

In the format provided by the authors and unedited.

Opportunities and challenges for a maturing science of consciousness

Matthias Michel^{1*}, Diane Beck², Ned Block³, Hal Blumenfeld⁴, Richard Brown⁵, David Carmel⁶, Marisa Carrasco⁷, Mazviita Chirimuuta⁸, Marvin Chun⁹, Axel Cleeremans¹⁰, Stanislas Dehaene^{11,12}, Stephen M. Fleming^{13*}, Chris Frith¹³, Patrick Haggard¹⁴, Biyu J. He¹⁵, Cecilia Heyes¹⁶, Melvyn A. Goodale¹⁷, Liz Irvine¹⁸, Mitsuo Kawato¹⁹, Robert Kentridge²⁰, Jean-Remi King^{21,22}, Robert T. Knight²³, Sid Kouider²⁴, Victor Lamme²⁵, Dominique Lamy²⁶, Hakwan Lau^{27,28,29*}, Steven Laureys³⁰, Joseph LeDoux³¹, Ying-Tung Lin³², Kayuet Liu³³, Stephen L. Macknik³⁴, Susana Martinez-Conde³⁴, George A. Mashour³⁵, Lucia Melloni³⁶, Lisa Miracchi³⁷, Myrto Mylopoulos³⁸, Lionel Naccache³⁹, Adrian M. Owen⁴⁰, Richard E. Passingham⁴¹, Luiz Pessoa⁴², Megan A. K. Peters⁴³, Dobromir Rahnev⁴⁴, Tony Ro⁴⁵, David Rosenthal⁴⁶, Yuka Sasaki⁴⁷, Claire Sergent⁴⁸, Guillermo Solovey⁴⁹, Nicholas D. Schiff⁵⁰, Anil Seth⁵¹, Catherine Tallon-Baudry⁵², Marco Tamietto^{53,54}, Frank Tong⁵⁵, Simon van Gaal⁵⁶, Alexandra Vlassova⁵⁷, Takeo Watanabe⁵⁸, Josh Weisberg⁵⁹, Karen Yan⁶⁰ and Masatoshi Yoshida⁶¹

