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Chapter 1 | Human Cognition

Cognitive Neuroscience

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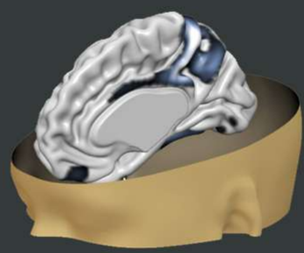

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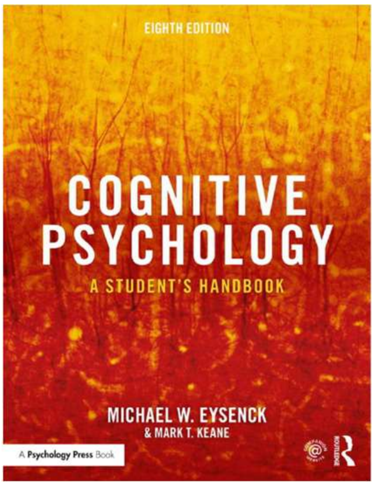
Required textbook



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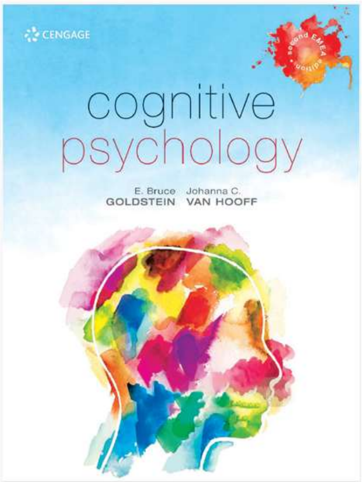
Optional to read




Contents

E. BRUCE GOLDSTEIN is Associate Professor Emeritus of Psychology at the University of Pittsburgh and Adjunct Professor of Psychology at the University of Arizona. He has received the Chancellor's Distinguished Teaching Award from the University of Pittsburgh for his classroom teaching and textbook writing. He received his Bachelor's degree in Chemical Engineering from Tufts University and his PhD in Experimental Psychology from Brown University. He was a postdoctoral fellow in the Biology Department at Harvard University before joining the faculty at the University of Pittsburgh. Bruce published papers on a wide variety of topics, including retinal and cortical physiology, visual attention and the perception of pictures before focusing exclusively on teaching (Sensation & Perception, Cognitive Psychology, Psychology of Art, Introductory Psychology) and writing textbooks. He is the author of *Sensation and Perception*, 10th edition (Cengage, 2017) and edited the *Blackwell Handbook of Perception* (Blackwell, 2001) and the two-volume *Sage Encyclopedia of Perception* (Sage, 2010). In 2016, he won "The Flame Challenge" competition, sponsored by the Alan Alda Center for Communicating Science, for his essay, written for 11-year-olds, on *What Is Sound?*

JOHANNA (HANNIE) C. VAN HOOFF is Lecturer at the Faculty of Science, University of Amsterdam, the Netherlands. She received her Master's degree (Cum Laude) and PhD in Physiological Psychology at Tilburg University. She then moved to the United Kingdom where she taught various cognitive and biological psychology courses at three different universities (Solent University, Portsmouth University and University of Kent at Canterbury) while continuing her research into attention and memory processes. Johanna has published many research papers in internationally renowned journals and she is an expert in the recording and analysis of event-related brain potentials (ERPs). She has been a long-standing member of the Psychophysiology Society and has organized conferences and workshops in that field. In 2009 she moved back to her home country, the Netherlands, where the focus of her work shifted to the development and teaching of courses integrating cognitive and biological sciences.

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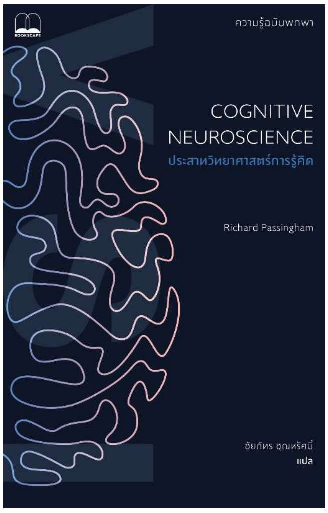
Optional to read

Emeritus Professor
Richard Edward Passingham
Department of Experimental Psychology, University of Oxford

- He graduated with a degree in Psychology and Philosophy. He then trained in clinical psychology in London before pursuing a PhD in **cognitive neuroscience**.
- His research has been on the *mechanisms* of *decision-making* and *motor learning* in the *brain*.

