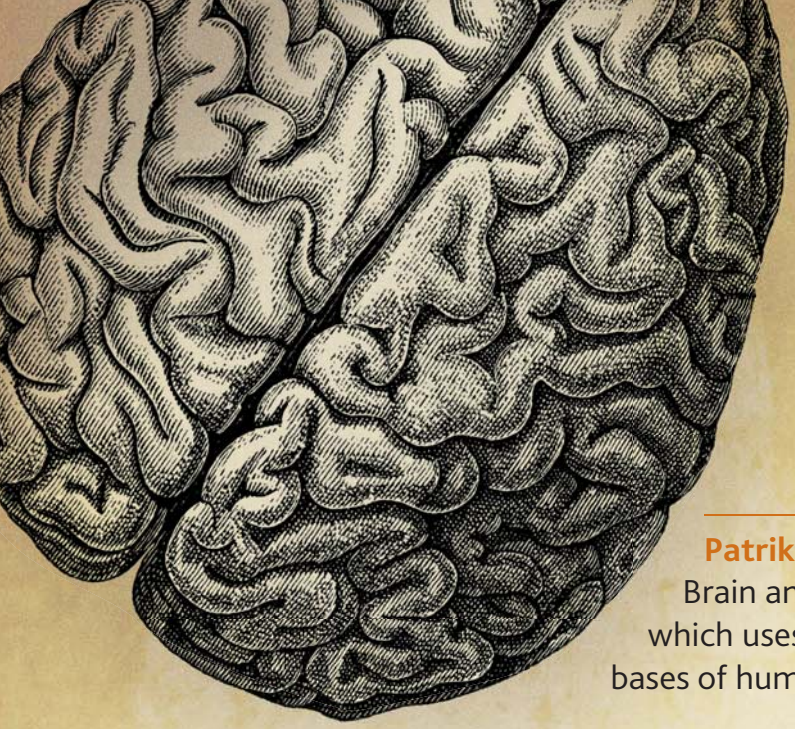

Brainwork

Patrik Vuilleumier discusses his work as Head of the Brain and Behaviour Lab at the University of Geneva which uses neuroimaging to investigate the cerebral bases of human mental functions, emotions and behaviour

Could you introduce yourself and provide a brief overview of your research focus?

I trained as a clinical neurologist in Geneva, Lausanne and Paris, which led me to witness the neurobiological mechanics making our mental life, actions, and feelings, as revealed by the terrible but fascinating consequences of some brain lesions. This triggered my interest in the neural bases of behaviour and cognition, which I began studying with neuropsychological tests in patients with brain diseases.

The appearance of neuroimaging techniques in the early 1990s sparked off a new interest when I discovered that brain activity underlying mental processes could be visualised and measured by non-invasive means in healthy people. In 2004, I was given the opportunity to set up a new group and launch the Brain and Behaviour Lab (BBL) as a platform of the Center for Neuroscience at the University of Geneva (UNIGE).

What is the goal of your work at the BBL at the University of Geneva?

Our ultimate goal is to understand the cerebral bases of human mental functions, emotions, and behaviour, both in healthy conditions and in neurological or psychiatric diseases. This knowledge will serve to better diagnose and differentiate brain pathologies prior to overt symptoms, as well as to improve assessment of the effect of specific treatments or the prognosis of diseases.

We combine multiple measures based on brain imaging techniques, recording morphology or connectivity as well as metabolic or electric activity while people perform various mental tasks. No single methodology is sufficient to fully understand brain functions in relation to complex or even simple behaviours, but combining approaches and linking the mechanisms at play at different levels is the best way to decode the myriad of brain processes at the root of the human mind.

What are the main methods used in your research? Have you developed any innovative approaches you would like to highlight?

The most important tool for us is functional magnetic resonance imaging (fMRI), which allows us to measure and localise with high precision changes in activation in the brain. While the standard approach is to compare the mean amplitude of activation in a given area, such as during different tasks, we have developed novel ways to decode activations evoked by different emotional states or stimuli, by considering the fine-grained distribution or 'landscape' of activity – the peaks and valleys – in a given area or across networks of areas. This approach can provide additional information about the 'content' of information that is processed in specific brain regions.

Another novel application of fMRI that we are currently exploring is online neurofeedback. The fMRI activity of one or more given brain regions can now be analysed in real time and shown to the subject while he/she is lying in the scanner. Crucially, the subjects can then be trained to increase or decrease activity in this region by using the real time feedback. We can utilise this approach to improve the control of various brain functions, including pain, perceptual processing, or emotion regulation.

