naveen SENDHILNATHAN

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Expertise

Deep learning | Reinforcement learning | Statistical machine learning | Natural Language Processing | Computational neuroscience | Cognitive neuroscience | Animal behavior | Motor learning | Electrophysiological neural recording | Eye tracking | Hand tracking | MRI | fMRI | EEG | EMG | Data Visualization

Technical Skills

Python: Tensorflow, keras, numpy, matplotlib, Jupyter, Google Colaboratory, Google cloud Platform, etc.

MATLAB | R | Neuron | Spike2 | LaTeX | HTML

Adobe: Illustrator | Photoshop | InDesign | Lightroom

Awards & Fellowships

2020 **Neural Control of Movement Award**
-to attend NCM meeting at Dubrovnik, Croatia (*canceled*).

2020 **Italian Academy of Columbia University-first rank scholar**
- to perform a scholarly research at Columbia University.

2019 **Kavli - Society for Neuroscience Award**
- to attend Society for Neuroscience meeting at Chicago, USA.

2019 **Chateaubriand Fellowship**
- short term fellowship by the Embassy of France in the US to perform a fMRI research project in ÉNS, Paris, France.

2019 **FENS-Japanese Neuroscience Society Award**
- for top 5 abstracts of the JNS meeting at Niigata, Japan.

2018 **Trainee Professional Development Award**
- for highest rated abstracts of the SfN meeting at San Diego, USA.

2018 **AANA Travel Award**
- to attend IISc national alumni meeting at Chicago, USA.

2018 **Gordon Research Seminar on Cognition poster award**
- third place.

2018 **Kavli - Society for Neuroscience Award**
- to attend SfN meeting at San Diego, USA. (*declined*).

2018 **FENS-IBRO/PERC Award**
- for highest rated abstracts of the FENS meeting at Berlin.

2018 **COSYNE Award**
- for top 4% abstracts of the COSYNE meeting at Denver, USA.

2017 **Australasian Neuroscience Society Award**
- to attend ANS meeting at Sydney, Australia.

2017 **Kavli - Society for Neuroscience Award**
- to attend SfN meeting at Washington D.C., USA.

2011 **Kishore Vaigyanik Protsahan Yojana Fellowship**
- 4 years fellowship by Department of Science and Technology, Government of India.

Other Interests

Traveling -traveled to 30+ countries in 6 continents | **Languages** - Tamil (native), English (bilingual), Hindi (bilingual), Spanish (C2), French (B2), Italian (A2), Sanskrit (read & write), Arabic (read & write) | **Graphic design** -10+ years experience as head designer for magazine, and freelancing | **Photography** - landscape and portrait | **Visual art** -painting in water medium and charcoal | **Music** -piano, mirudangam (Indian drum) | **Health & fitness**

References

Dr. Michael E. Goldberg Columbia University | meg2008 @columbia.edu
Dr. Jeffery D. Schall Vanderbilt University | jeffrey.d.schall@vanderbilt.edu
Dr. Aditya Murthy Indian Institute of Science | adi@iisc.ac.in

Profile

Computational neuroscientist with 8+ years of experience in developing and using computational and machine learning tools to work with unstructured data. Have successfully led several data-driven research projects from conception to deployment by working independently and through collaborations. Have presented key findings effectively at multiple national and international platforms through posters and as invited guest speaker.

	B.S. Biology and Chemistry				**M.A. Neurobiology and Behavior**				
	Indian Institute of Science,				Columbia University, New York, USA				
	Bangalore, India								
2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

Ph.D. Neurobiology and Behavior
Columbia University, New York, USA

Selected projects and research experience

How does Garry Kasparov play chess? - Neural correlates of reinforcement learning

- Designed novel cognitive and decision making paradigms to train primates. Engineered algorithms and developed software to track eye movements, hand movements and licking behavior simultaneously interfaced with neural recordings.
- Provided the first evidence in 50 years, for a reinforcement error signal in the Purkinje-cell simple spikes using reinforcement learning and drift diffusion models, machine learning tools, quantitative and computational analyses in Python and MATLAB [**article**].
- Presented these findings in front of a large audience in a podium talk at COSYNE [**YouTube**] among other scenarios.
- Built a stand alone spike sorting software that automatically classifies neural waveforms into simple and complex spikes with very little training data using CNN and unsupervised learning in Tensorflow [*manuscript under preparation*].
- Modeled learning related changes in high-dimensional state-space and studied the non-linear mixed selective interaction of choice and reward, using dimensionality reduction and subspace geometry through principle component analysis [**article**].
- Reversibly, pharmacologically inactivated different areas of cerebellum, and showed its causal necessity in reinforcement learning [**article**].

