BIOGRAPHICAL SKETCH

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NAME: Gottlieb, Jacqueline

eRA COMMONS USER NAME (credential, e.g., agency login): JG2141

POSITION TITLE: Professor of Neuroscience

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Massachusetts Institute of Technology, Boston, MA	B.S.	1986	Cognitive Science
Yale University, New Haven, CT	Ph.D.	1993	Neurobiology

A. Personal Statement

I have the expertise, leadership and motivation necessary to carry out the proposed work. I have a background in cognitive neuroscience and neurophysiology, with specific expertise in the oculomotor system and the frontal and parietal cortex. As a doctoral student at Yale University I characterized a novel frontal area, the frontal pursuit area, which is involved in smooth pursuit eye movements and lies next to the saccadic frontal eye fields. As postdoctoral fellow at the National Eye Institute I investigated mechanisms of attention in the parietal cortex. As assistant professor at Columbia University I expanded the parietal studies to understand reward and task influences on selective attention. I have extensively used neurophysiological recordings and reversible inactivation and am well aware of their power and limitations. In addition, I am actively collaborating with investigators using computational modeling of attention and decision making, and am well versed in applying computational techniques to experimental data. I successfully secured funding from NIH and private foundations. I administered research projects that resulted in peer-reviewed applications, mentored postdoctoral researchers and taught and mentored graduate students. The current application builds logically on my prior work that investigates the mechanisms of attention and its relation to other cognitive functions. In summary, I have a demonstrated record of successful and productive research in an area of high relevance for cognitive neuroscience, and my expertise and experience have prepared me to lead the proposed project.

B. Positions and Honors

Positions

1996-2001: Postdoctoral fellow, National Eye Institute
2001-2010 Assistant Professor, Department of Neuroscience, Columbia University
2010-2017 Associate Professor with tenure, Department of Neuroscience, Columbia University
2017-Present Professor, Department of Neuroscience, Columbia University

Honors

2001 Sloan Fellow (Sloan Foundation Fellowship)
2002 Klingenstein Fellow (Klingenstein Foundation Fellowship)
2003 McKnight Scholar Award (McKnight Fund for Neuroscience)
2005 Elected member, *International Neuropsychological Society*
2008 Associate Editor, *Journal of Neuroscience*
2008 Young Investigator Award (National Alliance for Research on Schizophrenia and Depression)

2008 Professional Schools Diversity Fellowship (Columbia University)
2009 Chair, Society for Neuroscience Minisymposium, “Cognitive functions of the parietal lobe”
2011 Member, Kavli Institute for Brain Science, Columbia University
2013 Permanent member, Sensory and Cognitive Processes Study Section, NIH
2014 Chair, Society for Neuroscience Symposium, “Information seeking, reward and attention”
2014 Organizer, “First International Symposium on Information seeking, curiosity and attention”
2015 Presidential Scholars for Science and Society Award (Columbia University)
2016 Organizer, “Second International Symposium on Information seeking, curiosity and attention”
2016 McKnight Cognitive and Memory Disorders Award (McKnight Fund for Neuroscience)
2017 Research Initiatives in Science and Engineering Award (Columbia University)
2018 Honorary Pasik Lecture in Neuroscience, Mount Sinai Medical School
2018 Organizer, “The Emerging Sciences of Curiosity”
2018 Donders Lecture, The Donders Institute for Cognitive and Brain Science
2018 Leader, Research Cluster on Curiosity, Center for Science and Society, Columbia University
2019 Elected vice-chair, The Gordon Research conference on Eye Movements
2021 Elected chair, The Gordon Research conference on Eye Movements

C. Contributions to science

1. Based on my work on the priority map in area LIP and its role in attention, I proposed the hypothesis that attention control is geared toward selecting information, and as such, is engaged at task junctures that have high uncertainty. I showed that LIP neurons have reward learning selectively at informative decision steps but not at decision steps that are irrelevant for a final reward. I also showed that LIP neurons explicitly encode the informativeness – expected information gains- of competing action relevant cues. Finally, I developed a behavioral paradigm for testing saccadic information seeking behavior in monkeys.

Gottlieb, J and Oudeyer, P.Y (2018): Toward a neuroscience of active sampling and curiosity. *Nature Reviews Neuroscience,* Dec;19(12):758-770

Gottlieb, J (2017): Understanding active sampling strategies: empirical approaches and implications for attention and decision research. *Cortex*, Aug 24. pii: S0010-9452(17)30276-9. doi: 10.1016/j.cortex.2017.08.019.

