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*Editorial*

# Brain Matters… in Social Sciences

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**Abstract:** Here we offer a general introduction to cognitive neuroscience and provide examples relevant to psychology, healthcare and bioethics, law and criminology, information studies, of how brain studies have influenced, are influencing or show the potential to influence the social sciences. We argue that social scientists should read, and be enabled to understand, primary sources of evidence in cognitive neuroscience. We encourage cognitive neuroscientists to reflect upon the resonance that their work may have across the social sciences and to facilitate a mutually enriching interdisciplinary dialogue.

## 1. Introduction

This short piece is the elaboration of a session we held at a Summer School organized by the Scottish Graduate School for the Social Sciences (SGSSS) in June 2016 at the University of Edinburgh. Our session was primarily aimed at introducing graduate students to brain science in a context where this may be seen as intimidating or irrelevant. In fact—we argued—neuroscience not only produces nice pictures of the brain but also evidence with significant impact on traditional social science disciplines. We predict that the ability to read and interpret primary sources of evidence, rather than extracting related information from the news or popular science books, will be an important arrow in the quiver of the future social sciences professionals. We are now writing in a neuroscientific outlet with the aim to promote interdisciplinary dialogue and invite both neuroscientists and social scientists to ponder on the implication of their work beyond strict discipline boundaries and on the necessity to keep pace with what is happening beyond their fences. The willingness to explore foreign territories and inquiry with other professionals will help refine interdisciplinary communications by building a common language and educating us to address questions from multiple, often complementary, perspectives. In turn, this may also help communicating research findings in a way that creates balanced expectations and avoid hype [1].

Here we employ the same broad definition of social sciences as adopted by the Economic and Social Research Council (ESRC), that is the study of the "society and the manner in which people behave and influence the world around us" (esrc.ac.uk). Social sciences include disciplines such as demography, human geography, economics, management and business studies, education, social anthropology, linguistics, law, politics, international relations, psychology, sociology, science and technology studies, social policy and social work and others. Several of these disciplines, such as philosophy, law and politics, pre-date the scientific study of the brain and its relation with human mind and behavior, which is the aspect of brain science we are specifically concerned with here and which originated at the end of the 19$^{th}$ century. This has recently been subsumed under the umbrella term of cognitive neuroscience and has been growing exponentially since the end of the 20$^{th}$ century with the diffusion of neuroimaging techniques.

## 2. What is Cognitive Neuroscience?

Cognitive neuroscience originates from the cross-fertilization of two older disciplines: cognitive science and neuroscience [2]. It investigates the neural bases of the mind with a plethora of methods offering complementary sources of evidence.

The scientific study of the mind became official in the second half of the 19$^{th}$ century, in concomitance with the publication of *Principles of Physiological Psychology* (1874) and the opening of the Institute for Experimental Psychology (1879) at the University of Leipzig by Wilhelm Wundt [3]. The first scientific models of mental processes were created through systematic experimental manipulation and repeated measurements of its effects on both subjective content and behavior. By the first half of the 20$^{th}$ century, however, subjectivity was rejected as a scientific object of study, and psychologists focused exclusively on observable behavior, especially in the United States. Typical experimental subjects were not humans but rats and pigeons, and psychologists engaged in a bid to discover the laws of behavior by manipulating rewards and punishments. Conditioning principles were assumed to govern learning and explain complex patterns of behavior without necessity to invoke a significant role for internal mental states. Although this approach produced valuable knowledge, its scope soon appeared too restricted. Mental processes regained center stage in the second half of the 20$^{th}$ century, with the advent of cognitive science.

Cognitive science is another umbrella term that unifies research on information processing associated with cognitive functions, regardless of its specific topic and methodological or even disciplinary approach (e.g. both cognitive psychology and computer science contribute to cognitive science). Cognitive scientists aim to create accurate and predictive models that describe the component processes of cognitive functions. Cognitive functions are a set of processes allowing humans to perceive stimuli, extract information, hold it in memory, and generate thoughts and targeted actions. From a cognitive science perspective, these can be studied without necessarily having to relate them to a biological substrate. From a cognitive neuroscience perspective, exploration of the biological counterpart of cognitive functions can provide important information to help generate, expand, constrain or discard cognitive models.

