Monell Chemical Senses Center
2023 Spring Colloquium

April 4, 2023

Sensory Control of Feeding Behavior

April 5, 2023

Natural Language Processing

Note: As part of our green meeting goals, this book is completely virtual and links to other resources typically available at the Spring Colloquium.

Our Publications List and Media Mentions are available on our website and available for viewing at your leisure.

If you have any questions about these materials email our Director of Communications, Karen Kreeger, at kkreeger@monell.org.

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SCHEDULE OF EVENTS

Tuesday April 4th

“Sensory Control of Feeding Behavior" Chair: Guillaume de Lartigue		
12:30 pm	**Welcome Session**	
1:00 pm	Sensory Nutrition: How Our Senses Shape Our Feeding Decisions	G. de Lartigue
1:30 pm	A Matter of Taste: Metabolic and Hedonic Aspects of Sugar Sensing	L. Schier*
2:00 pm	How Do Gut Signals Influence Brain Activity?	A. Alhadeff
2:30 pm	**Coffee Break**	
2:45 pm	Cortical Modulation of Feeding Mediated by Sensory Stimuli	S. Stern*
3:15 pm	Top-Down Control of Foraging	E. P. C. Azevedo*
3:45 pm	Motivational State Governs Lateral Hypothalamic Control of Food Seeking	M. Rossi*
4:15 pm	Maternal Diet During Pregnancy and Lactation Can Negatively Impact Offspring Reward Circuits	V. Paille*

Wednesday April 5th

“Natural Language Processing" Chair: Danielle Reed, Co-Chair Ha Nguyen		
8:30 am	**Welcome Session**	
9:00 am	Introduction: Value of Natural Language Processing	D. Reed
9:25 am	Too Sweet or Not Too Sweet? A Cross-National NLP Perspective	V. Parma
9:50 am	What We Talk About When We Talk About Smell	P. Meyer*
10:15 am	Understanding PNL, Panelist’s Natural Language, with Textual Analysis	S. Lê*
10:40 am	**Coffee Break**	
10:55 am	Losing the Sense of Smell Does Not Disrupt Processing of Odor Words	L. Speed*
11:20 am	Data-Driven and Survey-Based Approaches to Obtaining the Semantic Organization of Olfactory Vocabularies	T. Hörberg*
11:45 am	Reading Between the Lines: Language Insights into the Impact of Smell Loss on Quality of Life	P. Dalton
12:10 pm	**Closing Remarks**	

***Guest Speakers**

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Presentation Abstracts

Sensory Nutrition: How Our Senses Shape Our Feeding Decisions

Guillaume de Lartigue

Food is not only necessary to sustain life, but it also plays a crucial role in shaping our behavior and decision-making. The human brain is wired to allocate a significant amount of cognitive effort towards ensuring that our energy needs are met efficiently. To achieve this, we rely on the sensory properties of food to determine what, where, and how much to eat. This optimization provides a competitive advantage by maximizing time spent on other important activities while efficiently satisfying metabolic requirements.

The sensory properties of food, including sight, smell, taste, and texture, all play a vital role in influencing our feeding decisions. Additionally, interoception, the ability to sense information about our internal state, is an often-overlooked critical factor that impacts food intake. After a meal, rapid communication between the gut and the brain relays information about the nutrients and calories consumed, engaging multiple central circuits that influence both acute and long-term feeding behaviors.

Understanding how the brain integrates internal information about food can serve as a foundation for exploring different aspects of sensory nutrition. I will discuss new developments in how the brain integrates internal information. This will serve as a foundation for exploring different aspects of sensory nutrition and feeding decisions by our guest speakers. By delving into taste, hunger, reward, foraging, early life nutrition, and predictive learning, we can gain valuable insights into the significance and importance of the sensory properties of food, and how they shape our behavior.

