Dismantling the Transgender Brain

Eric Llaveria Caselles

ABSTRACT: In this paper, I analyze in detail a neuroscientific research paper that investigates the structural connectome of transmen and transwomen in relation to cismen and ciswomen. Situated within the frame of Feminist Science Studies and from an outsider-within perspective, my analysis meets three objectives. First, it provides an understanding of the research presented in the paper: what is the research question, which methods are they using, which paradigms do they follow? Second, it problematizes the findings of the research paper and the interpretation thereof by focusing on different conceptualizations of sex/gender within neuroscience; the limits of neuroimaging technologies and the privileging of particular lines of interpretations. Finally, it reflects upon the challenges of this exercise by asking about the role of ignorance and learning in interdisciplinary work; the impact of epistemic hierarchies and the political and ethical dimensions of the research paper. My conclusion is that the lack of engagement of the neuroscientists with perspectives from gender studies and with the voices of trans people constitutes a severe neglect of the social and political responsibility of researchers and reinforces the oppression of the trans community.

KEYWORDS: neuroscience, transgender, hardwiring paradigm, sex/gender binary, research ethics.

AUTHOR NOTE: Eric Llaveria Caselles was born in Valencia, Spain and named Maria after her grandmother. At the age of 17 s/he moved to Berlin and got involved in feminist and queer networks. He is currently finishing his MA Gender Studies at the Humboldt University. Interested in feminist and decolonizing approaches to knowledge production, he works at the intersection of epistemic injustice, social studies of science, history of science and trans studies. As a filmmaker, he has co-directed two shorts and directed a medium length film within a collaborative

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queer postpornographic sci-fi project. The personal impulses of this work have recently been published in the essay "From scientific fictions to postpornographic tales".

As a gender studies student with a background in social sciences and influenced by queer theory, my attitude towards biology and medicine in the past could be described as both ignorant and rejective. Inspired by the autobiography of Julia Serano (2007), a transwoman, feminist activist and biologist, and reflecting back on my experience as a queer trans person, I started questioning this stance and became interested in the production of transsexuality/transgenderism as an epistemic biomedical object (Rheinberger, 1997). One of the fields currently paying attention to transsexuality/transgenderism and reconfiguring it as biomedical object is neuroscience. Fernando Vidal (2009) understands current neuroscientific investigation as part of the history of the cerebral subject, a notion of selfhood developed from the 17th century on within western modernity. The brain becomes the material site of the modern self, with neuroscience becoming a privileged site from which to make socially relevant claims about virtually all issues affecting the individual and society. Given this position of authority and the insufficient approach in Neuroethics that "foreground mainstream interests (or panics) motivated by our attachment to the liberal humanist subject, and thus prioritize concerns for individual rights and the freedom of choice" (Roy, 2012, p. 218), Deboleena Roy calls for feminists in the humanities and social sciences to learn how to engage in neuroscience in a critical but constructive manner and enter a "shared space of perplexity" on the differences of sex, gender and sexuality in the brain (Roy, 2012, p. 220). In this paper[1], I take a step in this direction and analyze in detail an exemplary neuroscientific research paper on transgender brains. Situated within the frame of Feminist Science Studies and from an outsider-within perspective, my analysis has three aims. First, to provide an understanding of the research presented in the paper: what is the research question, which methods are they using, and which paradigms do they follow? Second, I problematize aspects of the research paper by introducing the work of neuroscientists inspired by gender studies and feminist scholarship as well as researchers from the social sciences and humanities with a focus on neuroscience. I will concentrate on the conceptualization of sex/gender, the limits of neuroimaging technologies and the privileging of certain interpretations above others. Finally, I reflect upon the challenges of this exercise asking about the role of ignorance and learning in interdisciplinary work; the impact of epistemic hierarchies and the political and ethical dimensions of the research paper.

I choose the paper because it met the criteria of being a recent publication dealing with transsexuality/transgenderism within the field of neuroscience. Being alien to the field I didn't have the knowledge to identify a key paper or tell which one was especially relevant, so I chose a generic paper that matched my specifications. I conceptualized the paper as exemplary of an established research paradigm I aim to reconstruct. The paper I will be analyzing is titled *Structural Connectivity Networks of Transgender People* and was published by the journal *Cerebral Cortex* in 2014 (Hahn et al.). The main research site for the study was the Functional, Molecular and Translational Neuroimaging Laboratory of the Department of Psychiatry and Psychotherapy at the Medical University of Vienna, an institution focusing on the application and development of neuroimaging techniques (Lanzenberger, 2008). The study looks at transgenderism as a form of psychiatric disorder through which it is possible to gain new insights into the functioning of sex differences in the human brain: "Our understanding of sex differences in the human brain is reflected in gender differences and endocrine influences in the prevalence and treatment of various psychiatric disorders. In this context, it is particularly interesting to study gender identity disorder" (Hahn et al., 2014, p. 3527). In doing so, the study fills a research gap in the assessment of brains of trans people in relation to cis people: "although previous investigations of transsexual people have focused on regional brain alterations, evaluations on an network level, especially those structural in nature, are largely missing" (Hahn et al., 2014, p. 3527). As will be explained later in more detail, the structural connectivity describes the brain as a network of neurons and brain regions connected to each other. "Structural" means that the connectivity measured is not related to any specific cognitive task. If this were the case, the researchers would be looking into functional connectivity. The researchers recruited "23 female-to-male (FtM) and 21 male-to-female (MtF) transgender patients before hormone therapy as compared with 25 female and 25 male controls" (Hahn et al., 2014, p. 3527), with the goal of comparing the structural connectomes of every group in relation to the three other groups. While on a global level the measurements between the groups didn't differ, the researchers found differences at the regional and local level. In my analysis I show that there can be no straightforward interpretation of these findings and raise a number of severe theoretical and methodological problems.

