

Tushar Chauhan (Curriculum Vitae)

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Research Interests

Biological computation, Spiking neural networks, Neural plasticity, Spike-timing dependent plasticity, Colour vision, Spectral colour, Binocular vision, Evolution of vision, Emergence phenomena, Biology-inspired robotics.

Current position

Postdoctoral Research Fellow at Centre de Recherche Cerveau et Cognition (CerCo), Centre National de la Recherche Scientifique (CNRS), Toulouse, France.

Education

- 01/05/2012 – 28/11/2016** **PhD in Experimental Psychology (Colour Vision)**
 Department of Experimental Psychology, University of Liverpool
 “Modelling Colour Appearance: Applications in Skin Image Perception”
 Primary supervisor: Prof. Sophie Wuerger
- 01/09/2009 – 07/09/2011** **Masters in Computer Science (Spectral and computational colour science)**
 Joint degree: School of Computing, University of Eastern Finland and
 Department of Informatics and Communication, Université Jean Monnet
- 01/08/2004 – 25/07/2008** **Bachelors (Major – Electrical Engineering, Minor – Physics)**
 Indian Institute of Technology, Madras

Professional Experience

- 01/04/2016 - Present** **Post-doctoral fellow**
 Centre de Recherche Cerveau et Cognition (CerCo), Centre National de la Recherche Scientifique (CNRS), Toulouse, France.
- Development of deep spiking neural networks (dSNNs) which extend typical convolutional frameworks to spiking architectures. The models will be used to investigate the links between natural statistics and motion processing in the early visual cortex. dSNNs are extremely efficient and can be implemented on neuromorphic hardware – thus allowing for real-time processing of spiking inputs.
 - Modelling the ELa-ELp (anterior and posterior extero-lateral nuclei) circuits in pulse-type, electric mormyrid fish. It is known that ELa encodes precise pulse-code representations of discharges from neighbouring fish, and ELp shows precise temporal filtering of ELa inputs across varying time-scales. The SNN model will try to explain this through interactions between inhibitory and excitatory populations in the ELp, with short-term plasticity at the synapses carrying ELa input, and longer-term, spike-timing dependent plasticity (STDP) within ELp.
 - Effect of photoreceptor decay on the plasticity in early visual areas of Age-related Macular Degeneration (AMD) patients. A multi-disciplinary approach is being adopted. 1. A retinotopic spike-timing dependent plasticity (STDP) network is

used to model neuronal plasticity in a topographically connected system of neurones. The model is being used to simulate photoreceptor decay and related cortical changes. 2. The model predictions will be compared to fMRI recordings in AMD patients and healthy controls (tested using artificial scotomas).

- The sub-optimality of the early visual system explained through biological plasticity. This study investigates how normative explanations of the receptive-fields found in the early visual system differ from process-based explanations (in particular, a model using STDP spiking networks). Our results show that the non-generative local nature of biological rules such as STDP explain the so-called sub-optimality found in V1 receptive fields. We also show that neural ensembles of STDP neurones, while sub-optimal (in terms of Fisher information), can mimic human-like performance in orientation discrimination tasks.
- Decoding of unique-hues from Electroencephalography (EEG) recordings. A novel approach using time-series Error-correcting output-code (ECOC) models was developed to decode Event-related potentials (ERPs). It was shown that 1. Unique hues can be decoded from ERPs between 90-300ms 2. Addition of luminance-contrast severely disrupts classification performance. This is one of the first analyses showing robust neural correlates of unique hues.
- Use of STDP based neural networks to model the emergence of binocular disparity selective units through Hebbian learning. In addition to developing and programming the model, the project also involved single-cell and population characterisation of the converged (simulated) neural populations. The activity of the network was decoded through pseudo-LDA classifiers.

