CURIOSITY: EMERGING SCIENCES AND EDUCATIONAL INNOVATIONS

University of Pennsylvania
Singh Center for Nanotechnology
Glandt Forum

December 7 8, 2018

| PROGRAM |
Friday, December 7

Welcome Remarks:

8:30 – 8:45: Perry Zurn (American University) & Arjun Shankar (Hamilton College)
"Why Curiosity? Social Dimensions"
8:45 – 9:00: Jackie Gottlieb (Columbia University)
"Why Curiosity? Scientific Dimensions"

Session 1: Curiosity, Cognition, and Decisions I

Chair: Jackie Gottlieb (Columbia University)
9:00 – 9:40 Mathias Gruber (Cardiff University)
"States of Curiosity Enhance Hippocampus-Dependent Memory"
9:40 – 10:20 Lieke van Lieshout (Radboud University)
"How Do Uncertainty and Reward Affect Curiosity"

10:20 – 10:30 Coffee

Session 2: Curiosity, Cognition, and Decisions II

Chair: Arjun Shankar (Hamilton University)
10:30 – 11:10 Antoni Rodriguez-Fornells (University of Barcelona)
"The Intrinsic Reward of Learning a New Language"
11:10 – 11:50 Robert Wilson (University of Arizona)
"The Role of Information and Randomization in Exploration and Exploitation"
11:50 – 12:30 Jackie Gottlieb (Columbia University)
"Uncertainty Reduction and Reward Motives in Curiosity and Decision Making"

12:30 – 1:00 Discussion

1:00 – 3:00 LUNCH

Session 3: Curiosity, Development, and Education I

Chair: Perry Zurn (American University)
3:00 – 3:40 Eliot Ludvig (Warwick University)
"The Irresistible Urge to Know Right Now: Costly Information-Seeking in Humans and Other Animals"
3:40 – 4:20 Goren Gordon (Tel Aviv University)
"Novel Quantitative Model-Based Curiosity Assessment Tools"
4:20 – 5:00 Edith Law (University of Waterloo)
"Teachable Robots for Enhancing Student Curiosity"
5:00 – 5:40 Pierre-Yves Oudeyer (INRIA, France)
"Theoretical Models of Curiosity and Educational Technologies"

Evening: Dinner for speakers

| PROGRAM |
Saturday, December 8

Session 4: Curiosity, Development, and Education II

Chair: Pierre-Yves Oudeyer (INRIA, France)

8:30 – 9:10 Suzanne Hidi (University of Toronto)
"Einstein's Error and Issues that Those of Us in Psychology Need Neuroscientists to Study"

9:10 – 9:50 Elizabeth Bonawitz (Rutgers University)
"Curiosity in the Developing Mind: How Prior Beliefs, Evidence, and Affect Influence Preschooler's Choices to Learn"

9:50 – 10:20 Natalie Rusk (MIT Media Lab)
"Curiosity to Create: How Making Motivates Learning"

10:20 – 10:50 Discussion
10:50 – 11:00 Coffee

Session 5: Curiosity, Knowledge Building, and Network Theory

Chair: Arjun Shankar (Hamilton College)

11:00 – 11:40 Ilhan Inan (Koç University)
"Curiosity, Awareness of Ignorance, and the Mental Representation of Unknowns"

11:40 – 12:20 Perry Zurn (American University)
"Curiosity as Praxis: Styles and Stakes"

12:20 – 1:00 Danielle S. Bassett (University of Pennsylvania)
"Curiosity: A Practice of Knowledge Network Growth"

1:00 – 3:00 LUNCH

Session 6: Radicalizing Curiosity in the Academy

Chair: Perry Zurn (American University)

3:00 – 3:40 Arjun Shankar (Hamilton College)
"Curiosity and College Mental Health"

3:40 – 4:20 Chanda Prescod-Weinstein (University of New Hampshire)
"Curiosity and the End of Discrimination"

4:20 – 4:50 Discussion

4:50 – 5:20 General Wrap-Up Discussion

Generously funded by the Center for Curiosity, INRIA, France, as well as by the Department of Bioengineering and the School of Social Policy and Practice at the University of Pennsylvania.