Situating Trans in the sexed brain

Throughout the article, it is remarkable that the authors use the terms "transsexual" and "transgender" interchangeably avoiding any reference to the unstable but meaningful delimitations between them. Susan Stryker defines her use of transgender

> as an umbrella term for a wide variety of bodily effects that disrupt or denaturalize heteronormatively constructed linkages between an individual's anatomy at birth, a nonconsensually assigned gender category, psychical identifications with sexed body images and/or gendered subject positions, and the performance of specifically gendered social, sexual, or kinship functions. (Stryker, 1998, p. 150)

In the introduction to the volume *Transfeminist Perspectives in and beyond Transgender and Gender Studies*, A. Finn Enke also defines "transgender" as an umbrella term for a multiplicity of identities, including "transsexual". Going further, they invoke the dimension of the term as a political and social movement against gender norms and hierarchies, fighting for the right of gender self-determination and civil and social rights for everyone (Enke, 2012a, p. 4; 2012b). Although the use of transgender as a global term is far from unproblematic (Jarrin, 2016), I understand the interchangeable use of "transgender" and "transsexual" to describe participants diagnosed with a "Gender Identity Disorder", as an erasure of trans people's ongoing struggle to reclaim their identities and experiences beyond pathologization of gender variance by psychiatric institutions.

The first line of the Hahn et al. paper reads: "The investigation of differences between men and women has been of great interest to the neuroscience community, as structural and functional aspects of the human brain show marked sex differences" (2014, p. 3527). The authors present a long list of studies as evidence of this claim, stating a strictly binary understanding of sex. From the sex differences illustrated, the authors emphasize differences in the prevalence and treatment of psychiatric disorders. They continue: "In this context, it is particularly interesting to study gender identity disorder" (Hahn et al., 2014, p. 3527). The authors define gender identity disorder as follows:

> This disorder is characterized by the strong desire to belong to the gender opposite from their biological sex, which is often accompanied by emotional and social burden. Subsequently, patients often seek hormonal treatment and sex reassignment surgery in order to allow for more congruence between gender identity and appearance. This divergence between gender identity and biological sex has been proposed to emerge from the temporal difference between sexual differentiation of the genitals and the brain. (Hahn et al. 2014, p. 3527)

From this definition it is possible to gain further insights into the concept of sex/gender as used by the authors. They understand sex as a binary category of male and female, defined through a relation of opposition, as an "either/or". They make a distinction between sex and gender and localize biological sex in the genitals and gender identity in the brain. The authors make explicit that their investigation of trans people's brains is subordinated to the paradigm of the male/female sex and gender binary, which might explain their deliberate ignorance of the meaning of the term transgender. Their definition of sex and gender is categorical and normative, becoming apparent in the use of the terms "opposition" (instead of thinking in gradual differences and overlap) and "congruence" (as opposed to mismatch, inappropriateness, incorrectness) to define "gender identity disorder" in relation to an unspoken sex-gender-order.

Swaab and Bao's Model of Sex, Gender and Transsexuality

To gain further insights into the framing of sex and gender in the study, I want to take a closer look at the model of sex and gender formulated by Dick Swaab and Ai-Min Bao (2011, 2013), which is the one followed by the studies' authors.

Swaab and Bao claim that sex and gender identity are defined during the intrauterine development and early neonatal phase. From the perspective of individual development, genes and hormones stand as the defining units that will determine sex, gender identity, sexual orientation. These units will shape further behavioural traits of the person such as toy preference and drawing patterns in kids. Moreover, they will also shape traits such as aggressivity, prevalence of conditions like depression, anxiety, schizophrenia drug abuse or Alzheimer's disease. Swaab and Bao present a two-step model of sex and gender identity in which sex stands for genital differentiation and gender for brain differentiation. In the first step, between the 6th and 12th week of pregnancy, the fetal gonads will develop as male if there are androgen receptors or female if there are none. After the differentiation of sexual organs, the sexual differentiation of the brain occurs. The brain anatomy and circuitry will be organized during pregnancy and in the first three months after birth as either male or female mainly through the effects of sex hormones, in which again testosterone holds the key role. Apart from sex hormones, they acknowledge the influence of genes and epigenetic changes depending on context variables such as exposure to chemicals, far-reaching experiences (child abuse) or mild events (contextual fear learning in rats) in the sexual differentiation of the brain anatomy. However, these context variables are not included in their interpretation of findings. In puberty, the brain circuits will be activated by sex hormones. In this account, the anatomical and physiological organization of the brain decides on gender identity and sexual orientation:

