,096	,865
	B Value	-12,066	-11,349	,793
	N	26	26	26
Fbeahv	Pearson's correlation	,032	,146	,120
	Sig.	,878	,478	,558
	B Value	1,523	5,152	2,814
	N	26	26	26

Note. N= number of participants. Correlation <0.05 is significant.

Table 13.

Hypothesis 5, FDR correction.

	BA 7	BA 10	BA 22

Mbehav	Pearson's correlation	,178	-,334	-,235
	Sig.	,384	,096	,248
	B Value	2.9E+15	-5,6E+15	-1,7E+15
	N	26	26	26
Fbeahv	Pearson's correlation	,178	,024	-,101
	Sig.	,384	,906	,623
	B Value	2,96E+15	4,23E+14	-7,5E+14
	N	26	26	26

Note. N= number of participants. Correlation <0.05 is significant.

Table 14.

Hypothesis 5, Bonferroni correction

		BA 7	BA 10	BA 22
Mbehav	Pearson's correlation	-,358	-,213	,195
	Sig.	,121	,507	,616
	B Value	-9,8E+14	-1,2E+15	3,23E+14
	N	20	12	9
Fbeahv	Pearson's correlation	-,264	-,234	,124
	Sig.	,260	,464	,751
	B Value	-7,7E+14	-1,2E+15	2,52E+14
	N	20	12	9

Note. N= number of participants. Correlation <0.05 is significant.

Python’s script for LI calculation.

```
LI = (len(left) - len(right)) / (len(left) + len(right))
print('Lateralization Index = ', LI)
```