Assoc. Prof. Dr.Chaipat Chunharas, MD, Ph.D.

- Neurologist, King Chulalongkorn Memorial Hospital
- He received his internal medicine training from KKU, neurology training from CU, and later went to pursue his Ph.D. in **experimental psychology** at UCSD.



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Why is it essential for us to learn cognitive psychology?

Psychology:
\+ to gain insight into the human *mind* and *behavior*.

Cognition:
the mental processes are forms of thinking, including attention, perception, learning, memory, language, problem-solving, and decision-making.

= **to understand how the mind works**

This knowledge will serve as a bridge to applied psychology: clinical psychology, educational psychology, neuropsychology, human–computer/machine/AI interaction.

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Do you agree with the quote?

"By changing our inner world, we can transform our external circumstances and the world around us."

Adapted from Gandhi's Philosophy

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Do you agree with the quote?

"Easing mental strength through <u>LLMs</u> can lead to a reduced ability to *recall*, *think critically*, or build *lasting knowledge*."

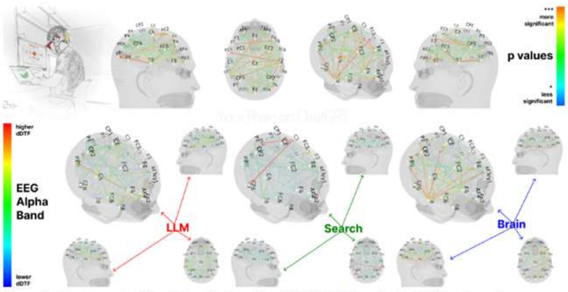

Figure 1. The dynamic Direct Transfer Function (dDTF) EEG analysis of Alpha Band for groups: LLM, Search Engine, Brain-only, including p-values to show significance from moderately significant (*) to highly significant (***).

- 32 electrodes of the EEG were used to assess cognitive load during essay writing. Frequency bands were analyzed.
- EEG revealed significant differences in alpha band connectivity, especially in the connection from left parietal (P7) to right temporal (T8) regions.
- Alpha band connectivity is often associated with internal attention and semantic processing during creative ideation.

Kosmyna, N., Hauptmann, E., Yuan, Y. T., Situ, J., Liao, X. H., Beresnitzky, A. V., ... & Maes, P. (2025). https://doi.org/10.48550/arXiv.2506.08872

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Why should we learn cognitive neuroscience?

Essential questions

- What is Neuroscience and Cognitive Neuroscience**?**
- What is the difference between Mind and Brain**?**
- How can we study how the mind works**?**
- Can we study cognition without the brain**?**
- How is information transmitted from one place to another in the nervous system**?**
- What does studying the brain tell us about cognition**?**

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Cognitive Neuroscience

Neuroscience

- Neuroscience is the study of the nervous system concerning its structure and function.
- This includes the brain, spinal cord, and networks of nerve cells, or neurons, throughout the body.

Cognitive neuroscience involves the intensive study of brain activity, which has shown what is happening in the brain during **cognition**, as well as behavior.

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Mind and Brain

Brain

- The physiological organ that is inside the skull.
- Regulates body functions, processes sensory input, controls movement, and supports cognition, emotions, and consciousness.

Mind

- A set of functions and processes, including perceiving, remembering, imagining, deciding, and feeling.

<u>Mental</u>

- An adjective referring to the operations, states, or phenomena of the mind.

Example: A stroke affects the brain by interrupting the flow of oxygen-rich blood, causing brain cells to die within minutes. This cell death results in **the loss of function** controlled by the damaged area of the brain, leading to varied effects such as paralysis, speech difficulties, **cognitive** <u>impairments</u>, **memory** <u>problems</u>, or **emotional** <u>uncertainties</u>.