> Structural differences in the brain resulting from the interaction of genes, sex hormones, and developing brain cells are thought to be the basis of, e.g. sex differences in gender role (behaving as a man or a woman in society), gender identity (the conviction that one belongs to the male or female gender) and sexual orientation (heterosexuality, homosexuality or bisexuality). (Bao & Swaab, 2011, p. 215)

In terms of evidence, this theory claims to link measurable anatomical or physiological signs (sexual organs, brain anatomy, hormone levels) to other more or less measurable variables like behaviour and cognitive skills (object preference, toy preference, drawing) (Bao & Swaab, 2011, p. 214), self-definition as male or female and sexual orientation. They don't take into account gender identities outside of the gender binary and their options for sexual orientation are heterosexuality, homosexuality, bisexuality and in some occasions even pedophilia (Swaab & Bao, 2013, p. 2977). But the theory has difficulties explaining how the connection between a certain anatomical fact and a specific behavioural or psychological derivative of it works or why it corresponds. This gap is settled in a sentence in which they refer back to evolutionary theory. After referring to a controversial sexed toy preference experiment with primates done by Alexander & Hines (2002) and ignoring crucial critical responses which problematise the validity of their claims (for example Jordan-Young, 2010; Ah-King, 2014), Bao and Swaab state: "It is thus logical to propose that the sex differences in playing behaviour originated in evolution before the hominids, and are imprinted under the influence of testosterone during our intrauterine development" (Bao & Swaab, 2011, p. 214).

In the outline of this theory of sex and gender identity, Swaab and Bao do not derive their evidence from a discussion of the constitutive elements upon which it rests: genetic determination of sex, neuroendocrinology, brain physiology and behavioural and cognitive aspects of gender. Instead, they look into "disorders" to provide empirical evidence of his model. They define transsexuality as "the most extreme gender-disorder" consisting "of the unshakeable conviction of belonging to the opposite gender" (Bao & Swaab, 2011, p. 216; Swaab & Bao, 2013, p. 2983); or "people with male sexual organs who feel a female identity, or vice versa" (Swaab & Bao, 2013, p. 2979). This definition rests on the closed, binary, oppositional and normative notion of sex as male-female that appears in the Hahn et al. paper. It simplifies and bends rhetorically the experiences of trans people, ignoring the diversity of identifications and self-definitions, suggesting the fixity and stability of a trait – a "unshakeable conviction" or "feeling" – and thus being able to define it as an inborn, essentialized quality. Following this model of sex and gender determination during pregnancy, Bao and Swaab explain the mechanism by which transsexuality arises as follows:

> The theory of the origins of transsexuality is based on the fact that the differentiation of sexual organs appears before the sexual differentiation of the brain. As the two processes are not synchronous, it could be that they take different routes under the influence of differently timed factors. If this is the case, one

> might expect to find, in transsexuals, female sexual organs with a male brain, vice versa. (Swaab & Bao, 2013, p. 2985)

What can be observed here is a biologization and essentialization of gender identity and behaviour through the recourse to evolutionary theory and transsexuality as gender identity disorder. By bringing in the evolutionary moment, male and female gendered behaviour is essentialized and situated outside of the realm of socialization. The biologization of gender identity occurs when the cross-gender identification of the transsexual person is explained solely in terms of genetic and hormonal factors. The male identity of the transmen is supposedly located in the brain (before hormone replacement therapy) and explained by the exposure of the fetus to "abnormal" hormones. The same should be the case for transwomen. This is where Hahn et al.'s study is situated. In the definition of the objectives of the study provided by the Austrian Science Fund [ASF] they state as their aim "to investigate differences between transsexuals and healthy control subjects in brain function and functional connectivity, brain morphology and structural connectivity" (ASF, n.d.). By providing evidence that the transmale brain resembles the cismale brain in a similar way that the transfemale brain resembles the female brain, the researchers would strengthen one essential hypothesis of the theory of Bao and Swaab: that gender identity and gendered behaviour as male or female are inborn and determined by sex differences in the brain. However, in Bao and Swaab's theory, the concepts of gender identity and behaviour are constructed as mimicking the properties of the concept of sex as unequivocally male or female, stable and consistent across all dimensions of behaviour and identity. This problem is addressed in the critiques and alternative paradigms that I will introduce in the following sections.

The Hardwiring Paradigm

The Hahn et al. study and the Swaab and Bao model are examples of what Rebecca Jordan-Young (Jordan-Young 2010; Jordan-Young & Rumiati, 2012) has labeled the hardwiring paradigm of sex and gender in neuroscientific research:

> At present, neuroscientific research on sex/gender in humans has stalled on sterile approaches encouraged by the dominant brain organization paradigm,

> which holds that steroid hormones at a critical period of fetal development give rise to permanent structural and functional sex/gender differences in the brain and behavior. The paradigm known colloquially as "hardwiring", has moved beyond the level of theory to be treated as a simple fact of human development. (Jordan-Young & Rumiati, 2012, p. 306f)