01/05/2012 – 28/11/2016 Doctoral candidate

School of Psychology, University of Liverpool, Liverpool, UK

- Estimation of discrimination thresholds for skin, skin-like textures, and uniform colours in 3-D colour space. The project involved work in psychophysical measurements in colour-controlled conditions, and subsequent modelling of the discrimination boundaries through ellipsoidal discrimination surfaces. The findings challenge the hypothesis that subtle skin-tone changes played a key evolutionary role in human colour vision. The results from the study were later applied to: 1. Calibrate a 3-D printing system for skin prostheses and 2. Develop a quasi-uniform colour difference metric optimised for the description of skin images.
- Modelling of chromatic adaptation in unique hues. Possible mechanisms and sites of chromatic adaptation were tested by employing Procrustes analysis to optimise diagonal, linear and affine models on a large set of Unique Hue settings. The results suggest simple von Kries-like transforms in a second-order colour space as the possible origin of the adaptation.
- Estimation of achromatic settings under various illumination conditions and stimulus brightness. Psychophysical measurements of 'neutral grey', an achromatic percept devoid of any hue, were made. A novel method of navigating colour space using unique-hues was proposed.
- Investigation of the Common Rate Controller (CRC). The CRC hypothesis was tested in the context of non-cartesian feature spaces – in particular, colour and

number spaces. Our results suggest that updates of mental representations in various feature spaces may share a common ‘clock’.

01/01/2015 – 28/11/2016 Research Assistant

St. Paul’s Eye Clinic, Royal Liverpool Hospital, Liverpool, UK

- Research assistant in a study evaluating OLED therapy in patients with diabetic macular oedema. Duties included administering colour vision and psychomotor vigilance tests, in addition to sleep and mental health assessment using questionnaires.

01/05/2012 – 31/12/2014 Researcher Engineer

TruColour Ltd., Liverpool, UK

- Development and optimisation of a novel display calibration technique based on human colour perception mechanisms. This involved computational simulations, algorithm development, and subsequent preparation of demonstrations for potential industrial investors.

Supervising and Mentoring activities

CerCo, CNRS, Toulouse, France.

- 2019-Present** Co-supervision of a doctoral student (only a sub-project of their thesis) at the University of Zaragoza. The project focusses on the use of abstract, rank-based STDP networks to detect scene labels using multiple frequency bands. The overarching aim is to interface these networks with neural prosthetics such as artificial retinæ.
- 2018-2019** Supervision of final master’s dissertation project. The project focussed on writing a fast, cython-based interface to process inputs from spiking cameras using event-based neural networks. The student will join the research group (Eco-3D) as a doctoral candidate in the next academic term.
- 2018-2019** Supervision of two first-year master’s projects. The projects are part of a bigger experiment in collaboration with Dr. Alexis Makin at the University of Liverpool, where the Common Rate Controller hypothesis is being investigated in the context of multiple feature spaces and concurrent tasks.
- 2017-2018** Co-supervision of final master’s dissertation. The aim of the project was to develop realistic tests using random-dot stereograms and orientated sine-wave gratings for measuring the disparity-tuning of neuronal receptive-fields obtained by unsupervised STDP learning. The student is now a doctoral candidate within the Eco-3D research group.

University of Liverpool, Liverpool, UK

- 2015-16** Supervision within the Nuffield Research Placements Scheme for school students. The Nuffield scheme particularly encourages students who don't have a family history of going to university or who attend schools in less well-off areas.

Jan – Jun, 2013 and 2014 Teaching Assistant – second year module Perception and Memory. Duties included conducting seminars, tutorials, and marking essays. The material covered basic concepts in neuronal physiology and the physiology of vision.

2012-16 Co-supervision of final-year undergraduate projects in the School of Psychology and the School of Environmental Sciences. The projects were in the following domains:

- Estimating Unique Hues settings for colour deficient observers.
- The effect of gender on perceptual thresholds for skin patch images.
- Spectral measurement and colour characterisation of soil samples collected at different depths from the Spanish Pyrenees.