Neuroscience studies the anatomy and function of nervous systems, in clinical and experimental settings. Similarly to the scientific study of mental processes, the scientific study of nervous systems gained great momentum towards the end of the 19$^{th}$ century. In those years, a new method for coloring nervous systems (i.e. staining) was introduced; this led to the identification of the cellular unit by which nervous systems are made: the neuron. In recognition of the importance of this discovery, the histologists Camillo Golgi (the inventor of the staining method) and Santiago Ramón y Cajal (the first to discover that the nervous system is made by separate cells rather than a continuous network) jointly received the Nobel prize in 1906. Neurons have three basic parts: a *cell body*, which is where metabolic processes occur (these processes are supported by oxygen and metabolites provided by the vascular system); an *axon*, that typically carries information via the rapid propagation of electrical charges and consequent release of chemicals (neurotransmitters) in the space between neurons; and *dendrites* that receive signals from other neurons via contact with the neurotransmitters that they release. Most neuroscientific techniques therefore target one or more of these processes and interact with or measure metabolism, blood flow, chemical and electrical activity in single neurons or in populations of neurons.

Similarly to the study of mental processes, scientific studies on functional localization in humans started at the end of the 19$^{th}$ century and then received a further boost in the middle of the 20$^{th}$ century, with the famous pre-operatory mapping studies of Wilder Penfield and colleagues [4,5]. Penfield applied small electrical currents to the exposed cerebral cortex of epileptic patients who were awake and awaiting for brain surgery. By targeting neighboring parts of the exposed cortex behind the central sulcus, for example, he noticed that patients could perceive tactile stimuli in neighboring parts of their body. This subtended a principle of topographic correspondence between populations of neurons and sensory stimulation on the body. He also noticed that the area of cortex devoted to each part of the body was not directly proportional to the size of the body part but to its sensitivity (e.g. the face is represented by a larger area of cortex than the trunk). The technique employed by Penfield can be described as intracranial stimulation and belongs to one of the two main categories of techniques: manipulation techniques, which can establish causal relationships between brain substrates and mental or behavioral processes. Other techniques belonging to this category are: extracranial brain stimulation (including Transcranial Magnetic Stimulation, TMS; Transcranial Electric Stimulation, TES; Transcranial Pulsed Ultrasound, TPU), lesions (spontaneous or artificially induced), pharmacological interventions, and optogenetics. The second category of techniques consists of measurement techniques, which detect and measure—rather than manipulating—brain states. These include direct (intracellular or extracellular) recordings from neurons, electroencephalography (EEG), event-related potentials (ERPs), magnetoencephalography (MEG), positron emission tomography (PET), functional magnetic resonance imaging (fMRI), and optical brain imaging.

Cognitive neuroscience is the label employed since the end of the 20th century to indicate research activities at the intersection of cognitive science and neuroscience. Cognitive neuroscience thus largely builds on the inheritance of older disciplines such as neuropsychology and experimental psychology, encompassing the use of all of the techniques available to the cognitive scientist and to the neuroscientist to create neurobiologically grounded models of cognition. Its aims are ambitious and include localizing cognitive functions, identifying the neural basis of typical and atypical cognition, and establishing a link between genetics and cognitive abilities via variations in brain structure and function. It is interdisciplinary and requires the mastering of concepts and methods from both cognitive science and neuroscience.

## 3. Brain Matters…

### *3.1. Example 1—Psychology*

It will come as no surprise that, historically, one of the first social sciences to benefit from using brain data was psychology in the second half of the 19th century. Until the scientific method started to be systematically applied to the study of the mind, philosophers used to investigate the phenomenology of cognition. They answered questions such as how we perceive the world, how we learn to speak, whether we have free will and if so by what age, etc. By the end of the 18th century, Immanuel Kant had forcefully introduced with his *Critique of Pure Reason* [6] the idea that we learn through innate mental categories: the structure of our knowledge is dependent on an innate mental structure. By the beginning of the 19th century, physicians had started to realize from the study of war wounds that injuries to different parts of the brain may be related to different impairments of mental functions. Franz Joseph Gall [7] hypothesized that the differential development of various parts of the brain may explain differences between people in character and abilities. He also maintained that by measuring bumps on the skull (i.e. a craniological measurement) it would be possible to measure the underlying brain structure and infer individual characteristics. Although this approach, called phrenology, turned out to be based on wrong assumptions, it helped popularize the idea that different mental functions are localized in different parts of the brain.