Rebecca Jordan-Young and Raffaella I. Rumiati explain conceptual flaws, empirical shortcomings and ethical issues of this model. Here I will refer only to the conceptual flaws as explained by Jordan-Young and Rumiati, since these are the ones that can be observed in the Hahn et al. study and because they amplify the objections I raised at the end of the previous section. The first falsity is the assumption that the brain is sexually dimorphic in the same way that genitals are. Evidence on structural differences in the brain between "males" and "females" are highly contested and the functional implications of anatomical divergences are even more obscure. Unlike genitals, the differences between brains in male and female defined populations are statistical outcomes at a group level they cannot be identified at an individual level. Taking the brain's plasticity into consideration, these differences could as well be the result of gendered social roles and experiences. This critique becomes even more crucial by questioning the notion of sexually dimorphic genitals (for example Fausto-Sterling, 2012). The second conceptual flaw is the omission of evidence contradicting the assumption of inborn gendered behaviour. As experiments with rats have shown, the "organizing" impact of hormones during pregnancy and in the first three months after birth are modifiable by experience and environment. For humans there are three forms of evidence which question the definition of gendered behaviour as an inborn, stable and unmodifiable trait. First, the variability within male and female groups in relation to cognitive abilities, occupational interests, educational interests and attainment and sexual orientation. Second, the variation across time and in different societies regarding which traits are seen as masculine and which as feminine. And finally, there is evidence of the modifiability of supposedly permanent traits following specific training. This type of evidence is the reason why a concept of gender identity constructed as mimicking the concept of sex bears little explanatory potential. The third conceptual problem raised by Jordan-Young and Rumiati is the fact that the only way to prove the "hardwiring" paradigm would be to expose human fetuses to monitored hormone levels. Since this is impracticable, the only way to look for empirical support are quasi-experimental designs that look for correlation between gendered behavioral traits and indications of early steroid hormone exposure. This is exactly what the Hahn et al. study does by looking at the correlation between transsexuality (defined as reversed gender identity) and the brain structure (defined as the reflection of early hormone exposure).

Neuroscience beyond the binary

The objections of Jordan-Young and Rumiati are a clear sign that neuroscientific research is not an homogeneous field and points towards alternative research paradigms being developed on the topics of sex and gender. Especially relevant in this regard is the NeuroGenderings network, “a transdisciplinary and international group of researchers from the neurosciences, the humanities and science studies working on and in the neuroscience of gender” (Dussauge & Kaiser 2012, p. 211). The network grew out of a first workshop held in Uppsala in 2010 with the title “NeuroGenderings: Critical Studies of the Sexed Brain” and has been active since. In the texts of researchers associated to the network, the composite term “sex/gender” is often used. This was introduced by Anelis Kaiser as a reaction to the lack of clear terminological definitions of sex and gender in neuroscientific research and a reflection of the impossibility to categorize neither sex nor gender as completely biological or completely social (2012). The composite sex/gender holds on to the important conceptual differences of “sex” and “gender”, but does not try to define where one ends and the other begins. This understanding is influenced by the deconstruction of sex as in the work of Judith Butler and stands in the tradition of Donna Haraway and Fausto-Sterling, among other Feminist Science Studies’ scholars, to question the claims of neutrality and objectivity of the natural sciences and reflect how biological facts are also socially constructed (Kaiser, 2012; Dussauge & Kaiser, 2012). One of the main challenges facing the scholars involved in the NeuroGenderings network is to translate this epistemological stance into empirical research.

In *Recommendations for sex/gender neuroimaging research*, Gina Rippon, Rebecca Jordan-Young, Anelis Kaiser and Cordelia Fine, all members of the NeuroGenderings Network, list four key principles that should guide brain researchers looking into sex and gender. *Overlap*, meaning that sex/gender differences in behavior and cognitive skills are less pronounced than most often assumed and likely to be overlapping. The overlap in behavior does not imply overlap in brain structure, since the same outcome can be reached by different neural means. This principle implies that brain dimorphism as analogous to the model of genital sex dimorphism is not an adequate model of representing the differences between men and women. *Mosaicism*, meaning that sex/gender in behavior, brain structure and functioning can't be modeled as two closed categories male/female. Gender is understood to be multi-factorial and one individual brain does not correspond to the male or female form as statistically defined, but will incorporate parts of both. The principle of *contingency* stands for a complex conceptualization of gender that takes into consideration the interaction of structural, social, individual and biological factors. Further, it demands attention to the fact that time, place, social or ethnic group, economic class, social situation etc. are factors shaping sex/gender. The principle of *entanglement* draws attention to the fact that neural differences between male and female can be modified, neutralized or even reversed as the effect of specific context, experiences or training. Acknowledging these principles demands different strategies for research design, data analysis and interpretation than the ones found in the Hahn et al. study. For example, the authors encourage the use of bigger samples for appropriate statistical significance of the results. Multi-dimensional, trait-based operationalization of sex/gender should be established instead of male/female according to gonadal sex. They are very critical of the already-mentioned "snapshot" comparisons between male/female since they automatically reproduce essentialist and fixed notions, even in contradiction to the theoretical rejection thereof (Rippon, Jordan-Young, Kaiser & Fine, 2014).