This event is free and open to the public.

| ABSTRACTS |

Danielle S. Bassett (University of Pennsylvania)
Curiosity: A Practice of Knowledge Network Growth

Curiosity is often a treasured component of one's personality, commonly associated with information-seeking proclivities with distinct neurophysiological correlates. The markers of curiosity can differ substantially across people, suggesting the possibility that personality also determines the architectural style of one's curiosity. Yet progress in defining those styles, and marking their neurophysiological basis, has been hampered by fairly fundamental difficulties in defining curiosity itself. Here we offer and exercise a definition of the practice of curiosity as knowledge-network building. To unpack this definition and motivate its utility, we begin with a short primer on network science and describe how the mathematical object of a network can be used to map items and relations that are characteristic of bodies of knowledge. Next, we turn to a discussion of how networks grow, how their growth can be modeled, and how the practice of curiosity can be formalized as a process of network growth. We pay particular attention to how individuals may differ in how they build their knowledge networks, and discuss how the sort, manner, and action of building can be modulated by experience. We close with a discussion of how this definition of the practice of curiosity motivates new experiments and theory development at the interdisciplinary intersection of network science, personality neuroscience, education, and curiosity studies.

Elizabeth Bonawitz (Rutgers University)
Curiosity in the Developing Mind: How Prior Beliefs, Evidence, and Affect Influence Preschoolers' Choices to Learn

Do children take actions to support learning? When does curiosity arise and how can it be fostered in early childhood? I will present research suggesting that preschoolers' curiosity is driven by a surprisingly sophisticated ability to evaluate "information gain"—depending on the expected utility of evidence from particular actions, given the learners' current beliefs. Additional studies will be presented that explore other factors that foster curious states, such as the role of affect, positive prediction error, and empowerment.

Antoni Rodriguez-Fornells (University of Barcelona)
The Intrinsic Reward of Learning a New Language

During the last decade we have accrued important knowledge regarding the cognitive and neural mechanisms involved in the hard process of learning a second language, these studies being essential to understand how the brain of bilinguals is sculpted. However, it is still unknown which are the neural processes underlying the human interest and drive to learn a language and what maintains in time this effortful activity. Recent theoretical models have proposed that during human evolution, emerging language-learning mechanisms might have been glued to phylogenetically older subcortical reward systems, reinforcing human motivation to learn a new language. Supporting this hypothesis, we recently showed that adult learners exhibited robust functional MRI activation in core reward-pleasure centers (ventral striatum) when successfully learning the meaning of new words. These results provided the first neural evidences of the important role of reward and motivation during language learning and supporting the idea that the strong coupling between neocortical language regions and the subcortical reward system provided a crucial advantage in humans for successfully acquiring linguistic skills. Following this research, we observed that successful active language learning (without the presence of external feedback) triggered also the activation of

motivation-reward memory circuits [midbrain dopaminergic circuits and the hippocampus]. Thus, intrinsic reward after active and successful learning seems to be strongly coupled with motivated-memory encoding processes needed to ensure future recall success.

We believe this intrinsically motivated-learning mechanism might be crucial for boosting formation of long-term memories, especially in our everyday lives, as we continually acquire new knowledge in the absence of any obvious immediate reward. A key question for the future is whether tapping into intrinsically rewarding forms of learning might be a more effective educational strategy than relying on external feedback and incentives. A second critical issue is to which extent the implication of this reward-learning intrinsic mechanisms could predict the success of the process of learning a new language (considering the contextual and sociolinguistic factors surrounding the learning experience). This could be crucial for improving the design of educational programs—for example, in teaching foreign languages—and also for improving the recovery of verbal skills lost after stroke.

Goren Gordon (Tel Aviv University)
Novel Quantitative Model-Based Curiosity Assessment Tools

While curiosity has been studied in depth, only a few assessment tools have been devised. The most used tools are self-report questionnaires and subjective observation of behavior. In order to overcome many of these tools' shortcomings, we have devised several novel quantitative model-based curiosity assessment tools. First, we use social robots as the experimenter, interaction object, and assessment tool in a novel paradigm to assess physical curiosity (i.e. expressions of curiosity with the body), as well as social curiosity (i.e. actively seeking social information during a social interaction). Second, we developed several tablet games, each addressing a different aspect of curiosity (e.g. question asking, free exploration), as a novel tool for children's curiosity assessment. Combined, we envision a radical change in the evaluation of curiosity intervention protocols, which can be based on quantitative pre-post curiosity assessment foundations.

