OMB No. 0925-0001 and 0925-0002 (Rev. 03/2020 Approved Through 02/28/2023)

**BIOGRAPHICAL SKETCH**

Provide the following information for the Senior/key personnel and other significant contributors.  
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Schoenbaum, Geoffrey

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

POSITION TITLE: Branch Chief and NIH Distinguished Investigator

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 |
| --- | --- | --- | --- |
| University of Georgia | BS | 1989 | Biology |
| University of North Carolina Graduate School | PhD | 1994 | Neurobiology |
| University of North Carolina School of Medicine | MD | 1996 | Medicine |
| Yale University | Resident | 1997 | Psychiatry |
| University of North Carolina Psychology Department | Post-doc | 1997 | Psychology |

**A. Personal Statement**

I am qualified to support this application by virtue of my expertise in animal behavior, the neural circuits involved in associative learning, judgment and decision-making, and single-unit recording. I have over 20 years of experience implementing relatively complex behavioral tasks to test hypotheses about how neural circuits mediate these simple functions. The lab has also published a number of studies using optogenetic approaches to manipulate mesocorticolimbic circuits. And we have extensive experience relating changes in these circuits to the loss of behavioral control that characterizes drug addiction. I also have substantial experience as a mentor. Since starting the lab in 2003, I have supervised over two dozen postdocs and graduate students. Postdocs training in the lab were collectively awarded several private foundation fellowships, six K awards, and one R03 grant and 12 have transitioned successfully into academic research/instructional positions (including 4 tenured and 4 tenure-track). I have also mentored several dozen postbacs or postbac-equivalents, nearly all of whom have gone on to PhD, MD, or combined degree programs.

**B. Positions and Honors**

*Positions:*

1997-2003 Associate Research Scientist, JHU, Department of Psychology, Baltimore, MD

2003-2008 Assistant Professor, University of Maryland, Departments of Anatomy & Neurobiology and Psychiatry, Baltimore, MD; Adjunct, Department of Psychology, University of Maryland Baltimore County, Baltimore, MD

2008-2011 Professor, University of Maryland, Departments of Anatomy & Neurobiology and Psychiatry, Baltimore, MD; Adjunct, Department of Psychology, University of Maryland Baltimore County, Baltimore, MD

2011-present Branch Chief, Cellular Neurobiology Research Branch; Senior Investigator, Tenured and Chief of the Behavioral Neurophysiology Neuroscience Section, NIDA-Intramural Research Program, Baltimore, MD; Adjunct, University of Maryland, Departments of Anatomy & Neurobiology and Psychiatry, Baltimore, MD; Adjunct, Department of Psychology, University of Maryland Baltimore County, Baltimore, MD

2019-present NIH Distinguished Investigator

*Honors:*

1989 Graduated Summa Cum Laude from University of Georgia

1989 Full Scholarship, M.D./Ph.D. Program at the University of North Carolina

1996 Received MD with Honors, University of North Carolina School of Medicine

2007 Awarded “Best Mentor” by UMB Program in Neuroscience graduate students

2008 Selected to give Special Lecture at Society for Neuroscience Meeting, Washington DC

2008 Awarded “Best Mentor” by UMB Program in Neuroscience graduate students

2009 Awarded Waletzky Prize by SFN and NIDA

2012 Selected to give Presidential Lecture at the Eastern Psychological Association Meeting

2013 Selected to give the Abraham Ribicoff Lecture by Yale Psychiatry

2013 Elected Eastern Psychological Association Fellow

2013 Elected into the Johns Hopkins University Society of Scholars

2016 Awarded the Pavlovian Research Award by the Pavlovian Society

2017 Awarded “Best Mentor” by NIDA-IRP IRTA Trainees

2018 Selected to give the Plenary Lecturer at the Winter Conference on Brain Research

2019 Named as NIH Distinguished Investigator

**C. Contributions to Science**

**Publication Statistics, January 2021:**

Google Scholar: 18659 citations, h-index 69

http://www.ncbi.nlm.nih.gov/pubmed/?term=schoenbaum+g\*

Orbitofrontal contributions to outcome signaling: Beginning with my graduate and postdoc work and continuing in my own lab, I have been involved in a series of papers that have been part of work showing that the orbitofrontal cortex is critical to signaling information about outcomes. We have linked these functions to single unit correlates and the influence of this information on processing in other circuits. More recently we have shown that the orbitofrontal cortex plays a critical role in both guiding behavior and in supporting learning, due in both cases to its function in signaling information about outcomes. We have also shown that the orbitofrontal cortex signals not just value but other features of outcomes, leading to current ideas about the role of this region in cognitive mapping and schema formation.

* **Schoenbaum**, G., Chiba, A., and Gallagher, M. (1998) Orbitofrontal cortex and basolateral amygdala encode expected outcomes during learning. Nature Neuroscience. 1:155-159.
* Burke, K.A. Miller, D.N., Franz, T.M., and **Schoenbaum**, G. (2008) The role of orbitofrontal cortex in the pursuit of happiness and more specific rewards. Nature. 454:340-344.
* Jones, J.L., Esber, G.R., McDannald, M.A., Gruber, A.J., Hernandez, A., Mirenzi, A., and **Schoenbaum**, G. (2012) Orbitofrontal cortex supports behavior and learning using inferred but not cached values. Science. 338:953-956.
* Zhou, J., Jia, C., Montesinos-Cartagena, M., Gardner, M.P.H., Zong, W., and **Schoenbaum**, G. (2020) Evolving schema representations in orbitofrontal ensembles during learning. Nature. Advanced Online Publication.