Foley, N.C., Kelly, S. K., Mhatre, H., Lopes, M. and Gottlieb, J (2017): Parietal neurons encode expected gains in instrumental information. *Proceedings of the National Academy of Science*. Published online before print, April 3, 2017, doi: 10.1073/pnas.1613844114
Press:
http://zuckermaninstitute.columbia.edu/news/curious-cells-how-brain-makes-its-mind
http://newsroom.cumc.columbia.edu/

Daddaoua, N. and Gottlieb, J (2016): Intrinsically motivated oculomotor exploration motivated by uncertainty reduction and conditioned reinforcement in non-human primates. *Scientific Reports*. Feb 3;6:20202. doi: 10.1038/srep20202.

Gersch T. M.*, Foley N. C.*, Eisenberg I., & Gottlieb J. (2014). Neural correlates of temporal credit assignment in the parietal lobe. *PLoS ONE*, *9*(2), e88725.

Gottlieb, J. (2012): Attention, learning and the value of information. *Neuron*, 76(2):281-95 PMID: 23083732

2. Extending the idea that attention is an information sampling mechanism, I opened a new line of research on curiosity and intrinsic motivation – the desire to sample information independently of the rewards of a task. I showed that humans have consistent strategies for learning in a large task space even when they are not given specific instructions. In addition, I showed that semantic curiosity attracts attention and anticipatory gaze.

Kobayashi, K., Ravaioli, S., Baranes, A, Woodford, M. and Gottlieb, J. (in press): Diverse motives for human curiosity. *Nature Human Behavior*

Dey, A. and Gottlieb, J. (in press, 2018): Attention, information seeking and active sampling: Empirical evidence and implications for learning. *The Cambridge Handbook of Motivation and Learning*

Oudeyer, P.Y, Gottlieb, J and Lopes, M (2016): Intrinsic motivation, curiosity and learning: theory and applications in educational technologies. *Prog Brain Res.* 2016;229:257-284. doi: 10.1016/bs.pbr.2016.05.005. Epub 2016 Jul 29.

Baranes, A., Oudeyer, P.Y and Gottlieb, J (2015): Eye movements encode semantic curiosity in human observers. *Vision Research*. 117:81-90. doi: 10.1016/j.visres.2015.10.009. Epub 2015 Nov 12.

Baranes AF, Oudeyer PY, Gottlieb J. (2014): The effects of task difficulty, novelty and the size of the search space on intrinsically motivated exploration. Front Neurosci. 2014 Oct 14;8:317. doi: 10.3389/fnins.2014.00317. eCollection 2014.

Gottlieb, J*, Hayhoe, M., Hikosaka, O. and Rangel, A. (2014): Attention, information seeking and reward, *J. Neuroscience,* 34(46):15497-504. doi: 10.1523/JNEUROSCI.3270 14.2014.

Gottlieb J, Oudeyer PY, Lopes M, Baranes A. (2013): Information-seeking, curiosity, and attention: computational and neural mechanisms. Trends Cogn Sci. 2013 17(11):585-93. PMID: 24126129

3. Using neural recordings and reversible inactivation, I showed that the parietal and frontal areas have very different contributions to visual monitoring and selecting actions. While dlPFC (dorsolateral prefrontal) neurons focus on task-relevant targets and block out irrelevant distractors, LIP neurons can maintain a target memory and also remain "open" to new information – i.e., respond robustly to salient distractors, consistent with prior findings from our lab that the cells encode novel or reward-associated, but action-irrelevant items. The findings reveal striking differences between two cortical areas that had been thought previously to have similar functions.