Jacqueline Gottlieb (Columbia University)
Uncertainty Reduction and Reward Motives in Curiosity and Decision Making

Curiosity is one of the most baffling motives in human behavior. When we perform a familiar task, we seek information to increase our chances of achieving our goal; for instance, we look out the window to see if we should take an umbrella and avoid getting wet. But in the case of curiosity, value becomes apparent only after the investigation; humans became interested in fire long before they could foresee the tremendous value that their interest would bring. This ability raises difficult questions about the motives that drive curiosity and the ways in which we select the questions we become curious about (given the practically infinite set of questions we could potentially explore). I will argue that curiosity rests on our ability to imagine internal states we expect to experience after gathering information. I will show that humans have intrinsic preferences over the prospect of reducing uncertainty (holding beliefs that are more or less accurate) and the prospect of obtaining positive (pleasant) observations, and these two motives combine with different strengths in different individuals, producing different curiosity "styles". I will also show that humans gather more information than is strictly necessary for performing a task, suggesting that informational preferences shape many of our actions. I propose that curiosity is a system of intrinsic motivation that arises from the interaction of fundamental processes of sensorimotor control with systems of emotion and motivation.

Matthias Gruber (Cardiff University)
States of Curiosity Enhance Hippocampus-Dependent Memory

It is widely assumed that curiosity has a fundamental impact on learning and memory. Although initial laboratory-based studies on curiosity states have indeed demonstrated curiosity-related memory enhancements, we still have a very limited understanding of the neural and cognitive mechanisms that distinguish curiosity-guided learning. In my talk, I will present a series of behavioral and neuroimaging studies that provide evidence of how curiosity states prioritize learning and memory consolidation for high-curiosity information but also for incidental information encountered during high-curiosity states. Critically, the stimulation of curiosity—but not the satisfaction of curiosity—mediates the positive effects of curiosity on memory via activation of the dopaminergic circuit and the hippocampus, which are essential brain areas for forming long-lasting memories. Interestingly, these findings and recent ideas about curiosity from psychology, cognitive neuroscience, and animal neuroscience show parallels to the neural mechanisms associated with reward, novelty, prediction errors, and exploration. Drawing from this evidence, I will present a new theoretical framework that can guide future research on how curiosity states lead to enhanced learning and memory consolidation of curiosity targets and incidental information.

Suzanne Hidi (University of Toronto)
Einstein's Error and Issues that Those of Us in Psychology Need Neuroscientists to Study

Einstein famously said that he was "only passionately curious." I maintain that he was passionately interested. In my talk, I will argue that interest and curiosity are distinct concepts and this distinction has scientific importance. Interest, defined as a cognitive and motivational variable that can be supported to develop, provides for a different type of information search than does curiosity. I will also point to the complications of the work by neuroscientists who have focused on information search related to simple, trivia question-type tasks, and have not yet considered the distinction between curiosity and interest. To disambiguate curiosity and interest is critical for educational practice that aims to facilitate learners' longer-range engagement with content. Finally, I will suggest four topics that future neuroscientific investigations could consider: 1) eye movements and information search, 2) affect generated by curiosity and interest, 3) causes of curiosity and interest, and 4) information prediction error. The results of such investigations could contribute not only to distinguishing curiosity from interest, but also to establishing the different types of information search that are their outcomes.

Ilhan Inan (Koç University)
Curiosity, Awareness of Ignorance, and the Mental Representation of Unknowns

I argue that to be curious about something is to be in a peculiar type of mental state that requires its agent to be aware of their ignorance concerning the object of curiosity. This, I shall argue, can be achieved only by those kinds of beings that have the capacity to form mental representations of unknowns. By distinguishing between the content of a mental representation and its object, I shall argue that only those beings that can merge representations of experienced entities to form novel complex representations of unexperienced entities (which are partially or completely unknown to the agent) have such a capacity. Appealing to the distinction between merely imagistic representations on the one hand, and representations that have semantic and conceptual content on the other, I raise the question (which I shall not attempt to answer) as to whether a being that does not possess a language can represent something as being unknown and thus become curious. I shall focus more on conceptual and especially linguistic representations and argue that our semantic knowledge of the meaning of a linguistic expression does not always require us to have knowledge of the referent of

the very same expression. That "word knowledge" does not always give us "world knowledge" is what gives rise to the possibility of representing something as being unknown. In the final part of the paper, I shall discuss some of the interesting implications of my theses, as well as the novel questions that it raises, with regard to the recent ongoing research on curiosity in psychology, neuroscience, and education.

