Two brain neuroscience: understanding our social selves

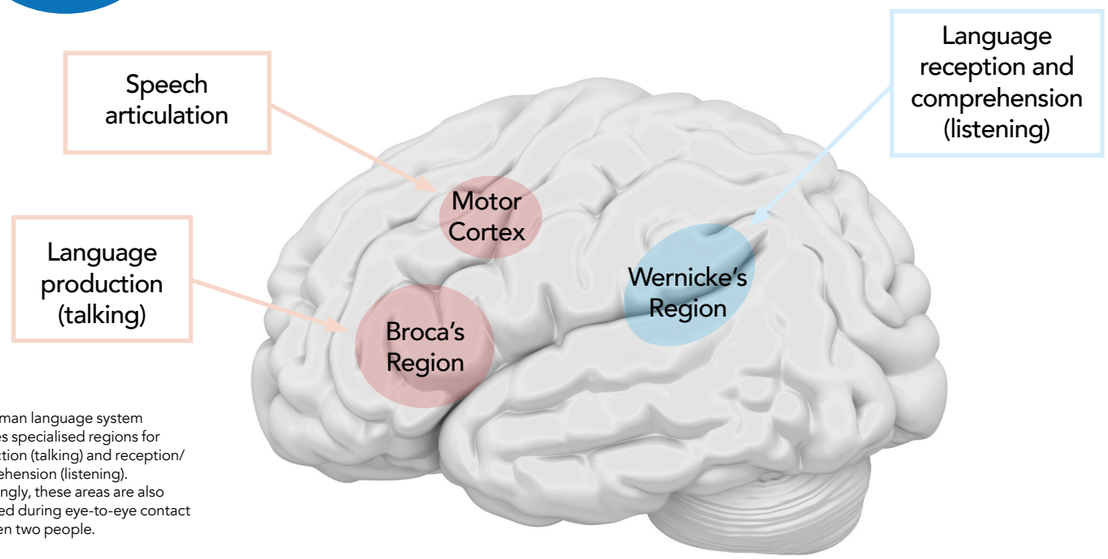
Humans are innately sociable mammals. However, almost all of our understanding of the neural basis of social interaction has been carried out with individual participants, limiting our knowledge of how our brains react to other humans. **Joy Hirsch**, Professor of Neuroscience at the Yale School of Medicine and University College London, has embarked on a truly pioneering research programme using new neuroimaging technology to study the human brain as it interacts with others.

Sociability is a fundamental part of the human story, with relationships comprising an enormous part of our lives. Our ability to understand and respond appropriately to social cues is fundamental to our ultimate success as friends, spouses, colleagues and parents. However, the ways in which our brains represent and process information during even basic interactions remain mysterious.

NEUROSCIENCE OF SOCIAL INTERACTION

The human brain has been described as being hard-wired for socialising, given the large areas given over to social cognition processing. What we know about the brain relies on clinical observation, autopsy, animal studies and neuroimaging. Much remains unknown about the brain due to its incredibly complex make-up, consisting as it does of billions of neurons and trillions of synapses. Luckily, brain scanning techniques provide us with vital insights. Social neuroscience has been advanced by neuroimaging, taking advantage of tools such as functional magnetic resonance imaging (fMRI), which relies on blood flow to highlight areas that are activated during a particular task or stimulus. Using these tools, scientists have spent many decades attempting to characterise the neural basis of our social brains, identifying areas and networks associated with language, empathy, face processing, eye contact and emotion. Although these approaches have provided fundamental information to paint a picture of how the brain works, they are carried out when the participant is in isolation, and how single-person experimental conditions really reflect the complex nature of a real person–person interaction is unknown.

Two-brain neuroscience is focussed on understanding the neural basis of real-time, dynamic communication between two people



The human language system includes specialised regions for production (talking) and reception/ comprehension (listening). Intriguingly, these areas are also activated during eye-to-eye contact between two people.