A Matter of Taste: Metabolic and Hedonic Aspects of Sugar Sensing

Lindsey Schier

Americans chronically consume too much sugar, a palate-pleasing habit that can be detrimental to metabolic health. For many years, the proverbial "sweet tooth" has shouldered the blame. The sensation we refer to as sweet begins with the activation of a heterodimeric G protein coupled receptor—T1R2+T1R3. Binding of any one of its various ligands—simple sugars, low calorie sweeteners, or D-amino acids—leads to the release of dopamine in central reward circuits and drives ingestive behaviors. Loss of this receptor virtually eliminates the appeal of sugars and other sweeteners. Yet, several findings over the years have suggested that certain saccharides (i.e., glucose) can be rapidly detected via alternative sensors in the taste system. In this talk, I will review recent evidence from my lab and others' demonstrating the presence of multiple glucose-specific signaling intermediaries in taste bud cells of rodents. I will discuss how (at least some of) these glucosensors are recruited during times of energetic need and/or by dietary factors to prioritize the detection and consumption of metabolically valuable fuels over other sweet-tasting substances. The collective findings in rodents suggest that sensory and metabolic information are conveyed through distinct, but possibly intersecting, taste pathways to guide nutrient intake. Considering that humans commonly consume mixed diets, comprised of both sweeteners and caloric sugar, more work is needed to fully understand the factors that recruit and shape these key sensors at the frontlines of nutrition.

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How Do Gut Signals Influence Brain Activity?

Amber Alhadeff

Hunger and food intake are tightly regulated by complex and coordinated gut-brain interactions. While we know some mechanisms through which the gut communicates with the brain, our understanding of how nutrients impact in vivo neural activity is in its infancy. Our previous work demonstrated the ability of nutrients in the gut to rapidly modulate neural activity in a small population of hunger-sensitive, hypothalamic neurons expressing agouti-related protein (AgRP). Fats, sugars, or proteins alone are each capable of inhibiting AgRP neuron activity. How are these nutrients in the gut signaled to the brain to update nutritional status in real time? Because individual macronutrients engage specific receptors in the gut to communicate with the brain, we reasoned that macronutrients may utilize different pathways to reduce activity in AgRP neurons. We therefore explore the relative roles of vagal afferent, spinal afferent, and gut peptide signaling in the regulation of AgRP neuron activity and food intake using fiber photometry to monitor AgRP neuron calcium dynamics as a proxy for neural activity. Our results demonstrate that different gut-brain pathways mediate the effects of fats and sugars on hypothalamic neuron activity. Further focusing on the monosaccharides glucose and fructose, we demonstrate that they too have different effects on AgRP neuron activity, where equi-caloric concentrations of oral or gut-delivered fructose are less effective than glucose at inhibiting AgRP neuron activity. Further, the time to maximally inhibit AgRP activity was slower after fructose infusion compared to glucose infusion, raising the possibility that hormonal signaling may mediate the effects of fructose. Indeed, fructose engages gut peptide signaling to inhibit activity in AgRP neurons, and ongoing studies seek to identify the gut-brain mechanisms mediating these effects. Overall, since AgRP neurons drive food intake, understanding the negative regulators of hunger circuits may inform new and effective weight loss strategies.

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Cortical Modulation of Feeding Meditated by Sensory Stimuli

Sarah Stern

An important goal of brain function is to maintain balance, also known as homeostasis. However, this balance can be broken, as indicated by the rise in rates of obesity and eating disorders. The insular cortex is a brain region hypothesized to play a role in flexible decision making, but how this might contribute to non-homeostatic feeding behaviors is not well understood. We hypothesized that the insular cortex integrates internal state and external sensory information to flexibly alter feeding behavior in a non-homeostatic manner. Using a combination of viral tracing, molecular profiling, behavioral and calcium imaging studies, we show that a novel population of neurons in the insular cortex, marked by nitric-oxide synthase-1, specifically mediate learned feeding behaviors, but play no role in homeostatic food intake. We then investigated the mechanisms by which this population alters food consumption. Overall, we find that the insular cortex plays a top-down role in controlling food intake through predictive learning about the surrounding environment.

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Top-Down Control of Foraging

Estefania Azevedo

Rapidly detecting novel sensory information enables animals to properly adjust their behavior in response to changing environmental demands. For example, foraging for food requires efficiently detecting the availability of food or the presence of a predator in complex environments. In our laboratory we want to understand how the brain processes sensory information to discriminate between what is food and what is a threat and how novel information can guide decision-making and control feeding behavior. Using state-of-the-art techniques in neuroscience, from in vivo calcium imaging, activity-based transcriptomics and animal behavior, we identified two complementary populations of cells that suppress feeding behavior when in the presence of opposite stimuli: a population of neurons in the dorsal hippocampus which express dopamine receptor 2 (dHdrd2), and another population of neurons in the lateral septum (LSNT) which express neurotensin. dHdrd2 neurons are silent during fasting and are activated by appetitive olfactory information while LSNT neurons are activated by multimodal aversive stimuli such as foot shocks or predator odor. Using optogenetics/chemogenetics we found that activation of dHdrd2 and LSNT neurons suppress feeding behavior. Chronic activation of LSNT neurons induces anorexia and anxiety-like behavior in mice mimicking chronic exposure to predator-rich environments.