A practical example of how neuroscience can work towards problematizing assumptions regarding the sex/gender binary is the study by Joel et al. *Sex beyond the genitalia: The human brain mosaic*, published in the Proceedings of the National Academy of Science, definitely not the usual suspect of radical queer-feminism. The researchers analyze MRIs of more than 1400 human brains to find out whether there is such a thing as a male brain and a female brain. They find an:

> extensive overlap between the distributions of females and males for all gray matter, white matter, and connections assessed" and state that "although there

> are sex/gender differences in the brain, human brains do not belong to one of two distinct categories: male brain/female brain. (Joel et al., 2015, p. 15468)

Further, I want to refer to one more aspect ingrained in brain research on sex/gender as voiced by Emily Ngubia Kuria:

> the problem of naturalization on gender/sex difference research stems from the fact that difference is boxed up in the concept of reproduction and reproductive capacity. […] Difference is discussed along the terms of procreation and the mainstream asserts that biological facilities have evolved to make the organisms better suited for procreation and survival of the species. (2012, p. 274)

As shown earlier on, this is the case in Swaab and Bao's model of sex and gender, in which they settle the question in a brief reference to a study of toy preference in vervet monkeys without taking into consideration all the difficulties that arise from this claim. As Kuria states, the link to mainstream evolutionary theory legitimizes "the heteronormative binary gender system that taboos bodies and sex practices that do not reproduce" (2012, p. 274). At this it is worth pointing to the work of Joan Roughgarden on a new model for evolutionary theory that includes the principle of social selection instead of sexual selection and is thus able to account for the evidence of sexual diversity found in nature (2010).

The Human Connectome

At the core of Connectomics lies a theoretical modeling of the human brain as a network of "billions of neurons connected by trillions of synapses and wiring that spans a distance halfway to the moon" (Sporns, 2012, p. 1) and it aims for the mapping of brain networks. The field of Connectomics was initiated by Olaf Sporns and Rolf Kötter around 2005; it entered NIH sponsorship in 2009 and has since become a major endeavor in the form of The Human Connectome Project (Sporns, 2012; Human Connectome Project, 2015). In graph theory, a graph is defined as "a mathematical representation of a real-world network or, more generally, of some system composed of interconnected elements" (Sporns, 2011, p. 7) and is built of nodes and edges. Applied to brain research, nodes stand for neurons or brain regions and the edges can represent different measures of association. The brain connectome is not an object found in our bodies, it is a highly constructed and crafted epistemic object that is related to a physiological material object (the brain), a theoretical model (graph theory), a set of technologies (neuroimaging machines, computers, software applications, etc.) and a complex infrastructure of research institutions, data sharing, etc. Although Connectomics seems to describe the brain, it much rather creates a new object that is related to the former but still needs to be seen as a distinct entity.

Crafting Connectomes

The Hahn et al. study looks for the structural connectivity of the brain, which Sporns defines as follows:

> Structural connectivity refers to a set of physical or structural (anatomical) connections linking neural elements. These anatomical connections range in scale from those of local circuits of single cells to large-scale networks of interregional pathways. Their physical pattern may be thought of as relatively static at shorter time scales (seconds to minutes) but may be plastic or dynamic at longer times scales (hours to days) […]. (Sporns, 2011, p. 36)

The researchers used diffusion-weighted and T1-weighted magnetic resonance images (MRI) to develop individual structural connectivity matrices. The differences in diffusivity in brain tissue allow inferences on the direction of fiber bundles of axons, since diffusion is more hindered across than along axon bundles. Because there is not enough spatial resolution in MRI scans to measure single brain cells, the brain has to be divided into regions before its data can be represented in the form of a network or graph. The parcellation of the brain in regions is a crucial step that will shape the outcome of the graph analysis. In the Hahn et al. study, the researchers defined 89 gray matter regions of interest (ROIs) based on three different studies. The topic of the first study is the effects of age and sex on the anatomical connectivity pattern (Gong et al., 2009). The second study looks at the effects of Alzheimer's disease in brain connectivity (Bozzali et al., 2011). The third study investigates brain abnormalities in Spina Bifida Meningomyelocele, a congenital birth defect affecting the nervous system (William et al., 2013). Besides the striking difference in research topics, the methods used and number of regions of interest defined in the three studies varies from each other. Hahn et al. (2014) provide no further explanation as to their choice of ROI, which to me raises questions about the adequacy of ROIs and consequently about the significance of the findings.

The paired associations between the 89 ROIs are worked out via the application of probabilistic tractography to the diffusion-weighted MRI scans. From here, fiber pathways representing the structural connectivity are reconstructed (Sporns, 2011; Bullmore & Sporns, 2009; Human Connectome Project, n.d.). According to the information provided by the Human Connectome Project, tractography measures are indirect, difficult to interpret quantitatively and error-prone. Due to their diameter (measuring 1μm), researchers can't trace individual axons and instead must study bundles of potentially tens of thousands of axons (to a scale of approx. 1–2 mm) in which axons might be going in different directions. Probabilistic tractography offers an estimate of the most likely fiber orientation (Human Connectome Project, n.d.). This raises questions regarding the significance and meaning of the measurements in relation to the actual structure and functioning of the brain.