Funding

01/01/2018 – 22/08/2020 Post-doctoral Research Fellowship

“Cortical reorganisation in AMD: A multidisciplinary approach”

Funding body: Fondation pour la Recherche Médicale (FRM)

Amount: €150,000

Publications and Conference Proceedings

Sadoun, A., Chauhan, T., Mameri, S., Zhang, Y., Barone, P., Deguine, O. & Strelnikov, K. (2020). **Stimulation-specific information is represented as local activity patterns across the brain.** *NeuroImage*, 223, 117326. [[doi](#)]

Chauhan, T., Héjja-Brichard, Y., & Cottureau, B. (2020). **Modelling binocular disparity processing from statistics in natural scenes.** *Vision Research*, 176, 27–39. [[doi](#)]

Makin, A., Baurès, R., Cremoux, S., & Chauhan, T. (2020). **Simultaneous mental updating in physical space and number space.** *bioRxiv*, 985424. [[doi](#)]

Chauhan, T., Masquelier, T., & Cottureau, B. (2019). **Sub-optimality of the early visual system explained through biologically plausible plasticity.** *bioRxiv*, 799155. [[doi](#)]

Chauhan, T., Xiao, K., & Wuerger, S. (2019). **Chromatic and luminance sensitivity for skin and skinlike textures.** *Journal of Vision*, 19(1), 13–13. [[doi](#)]

Chauhan, T., Masquelier, T., Montlibert, A., & Cottureau, B. (2018). **Emergence of binocular disparity selectivity through Hebbian learning.** *The Journal of Neuroscience*, 38(44), 9563–9578. [[doi](#)]

Xiao, K., Pointer, M., Cui, G., Chauhan, T., & Wuerger, S. (2015). **Unique hue data for colour appearance models. Part III: Comparison with NCS unique hues.** *Color Research & Application*, 40(3), 256–263. [[doi](#)]

Makin, A., & Chauhan, T. (2014). **Memory-guided tracking through physical space and feature space.** *Journal of Vision*, 14(13), 10–10. [[doi](#)]

Xiao, K., Qin, Z., Chauhan, T., Li, C., & Wuerger, S. (2014, November). **Principal component analysis for skin reflectance reconstruction.** In *Color and Imaging Conference* (Vol. 2014, No. 2014, pp. 146-150). Society for Imaging Science and Technology. [[url](#)]

Chauhan, T., Perales, E., Xiao, K., Hird, E., Karatzas, D., & Wuerger, S. (2014). The achromatic locus: effect of navigation direction in color space. *Journal of Vision*, 14(1), 1–11. [doi]

Conference and Invited Talks

Chauhan T. (2020, January). What does a simple rank-based Hebbian rule tell us about the primary visual cortex? *The Bear Lab, Massachusetts Institute of Technology*, Boston, USA. [Invited talk]

Chauhan T. (2020, January). Decoding unique hues from EEG signals. *Annual meeting of the Colour Group of Great Britain 2020*. London, UK. [Invited talk]

Chauhan T., Masquelier T., & Cottureau B. (2019, June). A bio-inspired STDP network for event-based unsupervised learning. *Information, Signal, Image and ViSion: Emerging visual sensors (GDR ISIS) 2019*, Paris, France. [Invited Talk]

Chauhan T., Masquelier T., Monlibert A., & Cottureau B. (2017, July). Emergence of disparity selective neurons through spike-based learning from naturalistic stereoscopic datasets. *Annual Computational Neuroscience Meeting (CNS) 2017*, Antwerp, Belgium.

Chauhan T., Masquelier T., Monlibert A., & Cottureau B. (2017, August). Learning binocular disparity selectivity through spike-timing dependent plasticity. *European Conference on Visual Perception (ECVP) 2017*, Berlin, Germany.

Prizes and Awards

14/05/2017 CNS Travel Award, awarded by the Organisation for Computational Neurosciences.

21/04/2015 Cambridge Research Systems Travel Award, awarded by the Colour Group, Great Britain.

01/09/2009 – 07/09/2011 Erasmus Mundus Masters Scholarship: CIMET (Colour in Informatics and MEdia Technologies). Amount €42,000.

Other academic activities

Reviewer Frontiers in Neuroscience, Vision Research

Languages

Native proficiency English, Hindi

Conversational (B1-B2) Italian, French, Marathi