Edith Law (University of Waterloo)
Teachable Robots for Enhancing Student Curiosity

Curiosity—the intrinsic desire for new information—has been shown to enhance learning, promote information-seeking behaviour, and improve memory retention. My long-term goal is to develop algorithmic and interaction techniques to support curiosity-driven teaching and learning in education contexts, through a teachable robot agent that acts as a peer to students.

In this talk, I will describe our recent research efforts towards this long-term goal of building a conversational robot that inspires curiosity in students. First, I will discuss several lab studies where we explicitly engineered the robot's behaviour to elicit curiosity. Second, I will discuss a participatory design study, involving interviews, role playing (i.e., robot puppeteering), and group brainstorming, where we probed the perspectives of teachers on how a conversational robot can help enhance students' interest and curiosity in the classroom. I will conclude by discussing the implications of these curiosity-inducing designs, the challenges, and potential research directions.

Lieke van Lieshout (Radboud University)
How Do Uncertainty and Reward Affect Curiosity?

Curiosity is a biological drive, but little is known about its behavioral and neural mechanisms. In a series of experiments, we disentangled the contribution of information uncertainty and reward approach bias to curiosity in humans. In a first study, we designed a novel lottery task in which we manipulated the uncertainty of the lottery outcome. Curiosity increased linearly with outcome uncertainty, which in turn was associated with BOLD signal in parietal cortex at the time of curiosity induction. The size of the information update at the time of curiosity relief was associated with BOLD signal in the insula. These findings point to a role of curiosity as a drive to improve one's current world model and implicate the parietal cortex and insula in this fundamental trait. In a second study, we adapted the lottery task to assess the effect of the (reward/punishment) valence of trial outcomes. Results revealed that curiosity was higher for the win context compared with the loss context, and increased with increasing outcome uncertainty, but there was no interaction between reward context and outcome uncertainty. These results suggest that curiosity is independently influenced by the potential for information updating and reward maximization.

Elliot Ludvig (University of Warwick)
The Irresistible Urge to Know Right Now: Costly Information-Seeking in Humans and Other Animals

People are often incredibly impatient to satisfy their curiosity—an impulse further amplified in the age of the internet where any fact is readily Googled. In other animals, this desire for information has been shown to lead to clearly sub-optimal behaviors. When faced with delayed probabilistic rewards, pigeons, rats, starlings, and monkeys will forego additional food or water to find out early whether the reward will eventually be arriving. Here, in two experiments, we show that 1) people also have a strong preference for resolving a gamble early, but only about desirable outcomes and 2) people will pay a significant cost for that information, even when no instrumental benefit can be gained. We developed a computational model of these information-seeking behaviors based on reinforcement

learning, where agents decide by mental sampling from past outcomes and learning by trial and error. The key insight from the modeling is that creatures behave as though good news about winning outcomes is rewarding in and of itself. I conclude with some suggestions about how this model might provide insights into the nature of curiosity.

Pierre-Yves Oudeyer (INRIA, France)
Theoretical Models of Curiosity and Educational Technologies

I will discuss the bidirectional causal interactions between curiosity and learning and how understanding these interactions can be leveraged in educational technology applications. In particular, I will discuss the learning progress (LP) hypothesis, which posits a positive feedback loop between curiosity and learning, and show how it enables us to predict various developmental phenomena in infants. Then, I will present recent work exploiting these conceptual and computational models in educational technologies, showing in particular how intelligent tutoring systems can be designed to foster curiosity and learning.

Natalie Rusk (MIT Media Lab)
Curiosity to Create: How Making Motivates Learning

Many people become curious to learn only when the information and ideas can be applied to something they're interested in making and sharing. The coding and maker movements present new opportunities to spark the interest of students who are not engaged in traditional classrooms. How can we design environments—both in-person and online—that encourage and support more young people to learn through the process of making projects? I will share stories and principles based on extensive research developing international educational initiatives, including the Scratch online community and the global network of Clubhouse community centers.