Our data suggest that the subcortical systems contain specialized populations that can rapidly integrate novel, salient information and adjust feeding behavior accordingly. Our goal is to not only advance our knowledge of how the brain integrates sensory information to control behavior but also, from an applied perspective we hope to give novel insights to understand behavioral flexibility, stress and coping mechanisms in generalized anxiety, eating disorders, post-traumatic stress disorders and other mental illnesses.

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Motivational State Governs Lateral Hypothalamic Control of Food Seeking

Mark Rossi

The lateral hypothalamic area is a critical node in the neurocircuitry that controls motivated behavior. Distinct neuronal populations located within the lateral hypothalamus are known to exert control over feeding behavior, body weight, and energy homeostasis. However, due to its considerable functional, anatomical, and molecular heterogeneity, little is known about the roles that individual cell types play in regulating appetitive and consummatory behaviors. Even less is known about how lateral hypothalamic neurons work in concert with distributed brain circuits and peripheral signals to orchestrate feeding in response to changing metabolic demands. One of the largest neuronal populations in the lateral hypothalamus synthesizes and releases the excitatory neurotransmitter, glutamate. These glutamatergic neurons are known to negatively regulate feeding such that their transient activation rapidly suppresses food seeking and consumption. Despite these observations, the role that this population plays in influencing appropriate feeding behavior in health and disease remains largely uncharacterized. I will discuss the results of recent experiments aimed at understanding how lateral hypothalamic glutamatergic neurons integrate peripheral signals to guide feeding behavior in times of caloric surfeit and deficit. This work has shown that anatomically and molecularly defined subsets of lateral hypothalamic neurons tune their output in response to circulating factors to meet current energy demands. Together, these results indicate that the function of lateral hypothalamic glutamatergic neurons is flexibly modified to guide motivated behavior and that their dysfunction may underlie metabolic pathologies such as obesity.

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Maternal Diet During Pregnancy and Lactation Can Negatively Impact Offspring Reward Circuits

Vincent Paille

Epidemiological studies and experimental data indicate that malnutrition during pregnancy and childhood may contribute to metabolic disorders in adulthood, which may be associated with abnormal eating behaviors such as a heightened preference for palatable foods. These behaviors are believed to be linked to changes in reward circuits within the brain. While it is now widely recognized that dopaminergic function is impaired during a high-fat diet, the ontogeny of these circuits following an unbalanced perinatal diet remains poorly understood.

To address this gap in knowledge, we utilized two rat models to examine the effects of perinatal protein restriction or exposure to a Western-style diet on the development of brain reward circuits during three key stages of early life: childhood, adolescence, and young adulthood. Our study focused on palatable food preferences, patch-clamp recordings of the Nucleus Accumbens (a key structure in the reward pathway), and the molecular signatures of reward circuits.

Our findings demonstrated that, regardless of the perinatal diet, all pups exhibited a heightened preference for fatty and sugary foods during childhood. However, a balanced diet during childhood appeared to "shield" individuals from the hedonic effects of palatable foods during adolescence. Moreover, a balanced diet during childhood and adolescence lead to the establishment of normal food preferences in adulthood, thanks to the reorganization of the brain structures involved in food intake. Thus, adopting a healthy and balanced diet early in life may help reverse the negative effects of perinatal malnutrition on the altered food preferences observed in humans.

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Introduction: Value of Natural Language Processing

Danielle Reed

Moments of inspiration can lead to new products or new ways of selling old products, and these moments of inspiration can often seem both magical and obvious simultaneously. How can we cultivate these moments of inspiration? One way is through analyzing the written word, pooling together text from millions of writing examples on a specific topic, and distilling the essence into a few rules. This pooling and analysis of a text is an approach we call Natural Language Processing (NLP). I will provide an example of these moments of inspiration from the food world, derived from the analysis of 6,500 menus from restaurants, 650,000 dishes offered by the least to most expensive restaurants, and the distillation of a few rules. As an example of a rule, we learn that the more expensive restaurants describe dishes using the location of the food, e.g., from local farms, butchers, or bakers, fifteen times more than less expensive restaurants! Innovation can start once the rules are explained and followed (or broken in interesting ways) to delight the consumer! Similarly, we used this text analysis method on Amazon food reviews to learn that consumers report that some processed foods are far too sweet. This example from the food reviews and menus analysis shows that NLP is a potent tool for understanding how entrepreneurs sell food. A step forward would be to apply this approach to studying fragrance and the sense of smell, a symposium topic. NLP methods are a rational path to creativity and innovation.