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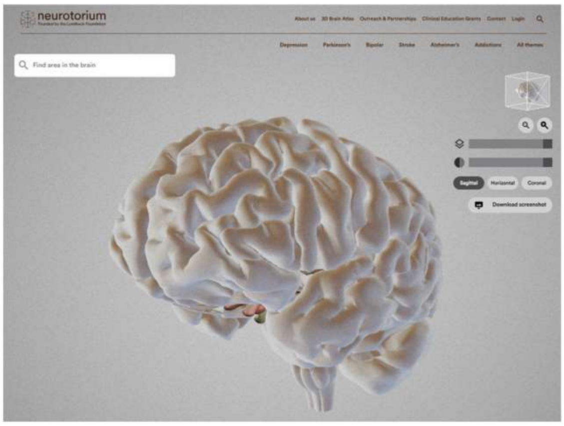
Brain terminology



https://neurotorium.org/tool/brain-atlas/

Major Divisions of the Brain
- Forebrain – includes cerebral cortex, thalamus, hypothalamus, basal ganglia, limbic system
- Midbrain – includes tectum, tegmentum
- Hindbrain – includes cerebellum, pons, medulla

Cerebral Cortex Lobes
- Frontal lobe
- Parietal lobe
- Temporal lobe
- Occipital lobe

Gyri & Sulci (examples)
- Precentral gyrus
- Postcentral gyrus
- Central sulcus
- Lateral sulcus

Functional Areas
- Broca's area
- Wernicke's area
- Primary motor cortex
- Primary somatosensory cortex
- Primary auditory cortex
- Primary visual cortex

Other Key
- Gray matter vs. white matter
- Corpus callosum
- Ventricles & cerebrospinal fluid (CSF)
- Neurons & glia
- Connectome

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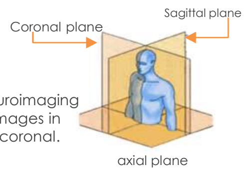
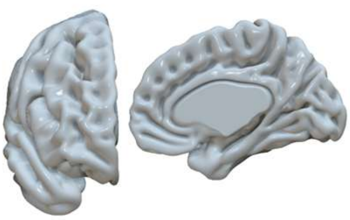
Brain terminology

*The advantage of volume acquisition in neuroimaging (e.g., MRI) is that it allows reconstruction of images in three orthogonal planes: axial, sagittal, and coronal.



Sagittal plane



Anterior view   Left view

*Right hemisphere

Horizontal/Axial plane

Left view   Anterior view

Frontal/Coronal plane

Left view   Anterior view

General Orientation
- Anterior (rostral) – front vs. Posterior (caudal) – back
- Dorsal (superior) – top vs. Ventral (inferior) – bottom
- Medial – toward the midline
- Lateral – toward the side

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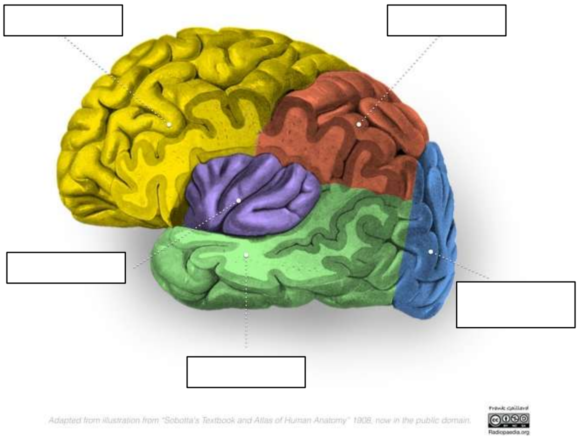
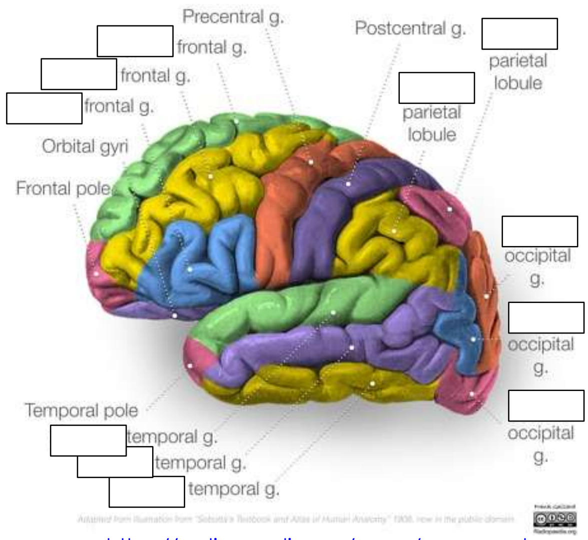
Brain terminology