Could you mention a few of your integral findings to date?

An important part of our research lies at the intersection between consciousness and emotion. This work has revealed the brain circuits through which emotions can influence behaviour and cognition in humans, and shown how such effects may operate, to a large degree, automatically, even without conscious awareness, and how they can be modulated by personality or contextual factors. These results delineate neural pathways by which emotions influence attention, memory, or action.

From where do you receive your funding? Do you find it difficult to acquire the funding and resources you need?

A large part of my time is spent on finding funds to support my group. I have been lucky to benefit from a private donation that contributed to pay for a new Chair in cognitive neuroscience and allowed buying the MRI scanner from the BBL. Such support by private sources is not only generous and precious, but also useful to encourage public institutions to make costly decisions. However, this support remains relatively rare in Switzerland and often misperceived by the public.

It is sometimes frustrating to learn that colleagues in the U.S. obtained funding from donators located in Geneva who prefer their name to be associated with famous universities such as Harvard, Stanford or the Weizmann Institute, even when colleagues from these universities actually envy research done in Geneva!

Collaborative approach to the human mind

An innovative research centre based at the University of Geneva brings together experts from a wide range of disciplines to try to find answers to some of the most fundamental questions about the functional basis of human emotions and behaviour

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THE BRAIN AND BEHAVIOUR LABORATORY (BBL) at the University of Geneva (UNIGE) is a research centre established to combine numerous cutting-edge techniques from neuroscience, physiology and behavioural sciences to study the neural and psychological underpinnings of the human mind using multi-dimensional, crossdisciplinary approaches. The BBL is jointly directed by two institutional bodies at UNIGE, bringing together more than 60 research groups and their students from psychology, medicine, biology and informatics as well as philosophy, law, literature and history.

Two current research projects at the BBL are pursuing multimodal imaging work on how emotional information and emotional states are represented in the brain and how corresponding patterns of brain activity may differ when emotional information is processed consciously or unconsciously. A project led by Swann Pichon focuses on how emotional states affect decision making; Yann Cojan is researching how hypnotism affects the brain on a neurological basis.

EMOTIONS AND DECISION MAKING

Swann Pichon is researching how basic emotions interact with perceptual and decisional processes, and behaviour regulation. "Uncovering mechanisms of affective cognition gives us many important insights into the understanding of the function of basic emotional systems, how they influence our perceptions, thoughts, and decisions," he explains. In particular, he wants to understand how positive and negative induced emotional states bias information processing and decision making later on.

Pichon and his team are combining techniques including functional magnetic resonance imaging (fMRI), peripheral physiology and hormonal measurements to study how experimentally induced emotional states produce changes in perception or decision making. Subjects first perform a dummy task involving either positive, negative or neutral emotional stimuli using video or words. The aim of this task is to sensitise or desensitise one or more specific brain regions. Next, subjects perform a second experiment that is designed to tap into these brain regions and assess how their responsiveness is impacted by the induced emotional states.

HYPER-SENSITISED AMYGDALA

Results so far show that prolonged exposure to negative information produces a hyper-sensitisation of the amygdala – the fear centre of the brain – to later information processing. Neurons in the amygdala are tuned to associate negative sensory information with a specific sensory context and generate a fear memory that warns of the presence of a potential threat.

However, after prolonged exposure to negative information, some of these neurons start to respond strongly to emotional and neutral information: negative emotional material in the first task sensitised amygdala responses to emotional but also non emotional information in the second task. Yet, as these amygdala neurons now are less able to differentiate negative from neutral information, this global sensitisation actually corresponds to a loss of the functional selectivity – a functional desensitisation – that the amygdala usually displays for negative information.

VIDEO GAMES AND (DE)SENSITISATION

Pichon is planning to use similar methods to study how video games influence the functioning of the limbic system, and how this could have an impact on aggressiveness and prosocial abilities. "Being repeatedly exposed to media violence desensitises individuals to real-life violence and increases the risk of developing aggressive behaviours," he explains. "Although this has been known for many years, we do not fully understand how exposure to violence may chronically alter brain processes and cause individuals to become desensitised to violence in real-life."

These issues address considerations regarding the development and use of video games, that have become an ubiquitous activity in our society. For instance, one could imagine video games designed with the aim of training pro-social abilities. There is a need to understand whether and how video games have an impact on brain plasticity, which neuroscience can provide, in order to feedback this knowledge in video games development.