Arjun Shankar (Hamilton College)
Curiosity and College Mental Health

This paper excavates the relationship between curiosity, value, and student mental health on university campuses. I will provide some theoretical starting points, focusing in on an anthropological theory of curiosity as a knowledge-emotion situated within nested regimes of value. I will connect this theoretical discussion with the issue of mental unwellness before progressing into a discussion of how curiosity is commodified within educational discourse, channeling all forms of curiosity towards the singular path of economic mobility and drive. I then analyze interview data with a group of college age students to provide examples for how this particular form of curiosity affects their way of seeing themselves, their goals and understanding of success, and, in turn, produces emotional states that are indicative of campus sickness. In the conclusion, I will suggest several productive avenues for further research into capitalism's effects on student curiosity and mental unwellness.

Chanda Prescod-Weinstein (University of New Hampshire)
Curiosity and the End of Discrimination

Systemic discrimination on the basis of gender and race, among other ascribed identities, harms minoritized people. In the process, it alters epistemic outcomes. In this talk, I will discuss what it means to confront the challenges associated with invoking an intersectional analysis of knowledge production in science and how this shapes creativity and curiosity in the field. Engaging new ways of

understanding how we produce scientific knowledge is a creative approach to solving deeply entrenched problems that shape the social phenomenon we call “science.”

Robert Wilson (University of Arizona)
The Role of Information and Randomization in Exploration and Exploitation

When you go to your favorite restaurant, do you always get the same thing, or do you try something new? Sticking with an old favorite ensures a good meal, but exploring other options might yield something better—or something worse. This simple conundrum, choosing between what you know and what you don’t, is called the explore-exploit dilemma. Whether it’s deciding on a meal, a vacation destination or a life partner, this is an important problem for humans and animals to solve.

In this talk, I will discuss how humans solve the explore-exploit dilemma using a mixture of two distinct strategies: directed exploration, in which information seeking drives exploration by choice, and random exploration, in which behavioral variability drives exploration by chance. In addition, I will show how these two distinct strategies appear to rely on dissociable cognitive and neural systems. Finally, I will present a unifying account of directed and random exploration in which they emerge naturally from a kind of mental simulation known as “Deep Exploration.”

Perry Zurn (American University)
Curiosity as Praxis: Styles and Stakes

For millennia, curiosity has been defined as a desire, a lust, an appetite, an impulse, an interest, a motivation, and a drive-state. That is, curiosity has been understood primarily as a propellant of action. While this approach has produced significant study of individual curiosity, it has left underdeveloped our understanding of collective and/or systemic curiosity. What if curiosity were less the propellant of the action than the action itself? In this talk, I explore the hypothesis that curiosity is a series of investigative practices, traceable in collectives and systems, as much as in individuals. Drawing on the history of Western thought, I develop several styles, or kinesthetic signatures, of curiosity as it appears *in practice*. I then explore the stakes of these practices in social dynamics, generally, as well as in educational settings, more specifically. Grappling with the practice of curiosity in political resistance movements and critical pedagogy, I close with some recommendations for centering the discussion of curiosity within efforts to diversify higher education.

| Speaker Bios |

Danielle S. Bassett is Eduardo D. Glandt Associate Professor in the Department of Bioengineering at the University of Pennsylvania. She is most well-known for her work blending neural and systems engineering to identify fundamental mechanisms of cognition and disease in human brain networks. She has received multiple prestigious awards, including American Psychological Association's 'Rising Star', Alfred P. Sloan Research Fellow, MacArthur Fellow Genius Grant, Early Academic Achievement Award from the IEEE Engineering in Medicine and Biology Society, and Office of Naval Research Young Investigator. She also recently received the Lagrange Prize in Complexity Science and the Erdos-Renvi Prize in Network Science. She is the author of more than 206 peer-reviewed publications, which have garnered over 14,500 citations, as well as numerous book chapters and teaching materials. She is the founding director of the Penn Network Visualization Program, a combined undergraduate art internship and K-12 outreach program bridging network science and the visual arts. Her work has been supported by the Center for Curiosity, the National Science Foundation, the National Institutes of Health, the Army Research Office, the Army Research Laboratory, the Alfred P. Sloan Foundation, the John D. and Catherine T. MacArthur Foundation, the Office of Naval Research, and the University of Pennsylvania.

