NAME	POSITION TITLE
Pagan, Marino	Postdoctoral Research Associate

EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE (if applicable)	MM/YY	FIELD OF STUDY
University of Pisa, Italy	Laurea (B.S.)	10/03 - 07/06	Computer Engineering
University of Pisa, Italy	Laurea Specialistica (M.S.)	09/06 - 07/09	Control Engineering
Scuola Superiore Sant'Anna, Italy	Diploma	10/03 - 07/09	Engineering
University of Pennsylvania	Ph.D.	09/09 - 12/14	Neuroscience
Princeton University (postdoc)	n/a	02/15 - present	Neuroscience

B. Positions and Honors

Research positions

2005-2007 Undergraduate research in Computational Game Theory at University of Pisa
Advisor: Prof. Bruno Codenotti
2007-2008 Research in Neuroscience as a visiting student at Massachusetts Institute of Technology
Advisor: Dr. James DiCarlo
2009-2015 Research in Neuroscience as a Ph.D. student at University of Pennsylvania
Advisor: Dr. Nicole Rust
2015-present Research in Neuroscience as a postdoctoral researcher at Princeton University
Advisor: Dr. Carlos Brody

Honors

2003-2009 Full scholarship (room and board) for the full duration of undergraduate studies as a winner of nationwide competition (1st out of 312 applicants), Scuola Superiore Sant'Anna
2012 Best oral presentation at BGSA Symposium, University of Pennsylvania
2012 Jameson-Hurvich Travel Award, University of Pennsylvania
2012 Admission to Computational Vision course, Cold Spring Harbor Laboratory
2013 Presenter's Travel Grant, CoSyNe
2016-2019 Simons Collaboration on the Global Brain Postdoctoral Fellowship
2020 Selected Speaker at NeuroLaunchpad Seminar Series
2021 Simons Foundation Autism Research Initiative (SFARI) Bridge to Independence Award

C. Contributions to Science

1. Neural representation of natural images in inferotemporal cortex: As an undergraduate student, I joined as a visiting student the laboratory of Dr. James DiCarlo at the Massachusetts Institute of Technology to study the role of high-level ventral visual areas during object-recognition. There, I applied a variety of computational techniques to characterize how neural populations in inferotemporal cortex (IT) represent natural images.

Pagan, M., Alemi-Neissi, A., Baldassi, C., Zecchina, R., DiCarlo, J.J., Zoccolan, D. (2011). From luminance to semantics: how images of natural objects are represented in monkey inferotemporal cortex. *CoSyNe*

Baldassi, C.*, Alemi-Neissi, A.*, **Pagan, M.***, DiCarlo, J.J., Zecchina, R., Zoccolan, D. (2013). Shape similarity, better than semantic membership, accounts for the structure of visual object representations in a population of monkey inferotemporal neurons. *PLoS Computational Biology*. 9 (8), e1003167 (PMCID3738466)
*co-first author

2. Neural mechanisms involved in finding specific objects and switching between targets: As a graduate student, I worked with Dr. Nicole Rust at the University of Pennsylvania to study the neural mechanisms responsible for our ability to find specific visual objects and rapidly switch between different sought targets. To study these questions, I employed a combined approach involving electrophysiology experiments and computational modeling. My results revealed that perirhinal cortex (PRH) performs a key computation to reformat inputs from IT into a representation that explicitly encodes whether a viewed stimulus matches a sought target. Surprisingly, a simple linear-nonlinear model was sufficient to capture the transformation between IT and PRH. This work was published in Nature Neuroscience in 2013.

I next sought to characterize the dynamics of these signals, and I found that the reformatting computation in PRH takes time to evolve. While this type of dynamic processing is normally attributed to complex recurrent circuits, I demonstrated that this phenomenon could also be accounted by an instantaneous linear-nonlinear model. These results were published in the Journal of Neuroscience in 2014.

A major challenge I encountered when interpreting data from IT and PRH stemmed from the fact that neural activity in these areas reflects complex mixtures of many different types of task-relevant signals. To address this issue, I developed a novel set of analytical tools to quantify task-specific signals in heterogeneous neural responses, and to relate these signals to measures of task performance. This work was published in the Journal of Neurophysiology in 2014.

In a joint collaboration with Eero Simoncelli at NYU, I developed a biologically plausible model to describe the computation performed by PRH neurons. This model extends the classic Linear-Nonlinear (LN) models that have been proven successful in describing neural computations in early sensory cortices. More specifically, I found that an optimal quadratic classifier can be reformulated as an LN-LN computation, analogous to "subunit" encoding models that have been used to describe responses in retina and primary visual cortex. I proposed a physiological mechanism by which the parameters of the model can be optimized using a supervised variant of a Hebbian learning rule. This work was published in Neural Computation in 2016.