HYPNOSIS AND CONTROL

Yann Cojan is leading a project at the BBL which uses neuroimaging to investigate attention and inhibitory executive control in hypnosis, a remarkable phenomenon that can have a profound effect on the subjective appraisal of many sensory or motor experiences such as pain perception, hallucination, paralysis and movement. Previous research into the effects of hypnosis has led to the suggestion that it may involve engagement of brain processes that mediate executive control and attention, in particular an inhibition process that could block certain actions or thoughts.

However, no studies have directly tested this suggestion. "It's important to determine if hypnosis involves executive control because executive functions permit regulation of cognitive and emotional processing," Cojan explains. "Subjects under hypnosis could therefore have a better control of their own behaviour and sensations than previously thought."

MEDIATING MOTOR CONTROL

The project also makes use of a range of techniques including fMRI, electroencephalography (EEG) and peripheral physiology. The researchers have tested whether a hypnotic suggestion of paralysis disrupts the formation of motor intentions, or instead activates specific inhibitory processes which act on normal motor intentions. Subjects performed a task where they prepared to make a hand movement and then, depending on the instruction, did or did not execute the movement. Some subjects were hypnotised with the suggestion that their left hand was paralysed while others were instructed to simulate left hand paralysis.

Cojan's team found that the motor cortex was normally activated during the preparation phase of the task despite the suggestion of paralysis, suggesting that hypnosis did not suppress activity in motor pathways. "This shows that subjects under hypnosis still have the intention to do the movement, leading to similar motor activity," Cojan states. "Hypnosis is not affecting the intention to move but acts through other mechanisms. These results contribute to resolve some debates on the role of reduced volition, as opposed to enhanced inhibition, during movement execution in hypnotic paralysis."

SOCIAL, CLINICAL AND PHILOSOPHICAL

This approach to understanding and modelling brain function brings wide-ranging outcomes and impacts, including social, clinical and philosophical implications. In his study of emotions and decision making, Pichon hopes that the combination of cognitive and brain imaging studies he is carrying out will provide new ways of thinking about issues around media and violence. These cognitive neuroscience models can provide a robust base onto which specific mechanistic hypotheses can be addressed, allowing this knowledge to be applied to real life situations.

Cojan's work on hypnosis has both a clinical and philosophical application. Clarifying the underlying mechanisms of the effects of hypnosis will help to give patients better ways of controlling pain and stress. Additionally, understanding hypnosis may give clues into the nature of human consciousness. "The fundamental cognitive neuroscience question is related to the body-mind problem," he says. "The ultimate goal of my work is to question this classic dualistic approach and help reunify body and mind in a more integrated concept."

Making connections between disciplines and expertise is a fundamental aspect of cognitive neuroscience. The opportunities for collaboration and multi-disciplinary work at the BBL enable innovative research to flourish. Although each of the research techniques used in these projects exists in other centres, their combination in a single laboratory make the BBL a unique cutting-edge research platform in Europe and worldwide.

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INTELLIGENCE

NEUROIMAGING OF THE MIND: HOW ATTENTION AND AFFECTIVE STATES REGULATE BEHAVIOUR AND CONSCIOUSNESS

OBJECTIVES

The aim is to understand how our perceptions and actions are shaped by brain mechanisms that facilitate or impinge the responsiveness of cortical and subcortical neural pathways, such as emotion, attention, and executive or inhibitory control. Modern brain imaging techniques are applied to identify the specific processes through which we respond to external or internal events, but also to train people to modulate them or restore impaired functions using neurofeedback.

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YANN COJAN received his PhD in neurosciences in 2006 from the Pierre et Marie Curie University (Paris VI). He has been a postdoc in the Laboratory for Neurology & Imaging of Cognition in the Neurosciences Center at the University of Geneva, Switzerland and is now postdoc in the University of Buenos Aires, Argentina.

SWANN PICHON has previously worked at the Department of Cognitive Studies at Ecole Normale Supérieure in Paris, where he obtained a Master's and a PhD in cognitive neurosciences. Previously he received his undergraduate degrees in computer sciences and cognitive sciences from the Universities of Edinburgh and Lyon.

PATRIK VUILLEUMIER is a neurologist with clinical training in Switzerland and France, and cognitive neurosciences research at the University of California Davis and University College London. Currently, he is heading the Laboratory of Behavioral Neurology and Imaging of Cognition, at CMU and HUG, University Medical School of Geneva. He is also Director of the Center for Neuroscience and Co-director of the BBL at the University of Geneva.

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