One of the usual ways to represent the structural connectivity of a brain is the connectivity matrix. Graph analysis is then applied to the connectivity matrices for an assessment and characterization of different networks in properties represented by numerical values. It is important to note that the meanings attributed to the values result from comparing sets of networks and can´t be drawn directly from the numerical values obtained. This process of deriving meanings from the values is made more complex as comparisons between networks are not always applicable: "Networks constructed using different parcellation schemes may significantly differ in their properties and cannot, in general, be quantitatively compared. Specifically, structural and functional networks may only be meaningfully compared if these networks share the same parcellation schemes" (Rubinov & Sporns, 2010, p. 1060). Brain networks can be characterized at different levels.

In the Hahn et al. study, they use measurements at global, hemispheric, lobar and regional/local levels. The values of the each group are compared to the other groups. Guided by Bao and Swaab's version of the hardwiring paradigm, the authors look for the following results. Firstly, differences in the structural connectivity values between the four groups. Secondly, evidence of stronger similarity of the MtF group connectivity values to the values of the cisfemale control group compared to the values of the cismale control group and respectively, a stronger similarity of the values from the FtM group to the cismale control group compared to the cisfemale control group. Thirdly, specific patterns of structural connectivity unique and specific to both the MtF and FtM groups that would stand as neural markers of transsexuality.

No relevant differences were found in the global measurements between groups. In the hemispheric measurements it was found that transwomen had lower HCR[2] value in the subcortical/limbic lobe of the left hemisphere, while both transwomen and transmen had lower HCR values of the subcortical/limbic lobe of the right hemisphere than ciswomen and cismen. More differences were found in local efficiency[3] values in several brain areas between the four groups. However, before being able to extract meaning from these findings, it is necessary to pay attention to several crucial challenges in the fields of Connectomics.

The limits of structural connectivity studies

Reviewing the literature on the human connectome, a number of limitations in the interpretation of data need to be delineated; firstly, that brain connectivity involves computations ranging from elementary computations carried out in subcellular compartments to single neurons cooperating in neural collectives. Thus, no single scale or process can be seen as more relevant than others or can be incorporated in other scales. Within the frame of Connectomics, it is impossible to understand cognition and behavior without taking into account the multiscale architecture of brain connectivity. From this perspective, the study offers a very limited analysis of the brain connectivity (Sporns, 2012).

Secondly, one must take into account individual variability of the brain: "statistical patterns may be preserved, but connectivity measured at the level of single neurons is highly variable across individuals both in terms of the number of elements and their connection topology. Even at the large scale, human brains exhibit significant individual variability for virtually all measurable features of brain structure" (Sporns, 2012, p. 44). Interestingly, this variability does not lead to different functioning of brains in some sort of "functional homeostasis" that allows "many different combinations of structural parameters to support nearly identical dynamic behaviour" (Sporns, 2012, p. 44). Taking into account the individual variability of the brain structure, what do the statistically calculated values of the four population groups stand for? Whose connectivity is being described? The authors include a visual representation of the average structural connectivity for each one of the research groups. In these images, the nodes and edges of each group are marked on four identical brain layouts: four gender identities become four types of brains. These highly constructed "virtual brains" subsume and supplant the individual "wet brains" (Beaulieu, 2014) of the participants, creating the impression of gender identity being an observable trait of the human brain.

Thirdly, researchers should also take into consideration the ongoing structural remodeling and plasticity of structural connectivity patterns. This happens both at subcellular scale through the continuous replacement of the constituent molecules of cells and tissues, and at a larger scale of cells and synapses through synaptic modifications, neuronal growth and structural plasticity. Further, differences in connectivity patterns have been identified related to different states of mind (Sporns, 2012, pp. 50–55). How telling can a single snapshot of a brain be? How would the values have differed in the Hahn et al. study if the measurements would have been taken at some other point? Following Schmitz and Höppner, "brain images are snapshots of a certain moment of physical materiality, which is always connected to individual biographies. Results of brain scans can thus not provide information on the processes that led to these developments, neither from nature nor from culture" (2014, p. 5; see also Schmitz, 2010).

Perhaps the biggest challenge is the interpretation of structural connectivity in relation to the functioning of the brain and human behavior and cognition. This is a question pervading all of biological research in terms of defining the relation of structure and function: how much can be known about how a system works by knowing how it is built? As Sporn writes: "The importance of structure does not imply that structure alone can fully predict all functional outcomes or that full knowledge of structure allows a keen observer to deduce all of the physiology and behavior of a biological system" (Sporns, 2012, p. 4).