¹Department of Philosophy, Sorbonne Université, Paris, France. ²Department of Psychology and Beckman Institute, University of Illinois at Urbana-Champaign, Champaign, Illinois, USA. ³Department of Philosophy, New York University, New York, New York, USA. ⁴Department of Neurology, Yale University School of Medicine, New Haven, Connecticut, USA. ⁵Philosophy Program, LaGuardia Community College, The City University of New York, Long Island City, New York, USA. ⁶School of Psychology, Victoria University of Wellington, Wellington, New Zealand. ⁷Department of Psychology and Center for Neural Science, New York University, New York, New York, USA. ⁸Department of History and Philosophy of Science, University of Pittsburgh, Pittsburgh, Pennsylvania, USA. ⁹Department of Psychology, Yale University, New Haven, Connecticut, USA. ¹⁰Center for Cognition & Neurosciences, Université libre de Bruxelles, Bruxelles, Belgium. ¹¹Chair of Experimental Cognitive Psychology, Collège de France, Paris, France. ¹²Cognitive Neuroimaging Unit, Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA), INSERM, Université Paris-Sud, Université Paris-Saclay, NeuroSpin center, Gif/Yvette, France. ¹³Wellcome Centre for Human Neuroimaging, University College London, London, UK. ¹⁴Institute of Cognitive Neuroscience, University College London, London, UK. ¹⁵Neuroscience Institute, New York University Langone Medical Center, New York, New York, USA. ¹⁶All Souls College and Department of Experimental Psychology, University of Oxford, Oxford, UK. ¹⁷The Brain and Mind Institute, The University of Western Ontario, London, ON, Canada. ¹⁸School of Philosophy, Cardiff University, Cardiff, UK. ¹⁹Department of Decoded Neurofeedback, Computational Neuroscience Laboratories, Advanced Telecommunications Research Institute International, Kyoto, Japan. ²⁰Department of Psychology, University of Durham, Durham, UK. ²¹Department of Psychology, New York University, New York, New York, United States. ²²Frankfurt Institute for Advanced Studies, Frankfurt, Germany. ²³Helen Wills Neuroscience Institute, University of California, Berkeley, USA. ²⁴Brain and Consciousness group (ENS, EHESS, CNRS), Département d'Études Cognitives, École Normale Supérieure - PSL Research University, Paris, France. ²⁵Amsterdam Brain and Cognition, Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands. ²⁶School of Psychological Sciences, Tel Aviv University, Tel Aviv, Israel. ²⁷Department of Psychology and Brain Research Institute, UCLA, Los Angeles, USA. ²⁸Department of Psychology, University of Hong Kong, Hong Kong, China. ²⁹State Key Laboratory of Brain and Cognitive Sciences, HKU, Hong Kong, China. ³⁰Coma Science Group, GIGA Consciousness, University of Liège, Liège, Belgium. ³¹Center for Neural Science, New York University, New York, New York, USA. ³²Institute of Philosophy of Mind and Cognition, National Yang-Ming University, Taipei, Taiwan. ³³Department of Sociology, UCLA, Los Angeles, California, USA. ³⁴State University of New York, Downstate Medical Center, Brooklyn, New York, USA. ³⁵Center for Consciousness Science, Department of Anesthesiology, University of Michigan, Ann Arbor, Michigan, USA. ³⁶Department of Neurology, NYU School of Medicine, New York, New York, USA. ³⁷Department of Philosophy, University of Pennsylvania, Philadelphia, Pennsylvania, USA. ³⁸Department of Philosophy and Institute of Cognitive Science, Carleton University, Ottawa, Ontario, Canada. ³⁹PICNIC Lab ICM INSERM, U1127 Paris, France. ⁴⁰The Brain & Mind Institute, Western University, London, Ontario, Canada. ⁴¹Department of Experimental Psychology, University of Oxford, Oxford, UK. ⁴²Department of Psychology, University of Maryland, College Park, Maryland, USA. ⁴³Department of Bioengineering, University of California, Riverside, California, USA. ⁴⁴School of Psychology, Georgia Institute of Technology, Atlanta, Georgia, USA. ⁴⁵Psychology and Biology, Graduate Center, City University of New York, New York, New York, USA. ⁴⁶Philosophy and Cognitive Science, Graduate Center, City University of New York, New York, New York, USA. ⁴⁷Department of Cognitive, Linguistic and Psychological Sciences, Brown University, Providence, Rhode Island, USA. ⁴⁸Laboratoire Psychologie de la Perception, Université Paris Descartes, CNRS, Paris, France. ⁴⁹Instituto de Cálculo, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Buenos Aires, Argentina. ⁵⁰Department of Neurology, Weill Cornell Medicine, New York, New York, USA. ⁵¹Sackler Centre for Consciousness Science, University of Sussex, Brighton, UK. ⁵²Cognitive Neuroscience Laboratory, INSERM, École Normale Supérieure - PSL Research University, Paris, France. ⁵³Department of Medical and Clinical Psychology, Tilburg University, Tilburg, The Netherlands. ⁵⁴Department of Psychology, University of Torino, Torino, Italy. ⁵⁵Psychology Department, Vanderbilt University, Nashville, Tennessee, USA. ⁵⁶Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands. ⁵⁷Donders Institute for Brain, Cognition, and Behaviour, Radboud University Nijmegen, Nijmegen, The Netherlands. ⁵⁸Department of Cognitive, Linguistic and Psychological Sciences, Brown University, Providence, Rhode Island, USA. ⁵⁹Department of Philosophy, University of Houston, Houston, Texas, USA. ⁶⁰Institute of Philosophy of Mind and Cognition, National Yang-Ming University, Taipei, Taiwan. ⁶¹Department of System Neuroscience, National Institute for Physiological Sciences, Okazaki, Japan. *e-mail: matthias.michel.curtin@gmail.com; stephen.fleming@ucl.ac.uk; hakwan@gmail.com

Supplementary Notes

Opportunities and Challenges for a Maturing Science of Consciousness

Supplementary Note 1: Data on the RDoC: <https://www.nimh.nih.gov/research-priorities/rdoc/index.shtml>

Supplementary Note 2: Using <http://psychjobsearch.wikidot.com>, since 2007, many job ads mention “neuroeconomics” or “social neuroscience”, but there is no single job ad mentioning “consciousness” or “awareness”. For more about the job markets in neuroeconomics: <https://neuroeconomics.org/career/> and social neuroscience: <http://www.sciencemag.org/careers/2010/05/peering-inside-social-brain>

Supplementary Note 3: Projects funded by the European Research Council: <https://erc.europa.eu/projects-figures/erc-funded-projects>. Between 2007 and 2017, 22 grants on a total of 8,962 grants have been awarded to projects related to consciousness (including 2 projects on the sense of agency) by the ERC. In total, 0.25% of ERC grants are attributed to the study of consciousness. These grants were awarded for projects related to the contents of consciousness rather than states of consciousness.

Supplementary Note 4: See NIH Research Portfolio Online Reporting Tools (RePORT): <https://projectreporter.nih.gov/reporter.cfm> and NSF Award Search: <https://www.nsf.gov/awardsearch/>. Based on data from the NIH RePORT, between 2007 and 2017, only 5 grants have been awarded for studying subjects related to contents of consciousness. Over the same period, the NIH has provided 103,280 grants. In total, 0.016% of NIH grants are attributed to the study of consciousness (i.e., states of consciousness or contents of consciousness).

Supplementary Note 5: Data can be found here: <https://projectreporter.nih.gov/reporter.cfm>. Between 2007 and 2017, 12 NIH grants have been attributed to study states of consciousness such as consciousness in epilepsy, recovery of consciousness after traumatic brain injury, consciousness and anesthesia, and various disorders of consciousness.