https://radiopaedia.org/cases/neuroanatomy-lateral-cortex-illustrations

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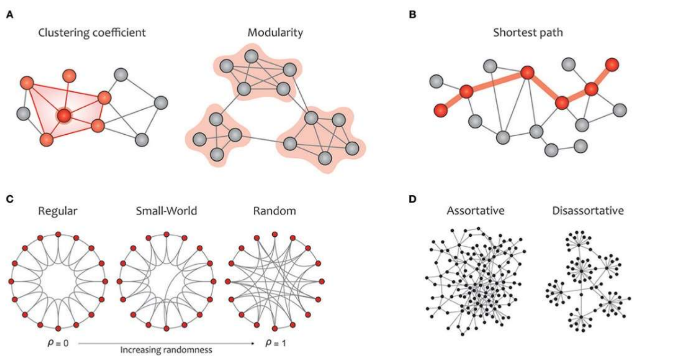
Brain organization
Connectome

A **connectome** is a **graph** that provides a map of the brain's neural **connections**.

Principles
- Cost control - use of energy and space, the cost would be minimized if the brain consisted of limited, short-distance connections
- Efficiency - the ability to integrate information across the brain



- **Average Path Length**: Affects the efficiency of information flow across the entire network. A shorter average path length ensures that information can travel quickly between any two nodes in the network, promoting global efficiency in communication and resource exchange.
- **Clustering Coefficient** (Transitivity): Affects the local cohesiveness or grouping within the network. It reflects how likely it is that two nodes connected to a common node are also directly connected to each other. A high clustering coefficient contributes to enhanced local connectivity and information sharing among closely related nodes.
- Measuring both together, we call "**small-world networks**"

Farahani, F. V., Karwowski, W., & Lighthall, N. R. (2019). Application of graph theory for identifying connectivity patterns in human brain networks: a systematic review. frontiers in Neuroscience, 13, 585.

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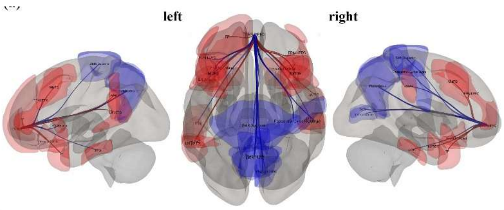
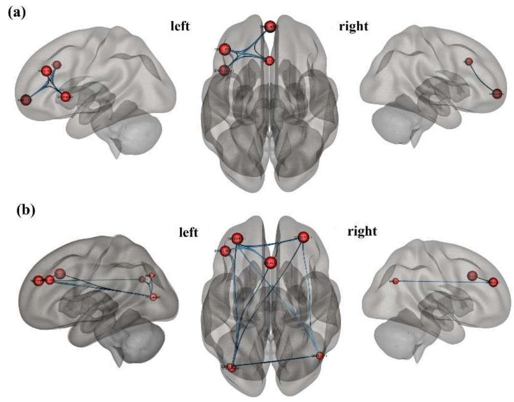
Brain organization
Connectome

Brain networks
- The frontoparietal network (FPN)
- The default mode network (DMN)
- The salience network (SN)
- The dorsal attention network (DAN)
- The visual network (VN)
- The auditory network (AN)
- The sensorimotor network (SMN)





The brain network from graph-based analysis, providing a 3D representation of the brain's connectivity concerning narcissistic traits (a) and antisocial traits (b). It's linking the triple network (DMN, SN, FPN) to personality traits and suggests both shared and distinct neural mechanisms for narcissism and antisociality.

Jornkokgoud, K., Bakiaj, R., Wongupparaj, P., Job, R., & Grecucci, A. (2025). Narcissistic and Antisocial Personality Traits are both encoded in the Triple Network: Connectomics evidence. *Psychophysiology*, 62(8), e70130. https://doi.org/10.1111/psyp.70130

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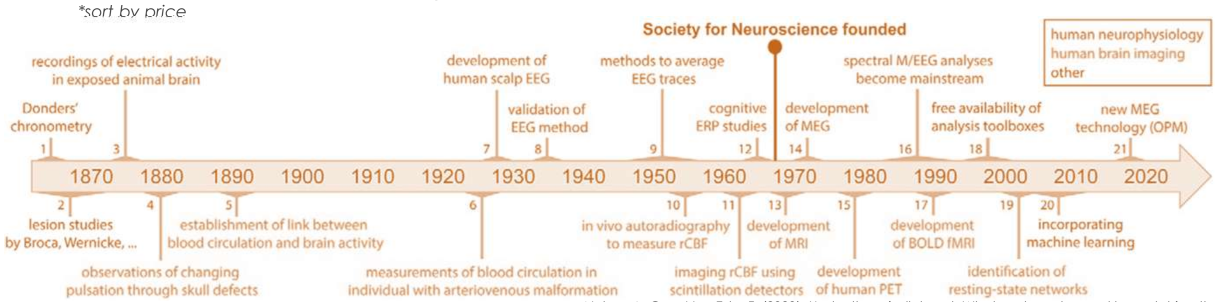
Methods
in cognitive neuroscience