Privileging interpretations

In the discussion of their results, Hahn et al. make no mention of the above limitations to their study, instead they simply proclaim that "here, we investigated the structural connectome of female-to-male and male-to-female transsexuals before hormonal treatment using graph theory", and make the values of "male and female healthy subjects" stand in for the references to the male and female brain (Hahn et al., 2014, p. 3530). The data obtained is put to work towards certain claims through rhetorical and interpretative labour. For example, the connectivity measurements obtained do not fit neatly to the expectations of the researchers. There are no differences in the global network metrics between the four groups. Instead of interpreting this in terms of similarity or as a hint towards a reduced significance of sex brain differentiation, the authors emphasize the "widespread differences" in hemispheric, lobar and regional levels, ignoring the overlap and similarities that were also registered at these levels (Hahn et al., 2014, p. 3530). The measurements of MtF and FtM differ from both male and female controls in ways that do not mirror each other. The authors, however, insist on an interpretation that reinforces the separation of trans-brains from cis-brains on the one side and trans-male from trans-female brains on the other: "the observed differences may indicate that the strong desire to exhibit the opposite sex coupled with the psychological stress is accompanied by pronounced but distinct structural signatures for FtM and MtF, respectively" (Hahn et al., 2014, p. 3531). In fact,the way in which MtF and FtM values differ from their respective control values, could as well be interpreted as grounds to question the adequacy of the conceptualization of trans as gender identity reversal within a framework of binary and opposite sex and gender. Instead, the authors opt for "the influence of the different hormones in males and females during puberty" as a possible explanation of the "opposite changes in structural connectivity between FtM and MtF observed here" (Hahn et al., 2014, p. 3531). But when is a structural signature *pronounced* or not? What are *widespread* differences? Also, the changes in structural connectivity between FtM and MtF should not be described as "opposite" because they don't have a direct negative correspondence to each other. The authors continue the discussion of the results by addressing the hypothesis that brains of MtF subjects will show structural similarities to the "female" brain and vice-versa for FtM subjects. Interestingly they don't refer to their own results but merely to other studies: "previous results and interpretations of regional differences suggest a transition from the biological sex to the actual gender identity", labeling this as "feminization" or "masculinization"

(Hahn et al., 2014, p. 3531). Contrary to their the cautious tone of uncertainty thus far, at the end of the discussion the authors conclude:

> The notion that gender identity is an innate characteristic, which emerges from a particular brain structure (Cantor 2011), is further substantiated by the current study, where most structural network metrics represented unique differences as compared with healthy controls. Taken together, these observations suggest that most local physiological aspects indeed undergo a biological transition to the gender identity, whereas characteristics on a network level may reflect the physiological stress accompanied by the psychiatric disorder. (Hahn et al., 2014, p. 3532)

I find this conclusion misleading for a number of reasons. First, the concept of gender identity used by Hahn et al. mimics the properties of the dominant concept of sex (binary, fixed, mutually exclusive) and does not reflect the complexities and dimensions of gender that other neuroscientific models do include. Anelis Kaiser, for example, suggest a model that takes into account (Recalled) Sex/Gender Socialization, Sex/Gender Identity, Sex/Gender Role Orientation, Sex/Gender Role Behavior, Sex/Gender Expression, Political Attitude Towards Sex/Gender Issues, and Culturally Embedded Biological Markers (Kaiser, 2014, pp. 50–52). Second, taking brain plasticity into consideration, the empirical observation of differences in brain structure do not allow one to conclude that this is an inborn characteristic. Third, there are severe theoretical and methodological limitations to the meaning of structural connectivity data, especially when constructing group typologies such as male, female, transmale or transfemale connectivity based on averages of different individual brains. And fourth, the findings are interpreted in a speculative manner in order to make them fit into the theoretical framework provided, and thus relativize and ignore the ways in which the findings don’t match the expectations, such as the overwhelming similarities of structural connectivity between the groups and the lack of expected correspondence between trans-male and trans-female brains.

Reflection

This exercise started partially from a place of ignorance – Robert Proctor defines ignorance as “a kind of *vacuum* or hollow space into which knowledge is pulled”; an “*infantile* absence”, but also “a *resource*” and “a *prompt* for knowledge, insofar as we are constantly striving to destroy it – fact by fact” (2008, p. 5). When I first read the Hahn et al. paper, I understood almost nothing and first had to achieve a basic understanding of the theoretical concepts, experimental rules and technological debates underpinning the work. Learning meant to stay in a movement away from the initial question and then again towards it. Within my practical constraints (time, access to material) I privileged a spatial type of knowledge that allowed me to map the relationships between different elements involved in the study. Any attempts to engage cross-disciplinarily must acknowledge/make transparent the (initial) degree of ignorance the author/researcher has towards the disciplines outwith their usual field of research. However, the will to learn and enter a new field of research alien to one’s own has to be seen in relation to the perceived relevance and existing hierarchies of the knowledges being produced. If I want to comment on neurological research on sex and gender, I have to grasp a certain amount of knowledge produced in this field not only to understand but also to be acknowledged and heard. On the contrary, neuroscientists who look into matters of sex and gender are not expected to learn from or do the same groundwork in gender studies, and as such their ignorance on these matters won’t invalidate their claims within most of the scientific community.

A second aspect of ignorance arises from the political implications of the selective nature of the production of knowledge:

> Part of the idea is that inquiry is always selective. We look *here* rather that *there* […], and the decision to focus on *this* is therefore invariably a choice to ignore *that*. Ignorance is a product of inattention, and since we cannot study all things, some by necessity – almost all, in fact – must be left out. (Proctor, 2008, p. 7)

This applies as much for my analysis as for the Hahn et al. study, but the inevitability of selectivity does not exempt researchers from social and political responsibility and accountability.