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Too Sweet or Not Too Sweet? A Cross-National NLP Perspective

Valentina Parma

Sweet taste preference is an important determinant in greater intake of high-calorie sugary foods, which predisposes one to increased risk of obesity and related metabolic disorders. Some diets are richer in sugars than others, affecting sweet preferences. Using Natural Language Processing methods, online food product reviews can be harnessed to evaluate regional dietary exposure to sweetness and associated profiles of preference for sweetness. We designed a study to examine differences in sweetness level, liking, and ingredients in Amazon food products across five countries (China, France, Mexico, Turkey and USA). We scraped from country-specific Amazon domains all products included in the Amazon Fine Foods Dataset during the period from June 23, 2000 to November 3, 2022. Preliminary analyses evaluated a total of 554,046 reviews (2% China, 7% France, 16% Mexico, <1% Turkey and 75% USA) on a total of 74386 products. Reviews for each product were classified according to phrases included in the reviews (i.e., the phrase “too sweet” is classified as oversweet whereas “not too sweet” is classified as not oversweet), and star ratings and ingredient list were extracted and matched to each review. As hypothesized, preliminary analyses reveal regional trends for “oversweetness.” Sucrose was the most prevalent sweetener in the US and China whereas honey was more prevalent in France, Mexico, and Turkey. Sucrose and honey also received the most oversweet reviews across all countries. Sweeteners that received the highest rating (out of Amazon’s five-point scale) were Sucrose and Molasses in China, Sucrose and Honey in France, Sucralose and Honey in Mexico, Honey in Turkey, and almost all sweeteners in the US received at least one 5-point rating. Relationships between reported sweetness, liking, and ingredient are used to characterize country-specific sweetness profiles and date is used to assess the influence of the COVID-19 pandemic on such profiles. The present work offers insights on quantifying regional dietary exposure to sweetness in a highly-replicable manner.

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What We Talk About When We Talk About Smell

Pablo Meyer

Language is often considered to be poorly adapted to precisely describe or quantify smell. However, we previously showed that for pure odors it is possible to build models using the chemical structure of molecules to predict perceptual values of natural language attributes of smells, also known as perceptual descriptors, using Natural Language Processing (NLP) tools. We now show that NLP-based models can also be used to better predict the discriminability of molecular mixtures. Furthermore, we tested whether this percept-based approach could be extended to unconstrained discourse, in particular as it pertains to the open narratives of the olfactory-perceptual experience of untrained raters. We did this in the context of loss or changes in smell due to SARS-COVID-2 infections and showed that we could classify whether a patient has COVID based on patients' descriptions of their smell sensation.

Overall, our results show that language can indeed be implemented in a general manner to measure and map smell attributes and can be used to explain properties of the olfactory perceptual space. Given that specialists including tea and wine tasters, beer brewers, cuisine critics and perfumers expend considerable labor to set up lexicons that are concise and hierarchical, and which cover the relevant perceptual space of odors, a general solution for predicting smell perceptual descriptors, independent of the lexicon used, would be extremely useful across a wide range of industries. Our results also suggest that linguistic descriptions of smell might be a useful tool to quantify the effects of known changes in olfactory perception in diseases such as Parkinson's, Schizophrenia and other neuropsychiatric or neurodegenerative diseases.

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Understanding PNL, Panelist’s Natural Language, with Textual Analysis

Sébastien Lê

In consumer testing, consumers are usually asked to evaluate products at different stages. For example, an evaluation at the time of product discovery and an evaluation during use. During these evaluation phases, it is usual to ask consumers why they like the product being tested on the one hand, and why they do not like it on the other. What to do with these different textual measures? How can they be compared? Can we obtain a representation of the products according to the reasons why they are liked in the different evaluation phases? This is what we will discuss in this presentation, during which we will see the contribution of multivariate methods and in particular multiple table methods.

This presentation will be illustrated using data from the evaluation of 14 fragrances by naive consumers. The data has been kindly provided by Strategir.