Elizabeth Bonawitz is Assistant Professor of Psychology and member of the Institute for Data Science, Learning, and Applications at Rutgers University, Newark. Her research bridges two research traditions: Cognitive Development and Computational Modeling. By bridging these methods, she hopes to understand the structure of children's early causal beliefs, how evidence and prior beliefs interact to affect children's learning, the developmental processes that influence children's belief revision, and the role of social factors (such as learning from others) in guiding learning.

Antoni Rodriguez-Fornells got his PhD at the University of Barcelona and worked afterwards at the University of Magdeburg (Germany, 1999-2002) as a postdoctoral researcher. His main topics of research have been language processing and cognitive control functions (performance monitoring). In 2002, he got a "Ramón y Cajal" research position from the Spanish Government and afterwards he joined ICREA (Catalan Institute for Research and Advanced Studies) as a Research Professor. Since then, he has created his research group (Cognition and Brain Plasticity Unit, CDBU) at the Hospital Bellvitge Biomedical Research Institute, University of Barcelona, devoted to the study of learning process and brain plasticity in healthy and brain damaged patients. His research is inherently interdisciplinary and requires expertise in interfacing research fields as brain plasticity, neuroimaging, brain development, learning and memory mechanisms. Recently, his main research has been focused on the investigation of the neural mechanisms involved in language learning in adults and infants (and especially its interface with cognitive control functions and motivation-reward mechanisms). This approach has been recently applied to understand preserved learning mechanisms in aphasic people.

Goren Gorden has a BMSc, MSc in physics, and an MBA from Tel-Aviv University, Israel. In the Weizmann Institute of Science, he finished one PhD under the supervision of Prof. Gershon Kurizki, on dynamical quantum decoherence control, a way to facilitate the emergence of quantum computers; and another PhD under the supervision of Prof. Ehud Ahissar, where he developed and extended mathematical models of curiosity, analyzed animal's behaviors with it and implemented it in robots that learned about their own body, similar to infants. He did his postdoc with Prof. Cynthia Breazeal at the Personal Robots Group in the MIT Media Lab, where he studied how curious robots

interact with curious children. He discovered that curiosity can be "contagious," i.e. children playing with a curious robot became more curious themselves. Goren now heads the Curiosity Lab at Tel-Aviv University, where he develops state-of-the-art computational models of curiosity; quantitative assessment tools for curiosity; and curious social robots that learn about other agents in their environment, all by themselves. Goren is also interested in scientific education and has a Teaching Certificate from MIT. He develops quantum computer games that teach quantum physics to children via play as well as gives popular lectures on quantum physics, the brain, and inter-disciplinary thinking.

Jacqueline Gottlieb is Professor of Neuroscience in the Mortimer B. Zuckerman Institute for Mind, Brain, and Behavior at Columbia University, New York. She completed her undergraduate education in cognitive science at the Massachusetts Institute of Technology, and her PhD in neurobiology at Yale University. In her doctoral dissertation, Dr Gottlieb described a new cortical area devoted to smooth pursuit eye movements in the frontal cortical lobe. She then moved to the National Institute of Health where she turned to the study of visual attention in the frontal and parietal lobes. In a series of influential studies, she established the visual (rather than motor) nature of the parietal attention response, and the integration of bottom-up and top-down signals that characterizes this response. In 2001, Dr. Gottlieb joined the Department of Neuroscience at Columbia University, where she continued to develop innovative approaches to attention and decision making and became a pioneer in the study of active information sampling and curiosity. Her current work includes interdisciplinary collaborations with researchers in cognitive neuroscience, economics, biomedical engineering, and artificial intelligence. In addition, she has been the organizer of scientific conferences on curiosity, attention and decision making in Europe and the United States, and the recipient of prestigious awards including the McKnight Scholarship, Klingenstein Fellowship, and Human Frontiers research grants.

Mathias Gruber is the Group Leader of the Motivation & Memory Lab at the Cardiff University Brain Research Imaging Centre (CUBRIC), UK. He holds a PhD in Cognitive Neuroscience from University College London and was a postdoctoral scholar at the University of California, Davis. Gruber's current research is funded by the European Research Council, the Welsh government, and the Welcome Trust.