The choice of transgender people as the study population, embeds the study within a new context of interactions between scientific research, clinical and medical settings and social and political struggles. The sample comprised 23 female-to-male […] and 21 male-to-female transgender outpatients. For comparison, 25 healthy female […] and 25 male controls […] were included in the study. In transgender patients, diagnosis of gender identity disorder was assessed by the Structured Clinical Interview for the Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV) by an experienced psychiatrist at the screening visit (Hahn et al., 2014, p. 3528).

According to information on the clinical trials (Lanzenberger, 2015) available online, the "study population" was recruited at the Unit for Gender Identity Disorder (MedUni Wien, 2015) at the General Hospital in Vienna, under the direction of Dr. Ulrike Kaufmann, co-author of the Hahn et al. paper, at the Clinical Department for Gynecological Endocrinology and Reproductive Medicine. The unit was created in 1999 and has established itself as the only center for trans people in Austria, currently providing for 400 trans persons (Mayerhofer, 2015). The conformity with the DSM and the ICD definitions of transsexuality and the complicity with the institutions and mechanisms of state-sanctioned violation of trans people's rights in Austria are heavily charged socio-political acts. Therefore the Hahn et al. study has to be held accountable for the ways in which it contributes to transgender discrimination and benefits from this political situation. According to TGEU[4]'s Position paper, "the 'mental disorder' label reinforces psycho-pathologization driving stigma, making prejudice and discrimination more likely, and rendering trans people more vulnerable to social and legal marginalisation and exclusion. The current mental health diagnosis thus contributes to increased risks for the individual´s mental and physical well-being" (TGEU, 2013, p. 2). In some countries, like in Austria, a diagnosis is needed in order for trans people to access healthcare and legal recognition, while in other countries, the diagnosis will lead to an exclusion of the person from the healthcare system or legal recognition or even promote "reparative therapies". The way the researchers conceptualized and conducted the Hahn et al. study stands in opposition to and disregards many principles voiced from the trans community, like the understanding of gender variance as a common human feature, full access to healthcare for trans people, respect and recognition for trans diversity, respect for trans people´s decisional autonomy, fighting stigmatization of trans people (GATE, 2011).

As Deboleena Roy states, it is crucial for neuroscientific research to reconsider their interest and motivation in locating difference (2012). The study of Hahn et al.

had the explicit goal "to investigate *differences* between transsexuals and healthy control subjects in brain function and functional connectivity, brain morphology and structural connectivity" (ASF, n.d., my emphasis). The researchers need to be held accountable to the questions raised by Roy in order to evaluate their work from a neuroethical perspective:

> (i) is difference being measured in the study for the purpose of understanding difference in and of itself, or is it being measured for the purpose of division?; (ii) does the study demonstrate an appreciation for biological complexity, or in other words, is there enough difference?; (iii) does the study assume that structural differences can be conveniently translated into functional differences? (Roy, 2012, p. 220)

I argue that the Hahn et al. study was not carried out with the purpose of understanding whatever differences might be found between transwomen, transmen, ciswomen and cismen in terms of brain structure. The experimental setup is designed to locate differences that are assumed beforehand to exist and to construct these differences as categorical. As I have shown, the study is based on a simplistic and questionable account of sex and gender; it does not demonstrate a critical assessment of its own methodology, and extrapolates the structural findings to functional and behavioral differences along the lines of an assumed model of masculine and feminine brain, identity and behavior. Therefore, the search for difference as is pursued in the Hahn et al. study is very questionable from a neuroethical point of view.

The fact that researchers in the Hahn et al. paper could write from an authority or expert position about transgender people in ways that completely ignored voices from the trans community made me feel a mixture of anger, sadness and frustration as I engaged with their study. Although I generally encourage research on trans-related issues, in order for the research to be ethically acceptable it *must* go hand in hand with a concern for the health and well-being of trans people, especially in light of the violence and discrimination trans communities face. What I instead encountered was an obstinacy to frame trans identities as pathological and, operating within the binary of male and female, to use the brains and bodies of trans people to reinforce static and oppressive notions of sex and gender.

I wonder, too, how much easier it might be to get access to funding for this kind of seemingly apolitical and neutral research rather than research committed to the care of trans people? This is not about science being on the "right" side of the political debate, it is about practices of silencing and ignoring the voices of and knowledge produced by oppressed positionalities as forms of epistemic injustice. As I keep reading and trying to understand the paper comparing "healthy controls" with "transsexuals", I need to detach myself from my own body and experience and mimic the position of neutrality that the researchers themselves assume. Writing this response is my way of resistance by creating a space in which my embodiment can exist and articulate itself.

Endnotes

[1] This paper is based on an exercise from the course *Biological Knowledge and Gender-Knowledge – an (im)possible Dialogue?*, taught by Dr. Kerstin Palm at the Humboldt-Universität zu Berlin.

[2] A value indicating whether a lobe is more strongly connected to the own hemisphere or the other.

[3] Local efficiency is a value that describes how efficient the exchange of information is within a network.

[4] Transgender Europe (TGEU) is a trans-led organisation that advocates for trans people's human rights and raises awareness on the multiple forms of discrimination faced by members of the trans community.

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