Did Stephen Hawking wink or blink? - Cortical neural correlates of goal-directed vs spontaneous movements

- Developed advanced eye tracking algorithms and used simultaneously recoded neural activity and beta frequency of local field potential, to delineate the differences in the mechanisms of generating non-goal directed and goal-directed eye movements [**article**].

How does David Beckham know where to hit the soccer ball? - Mechanisms of visuomotor transformation and motor planning

- Demonstrated a plausible mechanism of visuomotor transformation in the primate frontal eye fields by analyzing simultaneously recorded neural signals, time series and frequency information in the local field potential [**article**].

What makes Mike Tyson so good at boxing? - Decreases in variability across multiple time-scales during cortical computations to enable efficient behavioral performance

- Built biologically inspired computational neuronal models to investigate the neural variability within and across trials during cortical computations. Tested these model predictions on cortical neural activity and behavior in cognitive and motor tasks [**article**].

How did Beethoven play the Sonata? - Mechanisms of planning sequential movements

- Studied the mechanisms of planning sequential movements in the primate cortex using several computational analyses in python and MATLAB, state-space models and unsupervised machine learning tools [*two manuscripts under preparation*].

Selected leadership / teamwork experience

Co-chair and co-founder, Undergraduate Alumni Council, IIScAANA
- Built and facilitated successful professional relationships between students and alumni.
- Organized monthly talks by senior alumni around the world.

Trained and mentored 7 undergraduate interns over 4 years.
- Took initiatives to design new projects. Guided and advised them to come up with innovative solutions. Developed their quantitative, debugging, problem solving and communication skills. Provided continuous feedback and evaluated their performance.

Co-founder and head graphic designer, Quarks, the official undergraduate magazine of IISc
- Formulated the vision and mission of the organization.
- Developed creative detail oriented ideas and solution through critical thinking.
- Successfully increased the organization's size from 4 members to 40 by changing the focus to recruit creative and self driven individuals.

Head graphic designer, Pravega, the annual science and cultural festival of IISc
- Led a team of designers and generated roadmaps and actionable insights
- Resolved problems and managed relations.

Data analytics related short-term projects

- Developed highly scalable classifiers to classify art as fake vs legitimate using several supervised learning algorithms such as SVM, Random forest etc **[code].**
- Implemented a Naive Bayes model for text classification to identify spam emails **[code].**
- Designed a word prediction and sentence completion algorithm using a n-gram model.
- Utilized a k-nn algorithm to classify behavioral metrics such as ballistic saccadic eye movements made by primates [**article**] [**code**].
- Developed many data mining, statistical data analysis and data visualization tools **[code] [code] [code].**

Publications

manuscripts [9] ● podium talks [14] ● poster-abstracts [14]

manuscripts (published/under review)

2020 Causal evidence for mixed selectivity in the mid-lateral cerebellum to enable reinforcement learning
Sendhilnathan, N.[‡] Ipata, A. E.* & Goldberg, M. E.* | under review in **Cell**

2020 Neural correlates of goal-directed and non-goal-directed movements
Sendhilnathan, N.[‡], Basu, D., Goldberg, M. E., Schall, J. D. & Murthy, A.[#] | **bioRxiv**; under final review in **PNAS**

2020 Assessing within trial and across trial neural variability in macaque frontal eye fields and their relation to behavior
Sendhilnathan, N.[‡], Basu, D. & Murthy, A.[‡] | **European Journal of Neuroscience**

2020 Neural correlates of reinforcement learning in mid-lateral cerebellum
Sendhilnathan, N.[‡] Ipata, A. E.* & Goldberg, M. E.* | **Neuron**

2020 The mid-lateral cerebellum is required for reinforcement learning
Sendhilnathan, N.[‡] & Goldberg, M. E. | **bioRxiv,** under review in **Neuron**

2019 Complex spikes encode reward expectation signals during visuomotor association learning
Sendhilnathan, N.[‡], Ipata, A. E.* & Goldberg, M. E.* | **bioRxiv,** under review in **Nature Neuroscience**

2019 Mid-lateral Cerebellar Purkinje Cells Provide a Cognitive Error Signal When Monkeys Learn a New Visuomotor Association
Sendhilnathan, N.[‡], Ipata, A. E.* & Goldberg, M. E.* | **bioRxiv**

2018 Electrophysiological evidence for cerebellar involvement in higher-order cognitive processing
Sendhilnathan, N.[‡], Semework, M., Goldberg, M. E.* & Ipata, A. E.* | **bioRxiv**

2017 Simultaneous analysis of LFP and spikes reveals essential components of a visuomotor transformation process in frontal eye field
Sendhilnathan, N., Basu, D. & Murthy, A.[‡] | **PNAS**