Foley N.C., Jangraw D.C., Peck C.J., Gottlieb J. (2014) Novelty enhances salience independently of reward in the parietal lobe. *J. Neuroscience* 34(23):7947-7957 doi: 10.1523/JNEUROSCI.4171-13.2014

Suzuki, M., Gottlieb, J. (2013): Distinct mechanisms of distractor suppression in the frontal and the parietal lobe. *Nature Neuroscience*, 16 (1): 98-104. PMID: 23242309

Peck CJ, Jangraw D, Efem R and Gottlieb J.: Reward modulates attention independently of action value in posterior parietal cortex. *The Journal of Neuroscience* (2010) 29(36):11182–11191 PMCID: PMC2778240

Balan PF and **Gottlieb, J.** (2006) Integration of exogenous input into a dynamic salience map revealed by perturbing attention, *Journal of Neuroscience,* Sept 6; 26(36): 9239-49. PMID:16957080

4. I showed that the priority (or "salience") representation in LIP encodes not only the location of an attention worthy object but also the action associations of that stimulus. These action associations need not be spatial (e.g., may indicate a non-spatial manual action). We showed that their significance is not in guiding motor actions but in guiding selective attention based on motor associations. Finally, we designed a computational model showing how attention can be integrated with vision and motor control to select task-relevant cues.

Shomstein, S. and Gottlieb, J. (2016): Spatial and non-spatial aspects of visual attention: interactive cognitive mechanisms and neural underpinnings. *Neuropsychologia*. 2016 Nov;92:9-19. doi: 10.1016/j.neuropsychologia.2016.05.021. Epub 2016 May 30.

Schwemmer, M.A., Feng, S., Cohen, J.D., Gottlieb, J. and Holmes, P. (2015): A multi-area stochastic model for a covert visual search task; *PLoS One*. 19;10(8). doi: 10.1371/journal.pone.0136097

Gottlieb J., Snyder LH (2010): Spatial and non-spatial functions of the parietal cortex, *Curr Opinion Neurobiology*, 20(6):731-7401. 2. PMID: 21050743

Gottlieb, J., Balan P.F., (2009): The functional significance of non-spatial information in monkey posterior parietal cortex. *Journal of Neuroscience*, 29(25):8166-76. PMID:19553456

Oristaglio J., Schneider D. M., Balan P. F. and Gottlieb J. (2006): Integration of visuospatial and effector information during symbolically cued movements in monkey lateral intraparietal area. *Journal of Neuroscience,* Aug 9;26(32):8310-9 PMID:16899726

5. I showed that neurons in the monkey lateral intraparietal area (LIP) encode a "priority" or "salience" representation that selectively responds to attention-worthy objects or locations in a visual scene. In subsequent studies in my own laboratory I extended the findings by showing that the neurons integrate top-down and bottom up factors and correlate with capacity limitations during visual search.

The finding that LIP encodes a salience representation is highly significant because it is consistent with computational models of selective attention and provides a robust framework for understanding attention control.

Balan P.F., Oristaglio, J, Schneider D and **Gottlieb, J.** (2008): Neural correlates of the set-size effect in monkey lateral intraparietal area, *PLoS Biology* Vol. 6, No. 7, e158 PMID:18656991

Gottlieb J., Kusunoki, M. and Goldberg M.E. (2005): Simultaneous representation of saccade targets and abrupt onsets in monkey lateral intraparietal area. *Cerebral Cortex,* 15(8):1198-206 PMID:15616137

Gottlieb J. and Goldberg, M.E. (1999): Activity of neurons in the lateral intraparietal area of the monkey during an antisaccade task. *Nature Neuroscience* 2(10): 906-912. PMID:10491612

Gottlieb, J., Kusunoki, M. and Goldberg, M. E. (1998): The representation of visual salience in monkey posterior parietal cortex. *Nature* 391(6666): 481-484. PMID:9461214

6. I proposed an integrated theory of how the brain may compute priority base on the salience, rewards and action associations of visual cues, and showed how this idea can account for apparently discrepant finding regarding LIP cells.

Shomstein, S. and Gottlieb, J (2016): Spatial and non-spatial aspects of visual attention: interactive cognitive mechanisms and neural underpinnings, *Neuropsychologia Special Issue: Facets of Human Attention,* (16)30172-5. doi: 10.1016/j.neuropsychologia.2016.05.021.

Gottlieb, J., Balan P.F., Oristaglio, J and Schneider D (2008): Task specific computations in attentional maps. *Vision Research,* 49(10):1216-1226 PMID:18502468

Gottlieb, J., Balan P.F., Oristaglio, J, Suzuki M (2008): Parietal control of attentional guidance: The significance of sensory, motivational and motor factors, *Neurobiol. Learning and Memory,* 91(2):121-189.