- **EEG** - Electroencephalography
- **fNIRS** - Functional near-infrared spectroscopy
- **MEG** - Magnetoencephalographic
- **MRI** - Magnetic Resonance Imaging
- **fMRI** - Functional MRI
- **PET** - Positron Emission Tomography

*sort by price

- **EEG** - brain's electrical signals
- **fNIRS** - brain blood oxygen changes
- **MEG** - brain's magnetic signals
- **MRI** - brain structure images
- **fMRI** - brain activity via blood flow
- **PET** - brain metabolism with tracer



Nobre, A. C., & Van Ede, F. (2020). Under the mind's hood: What we have learned by watching the brain at work. *Journal of Neuroscience*, 40(1), 89-100.

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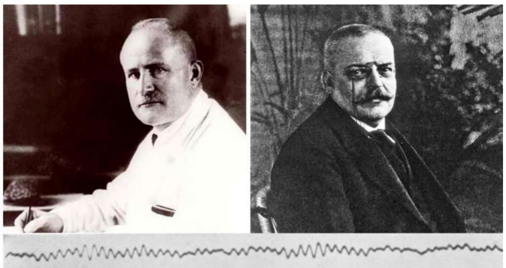
Methods

Electroencephalography


Über das Elektrenkephalogramm des Menschen.



An EEG (top) activity recorded from the scalp of Berger's *son*, Klaus (15 years old). It is the first scalp-recorded EEG activity published by Berger in a scientific paper. This EEG activity was recorded while Klaus was in a resting-state condition with eyes closed.

One year later, he named it "alpha waves"

Hans Berger (1873–1941; left side), a Professor of Psychiatry at the University of Jena, Germany, and Director of its psychiatry clinic, pursued a visionary goal in the early 1900s: to uncover the relationship between mental disorders and abnormal brain activity, detectable through heat and electrical currents. This ambition led to his groundbreaking discovery in 1924, when he recorded and described human brain electrical activity, coining the term "electroencephalogram (EEG)."

The German Psychiatrist and Neuropathologist **Alois Alzheimer** (1864–1915) is portrayed at the right side. Alzheimer's was a colleague of the famous German Psychiatrist Emil Kraepelin. Alzheimer published the first case of "presenile dementia," after named Alzheimer's disease.

- Berger H. Uber das electrenkephalogrammdes menschen. *Arch Psychiatr Nervenkr.* 1929;82:527–570.
- Babiloni, C., Arakaki, X., Baez, S., Barry, R. J., Benussi, A., Blinowska, K., ... & Kamondi, A. (2025). Alpha rhythm and Alzheimer's disease: Has Hans Berger's dream come true?. Clinical Neurophysiology.

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Methods

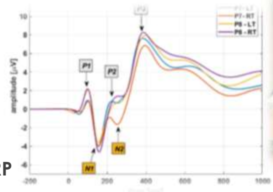
in cognitive neuroscience

The figure shows the choice reaction time experiment, related to Cognitive Psychology

Cognitive psychologists design experiments to test hypotheses about mental operations by manipulating what goes into the brain (Stimuli, ex, **X** in a different position as a target and **O** may come) and then observing the resulting behavior (Reaction Time and Accuracy).

Cognitive Constructs
- Perceptual encoding speed (stimulus recognition)
- Decision-making time (response selection)
- Response execution time (motor output)
- Cognitive control (when tasks manipulate congruency or conflict)

Jornkokgoud, K. (2025). Development of Computerized Multicomponent Cognitive Stimulation for Improving Cognitive Functions in Older Adults with Mild Cognitive Impairment: A Multimodal Investigation Using Neuropsychological and EEG/ERP Assessment. https://hdl.handle.net/11572/449932



EEG / ERP
ERPs:
- P100 / N100: *perceptual encoding* of stimuli
- N200: *conflict* detection or *inhibition*
- P300: decision-making, working memory updating
- Lateralized Readiness Potential (LRP): motor preparation before pressing a key

Time–frequency (oscillations):
- Theta: conflict monitoring, attentional control
- Alpha suppression: selective attention
- Beta: motor preparation and execution

fMRI Measures
- Activation patterns in which brain regions are engaged (e.g., prefrontal cortex, parietal cortex, motor cortex).
- Functional connectivity: how brain networks (e.g., fronto-parietal) cooperate during stimulus–decision–response.