Role of orbitofrontal input to dopaminergic circuits: Dopamine neurons have been shown to signal reward prediction errors in humans, monkeys and rats. Our lab was among the first to extend that finding to rats and has contributed to showing how these signals are constructed and deployed to affect learning and behavior. In initial work, we showed that they similarly encode changes in size versus timing of reward but that under free choice conditions, signals can initial represent optimal rewards even when not selected. Subsequently we demonstrated direct and distinct roles for orbitofrontal and ventral striatal input in determining the underlying state representations and associated reward predictions used by dopamine neurons to calculate errors. We have also linked this error signaling function with orbitofrontal-dependent learning in novel ways, and we are currently working to link it to changes in orbitofrontal function in addiction.

* Roesch, M.R., Calu, D.J., and **Schoenbaum**, G. (2007) Dopamine neurons encode the more valuable option when rats are deciding between differently sized and delayed rewards. Nature Neuroscience. 10:1615-1624 (also see News & Views highlighting article).
* Takahashi, Y., Roesch, M.R., Stalnaker, T.A., Haney, R.Z., Calu, D.J., Taylor, A.R., Burke, K. A., and **Schoenbaum**, G. (2009) The orbitofrontal cortex and ventral tegmental area are necessary for learning from unexpected outcomes. Neuron. 62:269-280.
* Takahashi, Y.K., Roesch, M.R., Wilson, R.C., Toreson, K., O'Donnell, P., Niv, Y., and **Schoenbaum**, G. (2011) Expectancy-related changes in firing of dopamine neurons depend on orbitofrontal cortex. Nature Neuroscience. 14:1590-1597.
* Takahashi, Y.K., Langdon, A.J., Niv, Y., and **Schoenbaum**, G. (2016) Temporal specificity of reward prediction errors signaled by putative dopamine neurons in rat VTA depends on ventral striatum. Neuron. 91:182-193.

Dopaminergic error signaling and its contribution to learning: In addition to replicating the classic error signals in rats, our lab has also contributed to new ideas regarding the role of dopaminergic signals in learning that goes beyond value and classic RPE signals. This includes the first demonstration that dopamine neurons exhibit error-like responses reflecting model-based estimates of value as well as value-neutral shifts in expected sensory information. This work joins other data showing error-like signals to shifts in state, new information, and even movement, showing that value-based error signaling may be a special case of a more general function. Consistent with this, we have published causal data showing that dopamine transients are both necessary and sufficient for value-neutral sensory learning.

* Sadacca, B.F., Jones, J.L., and **Schoenbaum**, G. (2016) Midbrain dopamine neurons compute inferred and cached value prediction errors in a common framework. eLIFE. 5:e13665.
* Takahashi, Y.K., Batchelor, H.M., Liu, B., Khanna, A., Morales, M., and **Schoenbaum**, G. (2017) Dopamine neurons respond to errors in the prediction of sensory features of expected rewards. Neuron. 95:1395-1405.
* Sharpe, M.J., Chang, C.Y., Liu, M.A., Batchelor, H.M., Mueller, L.E., Jones, J.L., Niv, Y., and **Schoenbaum**, G. (2017) Dopamine transients are sufficient and necessary for acquisition of model-based associations. Nature Neuroscience. 20:735-742.
* Stalnaker, T.A., Howard, J.D., Takahashi, Y.K., Gershman, S.J., Kahnt, T., and **Schoenbaum**, G. (2019) Dopamine neuron ensembles signal the content of sensory prediction errors. eLIFE. 8:e49315.

Role of orbitofrontal and dopaminergic dysfunction in addiction: Addiction is characterized by a failure to use information about outcomes to support learning and guide behavior. Work in my lab has shown that this may reflect drug-induced changes in prefrontal and dopaminergic circuits. We have shown that cocaine and opiate use affect a variety of behavioral functions that we know depend on areas, and more recently we have linked these functional changes to changes in single unit information processing in the orbitofrontal cortex, dopamine neurons, and shown that brief stimulation of orbitofrontal cortex is sufficient to restore normal function. Much of this work has replicated or been replicated by work in other labs and species, and we are working now to extend these studies into normal humans and patients.

* **Schoenbaum**, G and Setlow, B. (2005) Cocaine makes actions insensitive to outcomes but not extinction: implications for altered orbitofrontal-amygdalar function. Cerebral Cortex. 15: 1162-1169.
* Weid, H.M., Jones, J.L., Cooch, N.K., Berg, B.A., and **Schoenbaum**, G. (2013) Disruption of model-based behavior and learning by cocaine self-administration in rats. Psychopharmacology. 229:493-501.
* Lucantonio, F., Takahashi, Y.K., Hoffman, A.F., Chang, C.Y., Chaudhary, S., Shaham, Y., Lupica, C.R., and **Schoenbaum**, G. (2014) Orbitofrontal activation restores insight lost after cocaine use. Nature Neuroscience. 17:1092-1099.
* Takahashi, Y.K., Stalnaker, T.A., Marrero-Garcia, Y., Rada, R.M., **Schoenbaum**, G. (2019) Expectancy-related changes in dopaminergic error signals are impaired by cocaine self-administration. Neuron. 101:294-306.

**D. Research Support**

The lab is currently supported by intramural funding at NIDA-IRP.