Suzanne Hidi is an Adjunct Professor at The Ontario Institute for Studies in Education, University of Toronto. Her early research focused on the cognitive aspects of academic writing, such as task demands related to producing written summaries. Hidi's interest shifted to motivational issues in general and interest research specifically. She is the co-editor of *The Role of Interest in Learning and Development*. (Lawrence Earlbaum Associates) and *Motivation and Writing* (Elsevier Science). More recently, she is also the co-author of *The Power of Interest for Motivation and Engagement* (Routledge, 2016), which integrates neuroscientific research with behavioral findings in order to identify and explain the power of interest. Hidi's current focus is on the links between neuroscience and educational psychology. She co-edited the American Educational Research Association volume, *Interest in Mathematics and Science Learning* (AERA, 2015), *The Cambridge Handbook of Motivation and Learning* (in press), and is an invited Associate Editor of a Special Issue of *Educational Psychology Review* on Curiosity and Interest: Conceptual Distinctions, Relations, and Implications for Educational Practice. Her total Google Scholar Citations exceed 15,500.

Ilhan Inan recently joined the Philosophy Department at Ko University in Istanbul. Prior to that, he taught at Bo azi i University Philosophy Department for twenty years. He is the author of *The Philosophy of Curiosity* (Routledge, 2012) and his philosophical articles appeared in many respected international and national journals including *Philosophical Studies*. He works on philosophy of

language, broadly construed, to include philosophy of curiosity, evolution of language, creativity, and inostensible reference. He has published articles on how curiosity relates to reference, representation, belief, acquaintance, truth, knowledge, ignorance, and creativity. Currently he is working on an article on awareness of ignorance and a book manuscript on the subject of truth. Both works were motivated by his theory of curiosity: his theory that awareness of ignorance is based on the notion of mental representation of unknowns, and the referential theory of truth which he argues for in his book grew from his theory of curiosity based on the notion of reference to the unknown, or inostensible reference. Inan earned his PhD in philosophy from University of California, Santa Barbara.

Edith Law is Assistant Professor at the David R. Cheriton School of Computer Science at University of Waterloo, where she co-directs the HCI Lab and is affiliated with the AI group and the Game Institute. Her research focuses on developing new methodologies for combining humans and AI (e.g., human-in-loop systems, crowdsourcing, etc.) as well as studying how people make sense of intelligent systems (e.g., in terms of issues related to transparency, engagement, trust, and collaboration). She is the co-author of *Human Computation* (2011) and helped create the first AAAI Conference on Human Computation and Crowdsourcing (HCOMP). Her work on games with a purpose, large-scale collaborative planning, and curiosity as an incentive mechanism have won several best paper honorable mentions at the ACM SIGCHI conference.

Lieke van Lieshout is a PhD Candidate at the Donders Institute for Brain, Cognition, and Behaviour, Centre for Cognitive Neuroimaging at Radboud University and Radboud UMC. She investigates the behavioral and neural mechanisms underlying non-instrumental curiosity under the supervision of Prof. Floris de Lange and Prof. Roshan Cools.

Elliot Ludvig is Associate Professor of Psychology at the University of Warwick. His research examines how humans and other animals learn to make effective decisions. He completed his Ph.D. in Psychological and Brain Sciences at Duke University working on timing in pigeons. In his peripatetic research career, he has also spent time studying the behaviour of humans, animals, and machines at Princeton University, the Technion, the University of Alberta, PsychoGenics Inc., and Rutgers University.

Pierre-Yves Oudeyer is Research Director (DR1) at Inria and head of the Inria and Ensta-ParisTech FLOWERS team (France). Previously, he was a permanent researcher in Sony Computer Science Laboratory for 8 years (1999-2007). He studied theoretical computer science at Ecole Normale Supérieure in Lyon and received his Ph.D. in artificial intelligence from the University Paris VI, France. He has been studying lifelong autonomous learning, and the self-organization of behavioural, cognitive and cultural structures, at the frontiers of artificial intelligence, machine learning, cognitive sciences, and educational technologies. He has developed models of intrinsically motivated learning, pioneered curiosity-driven learning algorithms working in real world robots, and developed theoretical frameworks to understand better human curiosity and autonomous learning. He also studied mechanisms enabling machines and humans to discover, invent, learn, and evolve communication systems. He has published two books, more than 100 papers in international journals and conferences, holds 8 patents, gave several invited keynote lectures at international conferences, and received several prizes for his work in developmental robotics and on the origins of language. In particular, he is laureate of the Inria-National Academy of Science young researcher prize in computer sciences, and of an ERC Starting Grant EXPLORERS. He is also editor of IEEE CIS Newsletter on Cognitive and Developmental Systems where he organizes interdisciplinary dialogs in cognitive science, AI and robotics, as well as associate editor of IEEE Transactions on Cognitive and Developmental Systems and Frontiers in Neurorobotics. He was chair of IEEE CIS Technical

Committee on Cognitive and Developmental Systems in 2015-16. He is also working actively for the diffusion of science towards the general public, through the writing of popular science articles and participation in radio and TV programs as well as science exhibitions.