[‡]Corresponding author. * These authors contributed equally

podium talks

2020 Mechanisms of processing bottlenecks in the frontal eye field during sequential saccade planning *(selected)*, **Indian Academy of Neuroscience,** *(virtual)*
2020 Differential cortical control of goal-directed and non-goal directed saccades *(selected),* **Monsoon brain meeting** *(virtual)*
2020 Neural correlates of reinforcement learning in mid-lateral cerebellum *(invited),* **Indian Institute of Science,** Bangalore, India
2019 Cognitive learning related changes in activity profiles of mid-lateral cerebellar Purkinje cells *(selected),* **JNS meeting**, Niigata, Japan
2019 Neural signature of purposive and nonpurposive movements *(invited),* **Beijing Normal University**, Beijing, China
2019 Mid-lateral cerebellum provides a cognitive error signal when monkeys learn a new visuomotor association *(selected),* **ISN meeting**, Eilat, Israel
2018 Cerebellum for jocks and nerds alike *(selected),* **Columbia University Neurobiology and Behavior program retreat**, Palisades, NY
2018 Mid-lateral Cerebellum Provides a Cognitive Error Signal During Acquisition of New Visuomotor Association *(invited),* **ESI,** Frankfurt, Germany
2018 Does the Cerebellum contribute to cognitive processes? *(invited),* **University of Pisa,** Pisa, Italy
2018 Does the Cerebellum contribute to cognitive processes? *(invited),* **IMT School for Advanced Studies**, Lucca, Italy
2018 Electrophysiological evidence for cerebellar involvement in higher-order cognitive processing *(invited),* **SPAD meeting,** Pisa, Italy
2018 Mid-lateral Cerebellar Purkinje Neurons Participate in Visuomotor Associative Learning *(selected),* **COSYNE 2018,** Denver, USA
2016 Simultaneous Analyses of LFP and Spikes from Monkey Frontal Eye Field to Understand Visuomotor Transformation *(invited),* **University of Pisa**, Pisa, Italy
2016 Visuomotor transformation in Frontal Eye Fields *(invited),* **Bharathidhasan University,** Trichy, India

abstracts

2020 **Sendhilnathan, N.,** Ipata, A. E. & Goldberg, M. E. | **Bernstein Conference,** *(virtual)*
2020 **Sendhilnathan, N.,** & Goldberg, M. E. | **Neural control of movement meeting,** Dubrovnik, Croatia *(canceled due to COVID-19)*
2019 **Sendhilnathan, N.,** Basu, D., Goldberg, M. E. & Murthy, A. | **Society for Neuroscience meeting,** Chicago, USA
2019 **Sendhilnathan, N.,** & Goldberg, M. E. | **Zuckerman Institute Mind Brain Behavior Symposium,** New York, USA
2018 **Sendhilnathan, N.,** & Goldberg, M. E. | **Society for Neuroscience meeting,** San Diego, USA
2018 **Sendhilnathan, N.,** & Goldberg, M. E. | **Annual Harkness Summer Science Fair, Columbia University Medical Center,** New York, USA
2018 **Sendhilnathan, N.,** & Goldberg, M. E. | **Gordon Research Seminar,** Maine, USA
2018 **Sendhilnathan, N.,** & Goldberg, M. E. | **Federation of European Neuroscience Societies annual meeting,** Berlin, Germany
2018 **Sendhilnathan, N.,** & Goldberg, M. E. | **Sense2Synapse, Rockefeller University,** New York, USA
2017 **Sendhilnathan, N.,** Ipata, A. E., Semework, M. & Goldberg, M. E. | **Australasian Neuroscience Society,** Sydney, Australia
2017 **Sendhilnathan, N.,** Semework, M., Goldberg, M. E.* & Ipata, A. E.* | **Society for Neuroscience meeting,** Washington D.C.
2017 **Sendhilnathan, N.,** Semework, M., Goldberg, M. E.* & Ipata, A. E.* | **Neural Control of Movement meeting,** Dublin, Ireland
2016 **Sendhilnathan, N.,** Basu, D. & Murthy, A. | **Society for Neuroscience,** San Diego, USA
2015 Ipata, A. E., **Sendhilnathan, N.,** King, A. & Goldberg, M. E. | **Society for Neuroscience,** Chicago, USA

Scientific media coverage

2020 **My Neuro news**
2020 **What is the cerebellum? (News coverage by Columbia University's Zukerman institute)**
2020 **Research on cerebellum yields rewards (Nature news & views)**
2018 **Talk at the COmputational and SYstems NEuroscience meeting (COSYNE 18)**