MEG and fNIRS
- Provide complementary information on temporal resolution (when processes occur) and spatial resolution (where in the brain processes occur).

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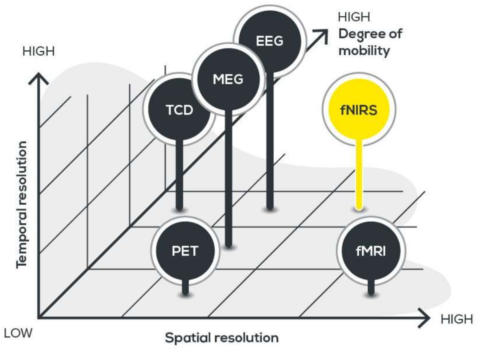
Methods
in cognitive neuroscience



Source: https://www.artinis.com/blogpost-all/comparison-fnirs-vs-fmri

Temporal resolution measures how frequently data is collected or how quickly changes over time can be observed, while **spatial resolution** measures the smallest feature that can be distinguished in a given area.

- **EEG** - brain's electrical signals
- **fNIRS** - brain blood oxygen changes
- **MEG** - brain's magnetic signals
- **fMRI** - brain activity via blood flow
- **PET** - brain metabolism with tracer

* Transcranial Doppler (TCD) is a noninvasive tool for measuring cerebrovascular hemodynamics.

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Educational Neuroscience

Table 1. A summary of the selected studies.

Authors	Design	Intervention/Intervening factor	Target	Neuroimaging measure
Takeuchi et al., 2019	Randomized with control and test group (N = 14)	Teacher gives hints via a tablet screen to facilitate solving of a puzzle task by student	Metacognition	fNIRS
Aar et al., 2019	Non-randomized study with control and test group (N= 84)	*Gap-Year* program: a personal development program for adolescents who have dropped out of higher education or stay undecided after high school.	Educational decision-making, self-esteem and self-concept clarity	MRI
Antonenko et al., 2019	Non-randomized study with two test groups (N= 140)	Cyber-enabled collaborative problem-solving via two types of scripts	Collaborative problem solving	EEG
Nenciovici et al., 2018	Non-randomized study with two test groups (N= 43)	Error correction	Error correction of scientific concepts	fMRI
Nissim et al., 2018	Randomized study two test groups and a control group (N = 24)	Aquatic motor activity training vs. on land motor activity training	Verbal working memory	MEG
Rominger et al., 2017	Non-randomized study with control and test group (N = 45)	*Subjective Relevance*: a reflection competence training program	Reflection ability	EEG
Lee et al., 2015	Single group design (N = 20)	Two form of instructions for solving mathematical problems: examples versus verbal directions	Difference in mathematical learning outcomes	fMRI

Table 1. A summary of the selected studies.

Authors	Design	Intervention/Intervening factor	Target	Neuroimaging measure
Taillan et al., 2015	Single group design (N = 22)	Two types of problems: homogeneous and heterogeneous problems	Mathematical problem solving	EEG
Daly et al., 2019	Single group design (N = 23)	Two types of problems: Mindset theory-problems vs standard problems	Motivation	EEG
Pietto et al., 2018	Randomized study with control and test group (N = 44)	Computerized, game-based cognitive training	Inhibitory control	EEG
Ludyga et al., 2018	Randomized study with control and test group (N = 36)	A daily, short combined aerobic and coordinative exercise session	Inhibitory control	EEG
Rosenberg-Lee et al., 2018	Non-randomized study with control and test group (N = 34)	Training program focused on improving arithmetic skills	Brain function associated with mathematical skills	fMRI
Sanger & Dorjee, 2016	Non-randomized study with control and test group (N = 40)	School-based mindfulness program	Attention processing	EEG
Horowitz-Kraus, 2015	Non-randomized study with two test groups (N = 54)	*Reading Acceleration Program*: a reading fluency program that improves word-decoding accuracy and reading comprehension	Reading speed and executive functioning in the linguistic domain	EEG
Karlsson Wirebring et al., 2015	Non-randomized study with two test groups (N = 73)	Pupils are asked to create a solution method to a mathematical problem themselves, rather than being presented with a solution	Mathematical problem solving performance	fMRI
Neville et al., 2013; Giuliano et al., 2018	Randomized study with two test groups and a control group (N = 141)	*Parents and Children Making Connections*: a family-based training program for lower socioeconomic status preschoolers	Selective attention, different standardized measures of cognition	EEG