Professor Joy Hirsch is at the forefront of a fascinating social neuroscience revolution, leading ambitious approaches to elucidate how our brains behave in lifelike social circumstances. Remarkably, these methods look at how our brains behave in live communications between two people. Prof Hirsch's ultimate aim is to develop a solid grounding for 'two-brain neuroscience', which is focussed on understanding the neural basis of real-time, dynamic communication between two people.

NEW TOOLS FOR A NEW ERA

A key hurdle is the methodology of studying two brains – what type of approach could allow scientists to deduce neural activity in two people at one time? As it turns out, a groundbreaking approach to social cognition requires the use of groundbreaking technology, known as functional near-infrared spectroscopy (fNIRS).

Professor Hirsch has been involved in developing and refining the use of fNIRS, allowing researchers to test the Interactive Brain Hypothesis in naturalistic settings. fNIRS is grounded in medical physics and relies on the detection of local changes in levels of oxygen and deoxyhaemoglobin in blood indicating underlying neural activity. In a similar vein to fMRI, fNIRS detects changes in blood oxygen as a proxy of brain activity in specific pre-defined areas. However, unlike fMRI, fNIRS does not require isolation in a scanning bore and can tolerate small amounts of head movement. Detectors of the fNIRS signal are head-mounted and the caps can be worn sitting, standing or walking.

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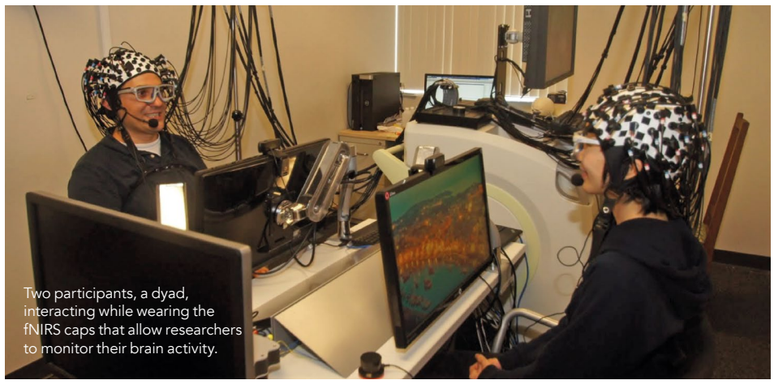

Two participants, a dyad, interacting while wearing the fNIRS caps that allow researchers to monitor their brain activity.

THE INTERACTIVE BRAIN HYPOTHESIS

Prof Hirsch's studies are centred around a new theoretical framework, known as the Interactive Brain Hypothesis. This hypothesis states that interpersonal interactions between people involve brain activity that is not seen during non-interactive, isolated behaviour. At its centre is the understanding that human-to-human interactions evoke unique responses in our brains.

In support of the hypothesis, recent studies taking place in Prof Hirsch's group have shown that pairs of individuals – referred to as 'dyads' – taking part in a poker game show activity in areas traditionally associated with empathy. The same areas are not activated when an individual plays similar games against a computer, highlighting the special nature of real-life interaction between humans. Furthermore, the team have also shown that the real-life eye-to-eye contact between two participants activates different areas of the brain than two people simply focusing on a photograph of a face. Intriguingly, this finding showed that there was unique activation of areas including parts of the brain involved in language, referred to as Broca's and Wernicke's areas. Broca's area – a region of our frontal lobe – is well established as being central to language production, whereas Wernicke's area – a region in the temporal and parietal lobes – is key to comprehension.

Language is perhaps the best characterised and most studied of our social abilities, with areas in the brain well established to be localised for understanding and generating language. The development of language abilities separates us from our closest evolutionary cousins, highlighting its fundamental importance to us as a species. Prof Hirsch's most recent findings in support of the Interactive Brain Hypothesis have illuminated how our brains function during this very human behaviour of talking and listening. In this study, dyads were shown to have increased brain activity when they were taking part in dialogue, as opposed to monologue, specifically in Wernicke's area, which suggests that this region could be involved in interpersonal interaction. Together, the findings from studies so far indicate that human brains do indeed behave in a distinctive way when confronted with another human.