Gottlieb, J. (2007): From thought to action: the parietal cortex as a bridge between perception, action and cognition. *Neuron*, 53(1): 9-16. PMID: 17196526

7. As a graduate student at Yale University, I described for the first time a new cortical area - the frontal pursuit area (FPA) - which lies just ventral to the frontal eye fields in macaque monkeys. The FPA is involved in generating smooth pursuit eye movements – slow eye movements that track moving targets and differ in their control and neural mechanisms from the rapid (saccadic) movements controlled by the main portion of the frontal eye field. I described the anatomical location of the FPA, the neural response properties, and the effects of microstimulation. Since then scores of studies have been conducted on the FPA and have shown that it is critical for the initiation and cognitive control of pursuit. Hence, the discovery of the FPA was a highly significant advance in understanding the neural mechanisms of smooth pursuit.

Gottlieb, J., MacAvoy, M. G. and Bruce, C. J.: Neural responses related to smooth pursuit eye movements and their correspondence with electrically-elicited smooth eye movements in the monkey frontal eye field. *Journal of Neurophysiology* (1994) 72(4): 1634-1653.

Gottlieb, J., Bruce, C. J. and MacAvoy, M. G.: Smooth eye movements elicited by microstimulation in the primate frontal eye fields. *Journal of Neurophysiology* (1993) 69(3): 786-799.

MacAvoy, M. G., Gottlieb, J. and Bruce, C. J.: Smooth pursuit eye movement representation in the primate frontal eye field. *Cerebral Cortex* (1991) 1: 95-102.

Complete List of Published Work in MyBibliography:
http://www.ncbi.nlm.nih.gov/sites/myncbi/collections/bibliography/45867370/

D. Research Support

Ongoing

National Eye Institute 1R01EY025158-01A1 ***2015-2020***
Top-down selection of task relevant cues
Role: PI, responsible for monitoring all aspects of the work.

Human Frontiers Science Program ***2016-2019***
Understanding curiosity: biological, behavioral and computational mechanisms
Role: co-PI, with Oudeyer, Kidd

INRIA, Bordeaux, France ***2016-2019***
Neural mechanisms of curiosity and attention
Role: co-PI, with Oudeyer and Lopes

The McKnight Fund for Neuroscience (PI) ***2015-2018***
Population dynamics encoding uncertainty and reward in the frontal and parietal cortex
Examine the coding of uncertainty and reward in frontal and parietal areas using multi electrode arrays
Role: PI, responsible for monitoring all aspects of the work.

National Institute of Mental Health R01 MH-098039-01 ***2012-2017***
Attentional control by uncertainty and reward: parietal and frontal mechanisms
Examine the coding of uncertainty and reward in frontal and parietal areas using individual electrode recording and reversible inactivation.
Role: PI, responsible for monitoring all aspects of the work.

Presidential Scholars in Society and Neuroscience, seed funds, Columbia University ***2015-2016***
Determinants of attention and information seeking in human economic choice
Role: co-PI, with Michael Woodford

Research Initiatives in Science & Engineering, seed funds, Columbia University ***2017-2018***
Integrating information sampling in decision theories using large scale testing of human behavior
Role: co-PI, with Michael Woodford (primary) and Pierre-Yves Oudeyer (unfunded collaborator)

National Institute of Mental Health, 1R03MH115644-01 ***2017-2019***
Neural mechanisms of saccadic information seeking behavior
Role: PI

Completed in the past 5 years

Human frontiers cross-disciplinary fellowship (to Adrien Baranes) *7/01/2012-12/30/2015*
Neural mechanisms of attention and intrinsic curiosity
The goal is to understand the links between attention and curiosity. **Role**: mentor

National Institute of Drug Abuse **5R21DA030095-02** 7/1/2010-68/30/2013
Pavlovian learning, attention and decisions
The goals are to examine reward processes in attention. **Role**: PI, monitoring all aspects of the work.

Kavli Foundation Fellowship (Himanshu Mhatre) *3/01/2011-2/30/2013*
Information seeking in the frontal and parietal lobes
The goal is to examine information selection during decision making **Role**: mentor

National Institute of Mental Health **5R03MH091590** 7/1/2010-6/30/2012
Neural mechanisms of long-term planning
The goals are to examine the neural mechanisms of extended temporal decisions. **Role**: PI

Fulbright fellowship (to Adrien Baranes) *7/01/2011-6/30/2012*
Neural mechanisms of attention and curiosity
The goal is to understand the links between attention and curiosity. **Role**: mentor.