With the observations of the French neurologist Paul Broca [8] on Monsieur Leborgne (also known as patient “Tan”) the idea of a cerebral localization of mental functions started to be widely accepted in the scientific community, also due to his rigorous methodological approach [9]. In Broca’s own words, that 50-year old patient showed a strikingly selective deficit in his language function, so Broca looked for information on his history, and found out that he had been admitted at Bicêtre 21 years earlier because he had lost the ability to speak: "When he arrived at Bicêtre … he was then perfectly healthy and intelligent, and differed from a sane man only in the loss of articulated speech … He understood all that was said to him; he even had very fine hearing; but, regardless of the question addressed to him, he always responded: 'tan, tan' … He was considered, on the contrary, as a man perfectly responsible for his acts" [8,10]. The symptom was still present at 50, when his physical (but not mental) health had widely deteriorated and he was re-admitted to hospital with a gangrenous leg. He died 6 days later and Broca performed a post-mortem analysis of his brain—without sectioning it in order to preserve the specimen for a museum. The inspection suggested to Broca that a localised lesion of the left frontal hemisphere had caused selective problems at articulating speech in the presence of normal language comprehension ("the third frontal convolution is that which presents the most extensive loss of substance"; "it is in the third frontal convolution that the disease began" [8,10]). A few months after publication of the report on patient "Tan", Broca found a patient with similar symptoms, Monsieur Lelong. At 84, Lelong had a stroke that left him unconscious. He partly recovered but remained unable to utter any words except for a selected few "oui, non, toi, toujours, Lelo". About one year later, he was admitted to hospital with a fractured femur and died after 12 days. Also in this case, Broca was able to analyse the brain post-mortem and wrote: "I will not deny my surprise bordering on stupefaction when I found that in my second patient the lesion was rigorously occupying the same site as the first" [10,11]. By 1865, 18 out of 20 patients with acquired speech difficulties or "aphasia" were found to have a left-sided lesion [12].

The importance of this work in a clinical neurological setting is obvious. But what is Broca's legacy for psychology? To be fair, the idea of a "faculty" of articulate language or its localisation in the frontal lobes was already in the air. However, Broca combined detailed accounts of clinical manifestations with systematic searches for the neurological correlate of the inability to produce articulate language (as opposed to language as a unitary function), he used the pathological (as opposed to craniological) method with post-mortem examination and focused the attention to individual cerebral convolutions rather than to the whole of frontal lobes. He paved the way for the use of clinical and neurological evidence to investigate the components of complex psychological faculties such as language.

In 1874, Carl Wernicke described a patient whose articulate speech was intact but who had instead difficulties in understanding verbal language [13]. His lesion was still in the left hemisphere but more posterior than Broca's patients' lesion. Wernicke put forward an anatomo-functional model, in which the faculty of language was fractionated into discrete but connected components, having different anatomical correlates. He distinguished between a "centre" for acoustic-verbal images, localised in the temporal lobe and a "centre" for motor-verbal images, localised in the frontal lobe. In the work of Wernicke, although still very rudimentary, we can already find the three main levels of description which are required in order to build a neuropsychological model: the *psychological* level, which aims to specify the architecture of the cognitive system, the *neurological* level, which aims to localise specific mental operations in the brain, and the *clinical* level, which describes distinctive behavioural symptoms and preserved abilities. In the second half of the $19^{th}$ century, many neurologists took the view that language was a multi-componential function. The most influential model was Lichtheim's, who added to Wernicke's model a conceptual component, containing the meaning of words. This specification of functional centres and connections between them allowed Lichtheim to predict the existence of different types of language impairments, depending on the level at which the language system was lesioned. Although cognitive neuroscience does not look for "centres" anymore, this approach marked the start of a new discipline, neuropsychology, which has informed and constrained the current models of mental functions by the analysis of associations and dissociations of symptoms and spared functions in neurological patients.