LOOKING TO THE FUTURE

Prof Hirsch's work has taken what is known about social cognition from standard testing and taken it to the next level. The aim of her programme is to advance understanding of social interaction, including cognition and social emotion, gesturing, eye contact and language, in an exhilarating new age of neuroscience research. Two-brain neuroscience promises to get to the heart of our social selves and the essence of what makes us human.

Q&A

What made you first want to study this exciting new field?
I am an academic explorer, and have aggressively pursued the questions of neural systems that underlie interaction between two people because these are our most important functions, little is known about them, and the questions challenge our theoretical frameworks and technology. I am drawn to questions without answers.

In the face of your fNIRS findings, are social neuroscience studies less reflective of how our brains really work than we thought?
fNIRS opens a window of opportunity to investigate the dynamic brain in real-time. Investigations of single-brain organisation and processes using conventional static neuroimaging technology have revolutionised our understanding of basic brain mechanisms. The new neuroscience of two individuals during interaction has the potential to be the next "quantum leap" in social neuroscience. I anticipate that these nascent investigations will lead to new insights into interpersonal conflict, and communications between individuals who are members of different social or economic groups/cultures. We value social diversity and yet know little about how to implement these social policies into action. The new neuroscience of two person interaction has the potential to address this knowledge gap.

Could these new tools help to understand neurological disorders where there might be a problem with communication, for example in autism spectrum disorders?
In addition to our current and on-going studies of typical interpersonal interaction between individuals, we are currently studying social dynamics in autism spectrum disorders, ASD. The hypothesis is that neural specialisations for interpersonal interactions are altered in ASD. Clinical applications for dual-brain fNIRS are an emerging new frontier. Communication problems are common symptoms in many psychiatric disorders such as depression, anxiety, PTSD, delusions, and schizophrenia, and dementia, as well as normal ageing, and may impact neural systems engaged during social interactions. These future directions are made possible by the development of a basic theoretical framework and computational as well technological tools.

Do you think robots will ever be able to provoke the same brain responses as fellow humans?
That would be a great research question.

Detail

RESEARCH OBJECTIVES

Professor Hirsch aims to develop "Two-brain Neuroscience", an exciting extension of the field to understand the neural reactions of two individuals during communication and interpersonal interaction.

FUNDING

NIMH R01 MH107513-01 Hirsch (PI) 7/1/15 – 6/30/20 Title: Mechanisms of Interpersonal Social Communication: Dual-Brain fNIRS Investigation.
NIMH 1R01MH111629-01 Hirsch/ McPartlnd (PI) 9/26/16 – 6/30/21 Title: Neural Mechanisms for Social Interactions and Eye Contact in ASD.
NIH 1R37HD090153-01A1 Hirsch (Sub Contract PI) 9/11/2017-6/30/2023 Title: Tracking neurocognitive changes during evidence-based reading instruction in typically and atypically developing children.

COLLABORATORS

Laboratory faculty: Adam Noah and Xian Zhang; **Laboratory manager:** Ray Cappiello; **Graduate students:** Swetha Dravida, Megan Kelley and Rahil Rogiani; **UCL collaborators:** Ilias Tachtsidis, Paul Burgess, Antonia Hamilton.

BIO

Joy Hirsch is a Professor of Neuroscience at Yale School of Medicine in the Departments of Psychiatry, Neuroscience, and Comparative Medicine where she is the current Director of the Brain Function Laboratory, and Sr. Investigator in the Haskins Laboratories, New Haven, CT USA. She is also Professor of Neuroscience in the Department of Medical Physics and Biomedical Engineering at University College London, London WC1E 6BT, UK.

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