Pagan, M., Urban, L.S., Wohl, M.P., Rust, N.C. (2013). Signals in inferotemporal and perirhinal cortex suggest an untangling of visual target information. *Nature Neuroscience*. 16 (8), 1132-1139 (PMCID3725208)

Pagan, M., Rust, N.C. (2014). Quantifying the signals contained in heterogeneous neural responses and determining their relationships with task performance. *Journal of Neurophysiology*. 112 (6), 1584-1598 (PMCID4137243)

Pagan, M., Rust N.C. (2014). Dynamic target match signals in perirhinal cortex can be explained by instantaneous computations that act on dynamic input from inferotemporal cortex, *Journal of Neuroscience.* 34 (33), 11067-11084 (PMCID4131017)

Pagan, M., Simoncelli E.P., Rust N.C. (2016). Neural Quadratic Discriminant Analysis: Nonlinear Decoding with V1-Like Computation, *Neural Computation.* 28 (11), 2291-2319 (PMCID6395528)

3. Collicular circuits for flexible sensorimotor routing: Flexible sensorimotor routing in response to changing environmental context is a hallmark of executive control. Pharmacological inactivations of the superior colliculus (SC) have suggested the SC plays a role in cognitive aspects of the process, but little is known about the specific role played by SC, and the underlying circuit mechanisms. In collaboration with Ann Duan and Alex Piet I have discovered the existence of a subset of rat SC neurons, distinguished by the timing of their context encoding and their correlation with behavior, that instantiate a specific link between the neural representations of context and of motor choice, and that encode the subject's choice far earlier than other neurons in the SC or in frontal cortex. These results put fundamental constraints on the SC neural representations, circuit structure, and circuit dynamics that underlie the SC's participation in flexible behavior.

Duan C.A.*, **Pagan, M.***, Kopec, C.D., Erlich, J.C., Riordan, A., Akrami, A., Brody, C.D. (2016). A collicular mechanism for flexible sensorimotor gating during task switching, *CoSyNe*
*****co-first author

Duan, C.A.*, **Pagan, M.***, Piet, A.T.*, Kopec, C.D., Akrami, A., Riordan, A.J., Erlich, J.C., Brody, C.D. (2021) Collicular circuits for flexible sensorimotor routing, *Nature Neuroscience*, 1–11 (PMCID34083787)
*****co-first author

4. Neural mechanisms underlying flexible selection and integration of evidence: Our ability to flexibly select, based on context, the relevant information to guide our decisions is a fundamental cognitive process, yet its neural underpinnings are still largely unknown. To address this issue, I developed an automated procedure to train rats for the first time to perform a task requiring context-dependent selection and integration of sensory information (adapted from Mante et al., Nature, 2013). In my task, rats are presented with a train of randomly-timed auditory pulses, where each pulse varies in its location (right or left) and its tone pitch (high or low). In separate blocks of trials, rats are cued to report either the prevalent location of the pulses, or their prevalent pitch. Rats learned to perform this task with high accuracy. While rats performed the task, I performed optogenetic and electrophysiology experiments. Optogenetic perturbation of the Frontal Orienting Fields (FOF) impaired rats' ability to form the correct decision, consistent with a causal role of this area in the task. Population analyses of FOF neural activity revealed that dynamics of rat FOF are highly similar to those of area Frontal Eye Fields (FEF) in macaque monkeys performing an analogous task. Taking advantage of the pulsatile nature of my task, I performed modeling and statistical analyses that uncovered a large heterogeneity in the neural mechanism employed by different rats to perform the task. These results open the door to the study of individual variability in the neural mechanisms supporting higher cognitive processes.

Pagan, M., Gupta, D., Piet, A., Brody, C.D. (2017). Flexible decision-making in rats, *CoSyNe*

Pagan, M., Tang, V., Brody, C.D. (2019). Representations and causal contributions of frontal cortical regions during a flexible decision-making task, *CoSyNe*

Pagan, M., Tang, V., Aoi, M.C., Sussillo, D., Mante, V., Pillow, J.W., Brody, C.D. (2020). Heterogeneous recurrent mechanisms underlying context-dependent computation in rats, *CoSyNe*

Pagan, M., Tang, V., Aoi, M.C., Sussillo, D., Mante, V., Pillow, J.W., Brody, C.D. (2021). Individual variability of neural mechanisms underlying flexible decision-making, *CoSyNe*

5. Development of a system for wireless, automated optogenetics and electrophysiology: Traditionally, collection of optogenetics and electrophysiology data in behaving animals is a slow process requiring constant supervision from the experimenter. After developing a procedure to automatically train large a number of rats to perform cognitive tasks, I sought to also increase the speed of data collection by automating the execution of optogenetic and electrophysiology experiments. Developing a wireless system was crucial to enhance scalability and to avoid a number of issues associated with tethered setups in freely-moving animals, including high impact on the rats' behavioral performances, frequent cable disconnections, and the need for tall operant chambers. Development of the system required designing of mechanical and electronic components, the creation of an automated software pipeline to process recorded data, and optimization of all parts to ensure robustness and ease of use by laboratory technicians. The system is now widely used in the Brody lab to automate data collection.

Pagan, M., Brody, C.D. (2021). High-Throughput Electrophysiology and Optogenetics in Freely-Moving Rats Performing Cognitive Tasks, *IEEE NER 2021*