In more recent years, the availability of manipulation techniques like TMS has allowed us to test associations and dissociations of symptoms in the same healthy participants (rather than between patients) by adopting a virtual lesion (or reversible lesion) approach. This offers a complementary approach rather than a replacement of lesion studies and enables the refinement of models of mental functions by using experimental tasks and protocols that would be impossible with neurological patients. In general, such techniques enable the psychologist to selectively modulate the efficiency of multiple components of a mental function and assess their interplay at the individual or the group level [14,15].

### *3.2. Example 2—Healthcare and bioethics*

Cognitive neuroscience has offered fresh and challenging evidence, which is awaiting to be fully incorporated in current practice, to healthcare professionals and bioethicists dealing with patients in permanent vegetative state (PVS) or minimally conscious state (MCS). Patients who wake up from a coma may show a dissociation between their spared wakefulness and impaired awareness; they are usually diagnosed with PVS (the most severe form) or MCS (a form with better prognosis) but the boundary between the two has now become less clear than it was in the past and there are suggestions that the "permanent" attribute be dropped from the VS diagnosis. These patients are particularly challenging because, although their eyes are open, they are unable to interact with their surroundings (e.g. they cannot execute commands, voluntarily track moving objects/people with their gaze or show a localized response to pain). Some of these patients recover spontaneously within a few months, while others remain in such state for years. Moreover the variability in the extent of their lesion is not related with the potential for recovery in a univocal way [16].

High profile legal cases such as those of Terri Schiavo and Eluana Englaro [17] have emerged where a lengthy legal battle preceded the permission to interrupt life support. In the case of Englaro, for example, the suspension of feeding and hydration after 17 years, which lead to the death of the patient in a few days, was in part based on the fact that she had not shown clear signs of awareness for a long time and her fitting the behavioral criteria for a PVS diagnosis [18].

Recent neuroimaging studies have suggested that patients who do not show any overt response to external commands may still intentionally modulate their brain activity even in the absence of overt behavior [19,20]. Up to 40% of patients with a diagnosis of vegetative state may show signs of conscious awareness when tested with neuroimaging techniques [16]. In recent years, a new measure has also been proposed that bypasses completely the need for the patient to follow any commands: the Perturbation Complexity Index (PCI; [21]). The PCI would be measured by targeting the brain with a small magnetic impulse and measuring the passive spread of electrical activity throughout the whole brain. Although this is still experimental and requires further validation, it is thought to offer an objective measure of the potential of the brain for recovery. It also shifts the emphasis from a behavioral-active to a bodily-passive way of diagnosing conscious awareness.

From a bioethical standpoint, the possible introduction of these techniques in routine medical practice will emphasize evidence of an individual's bodily potential over concerns about quality of life from the perspective of their familial and social network. It would mean giving control back to the patient as opposed to it lying with their family. From a philosophical standpoint this practice will both build on and further reinforce views that postulate the substantial identity between brain and mind. Lawmakers, healthcare professionals, cognitive neuroscientists, journalists and bioethicists are thus engaging in complex discussions on whether and how these new findings should change our future approach to the issue.

### *3.3. Example 3—Law and criminology*

Besides the substrates of consciousness, cognitive neuroscientists have also started to investigate complex mental processes such as moral beliefs, intentions and free-will and found evidence that challenges traditional notions of criminal responsibility and the law built around them [22]. In courtrooms around the world, neuroimaging findings about a defendant's brain anatomy and function are now used as evidence to show abnormalities, to argue why mitigating factors should be taken into account, or demonstrate the presence of crucial memories when self-reports appear unreliable. The more neuroimaging techniques, and fMRI in particular, are presented as mind-reading tools [23], the more it appears plausible that these will be used, in a not-so-far future, to overcome the intrinsic weaknesses of eyewitness's testimony or the lack of directly incriminating evidence. They are often presented as ideal tools to detect deception or malignancy in legal settings. Further, they are already used in some corporate settings to test the reliability of prospective employees [24].