Losing the Sense of Smell Does Not Disrupt Processing of Odor Words

Laura Speed

Language and olfaction are thought to be weakly connected: western languages like English have few words to describe olfactory experience and speakers have difficulty naming odors. Odor and language may also be weakly connected during language comprehension. Embodied theories propose language comprehension occurs via sensory simulation: activations in sensory regions of the brain. However, so far there is little evidence of olfactory simulation during language processing. To directly test whether olfaction is necessary for comprehension of odor language, we compared 57 participants with acquired anosmia and 56 matched normosmics on a set of language comprehension tasks. Participants completed a lexical decision task (deciding if words are real or not) with odor (e.g., lavender), taste (e.g., basil), and vision-related nouns (e.g., brick). We found no difference in response time or accuracy between the two groups of participants. Next, participants completed a semantic similarity judgment task with odor-, taste-, and vision-related words. Participants had to judge which of two words was more similar in meaning to a target word (e.g., is patchouli or vinegar more similar to menthol?). Anosmics were overall slower and more accurate in the task, but this did not differ across word type. Surprisingly, in an implicit memory task, anosmics remembered more odor-related nouns than control participants. Anosmics also rated odor- and taste-related nouns as more positively valenced than normosmics did. Together, these results suggest that olfactory simulation is not critical to the representation of odor-related language, but odor-related language is more salient and emotional to anosmic participants. We find no detriment to olfactory language in anosmics, supporting the proposal that odor-related language is not grounded in odor perception. Odor and language are weakly connected in language comprehension too.

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Data-Driven and Survey-Based Approaches to Obtaining the Semantic Organization of Olfactory Vocabularies

Thomas Hörberg

Odor experiences are hard to verbalize (Olofsson & Gottfried 2015), partly because most languages lack dedicated vocabularies for describing odor qualities (compared to, e.g., color vocabulary) (Majid 2021). Odors are instead described on the basis of their sources (e.g., woody), with reference to abstract properties (e.g., musty), with cross-modal sensory metaphors (e.g., sweet) or by hedonic evaluation (e.g., pleasant) (e.g., Poulton 2020). Since most of these descriptors are frequently used in other situations, odor vocabularies tend to be fuzzy and not clearly defined or differentiated. Thus, it is often unclear which set of words constitute the olfactory vocabulary within a language. In this talk, I present two approaches that identify the most frequently used odor descriptors in a given language and map the semantic organization of those descriptors. The first method is based on large-scale natural language data (Hörberg et al. 2022) and the second on web-based surveys. I give examples of the semantic organization of the odor vocabularies of a couple of languages that have been derived on the basis of these methods (Hörberg et al. 2022; Wnuk et al. 2020). If time permits, I will also present a practical application of the first approach in the domain of parosmia evaluation.

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Reading Between the Lines: Language Insights into the Impact of Smell Loss on Quality of Life

Pamela Dalton

The COVID-19 pandemic has increased the prevalence of smell loss throughout the population and has brought increasing awareness to the significant issues faced by individuals with persistent smell loss, whether a sequelae of COVID infection or from other causes. In 2022, funded by a Patient-Centered Outcomes Research Institute grant (PCORI), we developed and deployed an on-line survey to assess the US-based patient experience of smell and/or taste loss. The survey questions (multiple-choice, binary and open-ended) included demographic data, responses reflecting the degree, duration and timing of smell or taste loss and the impact on safety, health, diet and social interactions. Within a 3 week period, a total of 5,352 participants (11% 18-24 years old, 30% 25-39 years old, 38% 40-60 years old, 21% 60 years old or older; 73% female; 88% white) completed the questionnaire. Respondents were also asked if they were interested in participating in follow-up 'listening sessions'. From those responses, up to 10 individuals per group representing 6 different demographic categories were selected to participate in one-hour Zoom sessions, each facilitated by a member of the Smell and Taste Association of North America (STANA) and another member of the study team. Five groups consisted of individuals reporting (1) congenital anosmia, (2-3) anosmia/hyposmia (Covid and non-Covid related), (4) parosmia, and (5) smell loss among older Individuals (65+) as well as one group devoted to (6) parents/caregivers of affected individuals). Transcripts from these sessions were analyzed to provide both a deeper dive and a natural language analysis of the social, emotional and safety impact of chemosensory loss among a diverse US-based population.

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RESEARCH INTERESTS OF SCIENTIFIC STAFF

The following lists the current research interests of the staff of the Monell Center. Click their name to go to the scientist's research page on our website. These pages include information on their education, research summary, and relevant publications.

Acting Director & President

Nancy Rawson
Ph.D., Biology; University of Pennsylvania (USA)

Distinguished Member

Gary K. Beauchamp
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