Corrado Matta (2021) Neuroscience and educational practice – A critical Assessment from the perspective of philosophy of science, *Educational Philosophy and Theory*, 53:2, 197-211, https://doi.org/10.1080/00131857.2020.1773801

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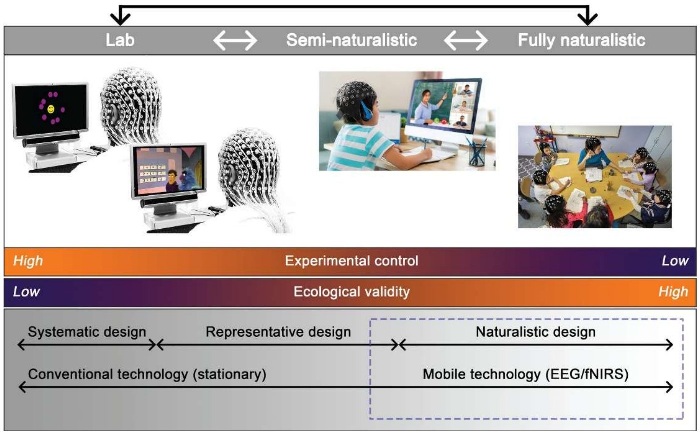
From clinical to educational settings
EEG and fNIRS
From lab to nature

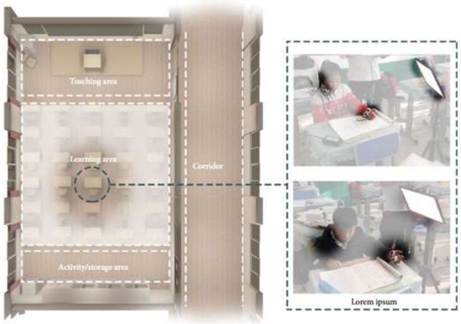


- Janssen, T. W., Grammer, J. K., Bleichner, M. G., Bulgarelli, C., Davidesco, I., Dikker, S., ... & van Atteveldt, N. (2021). Opportunities and limitations of mobile neuroimaging technologies in educational neuroscience. Mind, Brain, and Education, 15(4), 354-370.

Effects of the Light Environment in Elementary School Classrooms on Students' Cognitive Performance

TABLE 1: Space environment research based on physiological signals.

Ref.	Factor	Participants	Age Range	Age Mean	Age SD	Task	Results
[37]	Illuminance, CCT	10M; 10F	30–40	35.4	2.71	Study the effects of color temperature and illuminance combinations on EEG in different office spaces	The AP of β increased significantly with increasing illumination
[38]	Space	24M; 20F	28–35	31.2	1.30	Measure the EEG responses of users when they experience changes in building elements	Channels F4 (right frontal lobe) and P3 (left parietal lobe) showed multiple significant differences in the RAB indicators



- Gao, B., Fu, Y., Gao, J., Liu, H., & Gao, W. (2025). Effects of the Light Environment in Elementary School Classrooms on Students' Cognitive Performance and Galvanic Skin Indicators. Indoor Air, 2025(1), 3122870.