How realistic are these claims? According to certain media reports and to firms offering the latest scientific lie detection services, these are realistic expectations and it is only a matter of time before fMRI becomes available everywhere. However, social scientists may have to dig a little deeper than enthusiastic media reports and not be misled by scientific-looking claims that are made in an obvious conflict of interest. They may need to reach out for primary sources. Because if they do, they will discover that most neuroscientists would agree that fMRI should not be used as lie detector [25]

There are several reasons, scientific and not, why we should be skeptical about the potential for fMRI in lie detection. First of all these claims rest on unwarranted assumptions and inferences pertaining to both cognitive models of lying and the mapping of mental content to brain substrates. Second, the differences between the forensic and the laboratory setting makes it impossible to apply lab results into the real world: whilst in the former the truth is most often unknown and the individual may have an incentive to adopt countermeasures, in the latter experimenters often know what the truth is and participants do not have incentives as strong to adopt countermeasures. Third, and contrary to public expectations, MRI scanners are not mind readers: they measure correlates of mental activity through changes in oxygenated blood flow, which proponents suggest they denote lying. Fourth, the effect of many potential confounds (e.g. age, social diversity, mental disorders, personal incentives) on fMRI responses in a laboratory and in a forensic setting is largely unknown. Moreover, fMRI responses are highly vulnerable to countermeasures, among other concerns.

In addition to the scientific concerns, there is a long list of legal and ethical hurdles that make it very unlikely that fMRI will be adopted in the courtroom any time soon. These have been analyzed elsewhere [24]. Thus, some basic understanding of the neuroscientific literature, combined with knowledge of relevant legal and ethical clauses, will produce a more realistic appreciation of this issue and related expectations in both neuroscientists and social scientists alike.

### *3.4. Example 4—Information studies*

The success and popularity of brain science offers novel material for studies in information science. Castel et al. [26] conducted an interesting study on the allure of brain images in science communication. They showed that the pairing of logically flawed news information with a picture of brain activations could sway readers' judgments away from critical thinking. Indeed, news accompanied by an image of brain activations were judged as more scientific that news accompanied by box plots or complex images that could not be as directly related to brain anatomy. The authors speculated that these images may be easily mistaken by the public (anybody who does not work in neuroscience) as real photographs of the brain. In fact, most images are not pictures of single brains, and fMRI does not measure brain activation directly: colored blobs indicate maps of statistical significance in the levels of oxygen in the local blood flow rather than neuronal activations. Weisberg et al. [27] further reported that people tend to find bad explanations of psychological phenomena more convincing, if they contain some reference to neuroscientific data rather than to psychological constructs only. This has alerted information scientists of the power of neuroscience and the need to inform and educate both professionals and the general public.

Accordingly, Legrenzi and Umiltà [28] have raised a warning against the hype surrounding anything containing the prefix *neuro*- (their critical essay is conveniently titled “Neuro-mania”). These criticisms are valid and likely motivated by a widely perceived tradeoff between the ever-increasing popularity of neuroimaging among social scientists and the importance of the contribution that most of the studies conducted with neuroimaging have actually brought about within and outside of brain sciences. They should be taken *cum grano salis* and with the understanding that the phenomenon the authors are targeting concerns especially the recent wave of fMRI studies rather than brain science *tout court*.

A few years down the line, independent researchers failed to replicate the nefarious neuroscience effects mentioned above [29] and highlighted that the original studies had actually found effects of almost negligible size. However, we expect this revised specialist view not to find its way into the popular media—and thus reach the public or experts in information studies—as easily as the original view [30].

## 4. Conclusion

In summary, here we argued that brain studies matter in social sciences by offering examples from different disciplines where brain studies have changed, are changing or claim the potential to be a source of change of the way we approach topics in the social sciences. We believe that it is useful and important for social scientists to acquire foundational concepts and become aware of the advantages and limitations of the most popular neuroscientific techniques. In this way they can reach a critical appreciation of the evidence reported in primary and secondary sources and with potential impact on their fields. These foundational concepts are a first step to enable the interpretation of the claims that we often read in the news and the navigation through the peer-reviewed scientific literature (that is access to primary sources of evidence). On the other hand it is useful and important for neuroscientists not to shy away from questioning how their research may affect both theory and practice in other fields and from exploring ways to communicate in a truthful but accessible way with other professionals.

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## Conflict of Interest

All authors declare no conflicts of interest in this paper.

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