Natalie Rusk is a research scientist in the Lifelong Kindergarten Group at the MIT Media Lab. She is one of the creators of the Scratch programming language, which more than 20 million children use to create interactive stories, games, and animations and share them with others around the world. She is a founder of the Clubhouse after-school network, where youth design projects that build on their interests across 100 community centers in 18 countries. She is author of the *Scratch Coding Cards* and editor of *Start Making! A Guide to Engaging Young People in Maker Activities.* She earned a Master's from Harvard Graduate School of Education and a PhD in child development from Tufts University.

Arjun Shankar is a lecturer at Hamilton College. His work brings together theories in globalization and development, literary and visual ethnography, affect theory, and curiosity studies. His research has been published in *American Anthropologist, Visual Anthropology Review*, *Anthropology and Humanism*, and *Visual Communication Journal*. His current book project, *How Development Feels,* re-theorizes the concept of "development" given the emergence of transnational diasporic networks, the increased use of digital technologies, and human rights discourses that together influence how social change can and should occur. His work has been supported by a Fulbright-Hays DDRA Fellowship and a Zwicker Award, amongst others. He is a member of the Society of Visual Anthropology Board and part of the photo-essay editorial collective for *Cultural Anthropology*. As a media maker as well as a scholar, Arjun encourages teachers and researchers to "think with multimodality," making the audiovisual part of research design as well as classroom instruction.

Chanda Prescod-Weinstein will be an Assistant Professor of Physics at the University of New Hampshire, starting in January. She is a theoretical particle physicist and cosmologist as well as researcher in feminist science, technology, and society studies. One of under 100 Black American women to ever hold a PhD in physics, she has a particular interest in the social and epistemic location of Black and Indigenous women in American physics and astronomy.

Robert Wilson studies the neuroscience of reinforcement learning and decision making in humans with a particular emphasis on the tradeoff between exploration and exploitation. Bob got his PhD in bioengineering from Penn in 2009 with Leif Finkel, after which he did a postdoc at Princeton with Jon Cohen and Yael Niv. Since 2015, he has been Assistant Professor of Psychology and Cognitive Science at the University of Arizona where he directs the NRD lab.

Perry Zurn is Assistant Professor of Philosophy and the Co-Director of the Curiosity, Mindfulness, and Education Lab at American University. His research contributes to curiosity studies and the philosophy of punishment, and more broadly concerns research ethics and political philosophy. He is the author of *The Politics of Curiosity* (University of Minnesota Press, under contract) and the co-author of *Curious Minds* (MIT Press, under contract). Zurn is also the co-editor of *Curiosity Studies: Toward a New Ecology of Knowledge* (University of Minnesota Press, forthcoming), *Intolerable: Writings from Michel Foucault and the Prisons Information Group, 1970-1980* (University of Minnesota Press, forthcoming), *Active Intolerance: Michel Foucault, the Prisons Information Group, and the Future of Abolition* (Palgrave, 2016), and a special issue of the *Carceral Notebooks* 12 (2017). His essays and translations have appeared in the *American Philosophical Association LGBT Newsletter*, *Journal of the American Psychoanalytic Association*, *Journal of French and Francophone Philosophy*, *Modern and Contemporary France*, *philoSOPHIA*, *Radical Philosophy Review*, and *Zetesis*. Zurn is also committed to diversity work; he served as Program Manager for the

McNair Scholars Program at DePaul University (2011-2015), as member of the American Philosophical Association's Diversity Institute Advisory Panel (2015-2018), and currently serves as chair of the APA Committee on LGBTQ People in the Profession (2018-2021).

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This event is free and open to the public.
Contact Perry Zurn (pzurn@american.edu).