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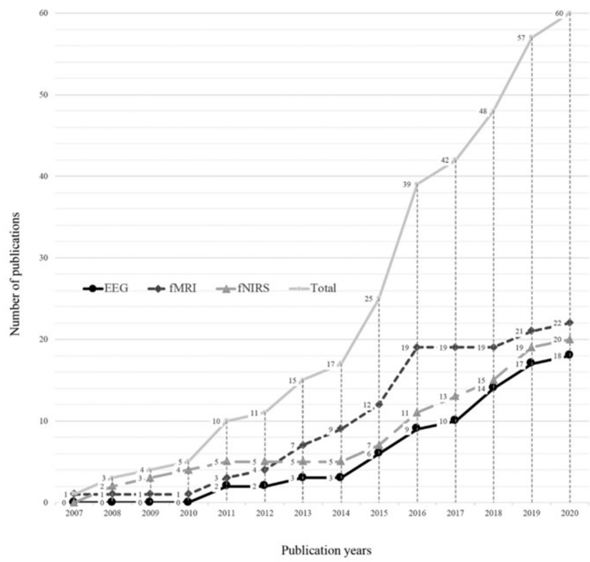
Functional near-infrared spectroscopy
(fNIRS) use in medical education

The use of functional neuroimaging techniques to measure *learning*, neurocognitive *engagement*, or *expertise development* is an emerging research method in health professions *education*.



Toy, S., Huh, D. D., Materi, J., Nanavati, J., & Schwengel, D. A. (2022). Use of neuroimaging to measure neurocognitive engagement in health professions education: a scoping review. Medical education online, 27(1), 2016357.

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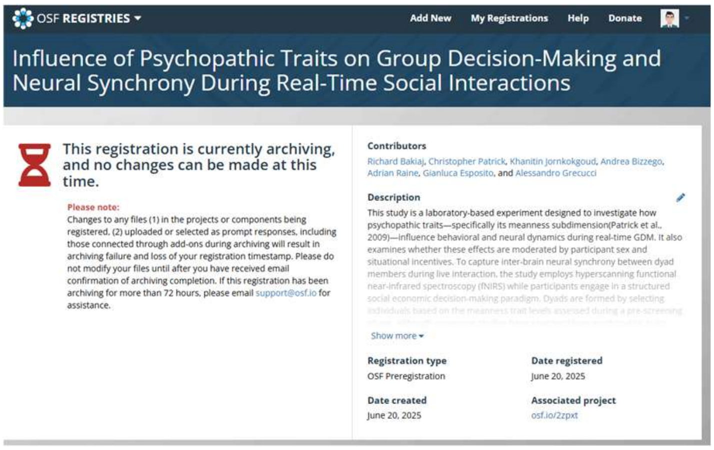
Influence of Psychopathic Traits on Group Decision-Making and Neural Synchrony During Real-Time Social Interactions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Influence of Psychopathic Traits on Group Decision-Making and Neural Synchrony During Real-Time Social Interactions

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Changes to any files (1) in the projects or components being registered, (2) uploaded or selected as prompt responses, including those connected through add-ons during archiving will result in archiving failure and loss of your registration timestamp. Please do not modify your files until after you have received email confirmation of archiving completion. If this registration has been archiving for more than 72 hours, please email support@osf.io for assistance.

Contributors
Richard Bakiaj, Christopher Patrick, Khanitin Jornkokgoud, Andrea Bizzego, Adrian Raine, Gianluca Esposito, and Alessandro Grecucci

Description
This study is a laboratory-based experiment designed to investigate how psychopathic traits—specifically its meanness subdimension(Patrick et al., 2009)—influence behavioral and neural dynamics during real-time GDM. It also examines whether these effects are moderated by participant sex and situational incentives. To capture inter-brain neural synchrony between dyad members during live interaction, the study employs hyperscanning functional near-infrared spectroscopy (fNIRS) while participants engage in a structured social economic decision-making paradigm. Dyads are formed by selecting individuals based on the meanness trait levels assessed during a pre-screening

Show more ▾

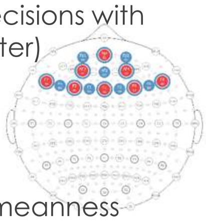
Registration type
OSF Preregistration

Date registered
June 20, 2025

Date created
June 20, 2025

Associated project
osf.io/2zpxt

- fNIRS hyper-scanning will be utilized.
- We will record prefrontal activity while each pair makes joint cooperation versus non-cooperation decisions with a third participant (computer)



- We hypothesize that high meanness dyads will exhibit lower cooperation rates and a distinct pattern of inter-brain synchrony compared to low meanness dyads.

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You can now answer
The question of why we should learn cognitive neuroscience.

- Understanding the Brain–Mind relationship and how mental processes.
- Advancing psychology and clinical Practice
- Clinicians and educators to design interventions grounded in brain science
- Driving Innovation in Education

What's next?

- Chapter 1 | Human Cognition
  Computational Cognitive Science

Thank you for your attention.

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