SENSORY PROCESSING: HOW THE PAST AFFECTS THE PRESENT

Paris, 21 and 22 November 2013

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PSL RESEARCH UNIVERSITY

INVESTISSEMENTS D'AVENIR

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Venue:
Amphi Curien, PSL,
62-bis Rue Gay-Lussac, Paris.

What we perceive at a given instant is to some extent influenced by past experience. However, the precise nature of this influence has still to be clarified. In one view of sensory processing, memory and context effects come after basic feature extraction, which is for the most part hardwired, and then modulate perceptual outcome. A different view is that rapid plasticity is pervasive in the system and shapes perception at many levels of processing, in an adaptive manner. In this workshop we plan to bring together psychophysicians, neurophysiologists, and theoreticians, in order to review the evidence for adaptive processing in sensory perception (audition, vision, whisker system) and extract some of its functional principles and benefits.

SPEAKERS:
Merav Ahissar, Mathew Diamond, Emmanuel Dupoux, Kenneth Harris, Hynek Hermansky, Annika Linke, Lori Holt, Patrick Kanold, Leila Khouri, Yonatan Lowenstein, Andrew Oxenham, John Rinzel, Daniel pressnitzer, Aaron Seitz.

INVITED DISCUSSANTS:
Trevor Agus, Daniel Bendor, Samuele Carcagno, Rhodri Cusack, Laurent Daudet, Laurent Demany, Fred Dick, Jean-Marc Edeline, Mounya Elhilali, Bernhard Englitz, Jonathan Fritz, Makio Kashino,, Christian Lorenzi, , Pascal Mamassian, Miguel Maravall, Maneesh Sahani, Jan Schnupp, Daniel Shulz, Shihab Shamma, Jean-Luc Schwartz, Daniel Tollin, Naftali Tishby.

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Schedule:

Each 50' slot comprises a 20-30' minute talk and a 30-20' discussion.

Thursday 21

9:30 INTRODUCTION
9:50 (50') Aaron Seitz
10:40 (30') COFFEE
11:10 (50') Kenneth Harris
12:00 (50') Yonatan Lowenstein
12:50 (80') LUNCH AT PSL
14:10 (50') Mathew Diamond
15:00 (50') Lori Holt
15:50 (30') COFFEE
16:20 (50') Hynek Hermansky
17:10 (50') Emmanuel Dupoux

Dinner at Le Mauzac, 7 Rue de l'Abbé de l'Épée 75005 Paris, at 8 pm

Friday 22

9:00 (50') Daniel Pressnitzer
9:50 (50') Laila Khouri
10:40 (30') COFFEE
11:10 (50') John Rinzel
12:00 (50') Merav Ahissar
12:50 (80') LUNCH AT PSL
14:10 (50') Andrew Oxenham
15:00 (50') Patrick Kanold
15:50 (20') COFFEE
16:10 (50') Annika Linke
17:00 (50') END

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How experience shapes perception; influences of environmental statistics, attention and reinforcement

Aaron Seitz

Here I present a number of lines of research demonstrating how the adult perceptual system is constantly being molded by both by the statistics of stimuli in our environment and by how we interact with these statistics. I will first present evidence that our perception is quickly altered by statistical regularities and that just a few trials of experience can both lead to sensitivity improvements for regularly presented stimuli but also biases in the perception of other stimuli. I'll then discuss evidence of how reinforcement mechanisms act as gating mechanisms to shape how the brain encodes environmental statistics, with the system best capturing environmental elements that are present at times of reward. This is further shaped by attentional processes, where attention is selective and can positively or negatively impact the processing of incoming information. Together, this suggests that our sensory systems continuously attempt to model the statistics of the environment, however, that reinforcement up-regulates learning nonspecifically (benefitting even task-irrelevant stimuli), whereas directed attention is selective and regulates stimulus signals according to behavioral goals (ie up-regulates stimuli of interest and down-regulates distracting stimuli). As a result, our perceptual systems are jointly shaped by the environment, what we find rewarding and punishing and what we expect from it and find interesting in it.

Temporal dynamics of cortical population activity

Kenneth Harris

Spatial and temporal generalization: lessons from professional basketball

Yonatan Lowenstein

Tactile acuity and working memory in rats and humans

Mathew Diamond

The work of the Romo laboratory has shown that primates can store graded sensory stimuli in working memory for subsequent manipulation, but until now there is no demonstration of this capacity in rodents. Here we describe tactile working memory in rats - they compare two "noisy" vibrissal vibrations (termed "base" and "comparison") separated by an inter stimulus interval. In analogous experiments, humans compare two vibratory stimuli on the fingertip. On average, the tactile acuity and working memory of rats is inferior to that of human subjects, but good rats perform better than poorer humans. The rats' and humans' memory trace of the base stimulus appears to be affected by statistical distribution of preceding stimulus pairs. Time permitting, we will describe neuronal activity recorded during execution of the behavioral task.

Speech, melodies and invaders from space: What speech reveals about how the auditory system uses the past to interpret the present

Lori Holt

The ease of everyday conversation masks the cognitive and perceptual challenges of translating from acoustic signal to meaning. Long relegated as a special perceptual system, it appeared that speech could tell us very little about more general issues of auditory processing. The latest research guides us away from this classic way of thinking about speech. I will illustrate how perceptual challenges from human speech perception illuminate how experience shapes auditory perception at different time scales - from the influence of a single precursor sound, to distributions of sounds across seconds, to statistical regularities in acoustics experienced across multiple training sessions. For each phenomenon, I will make connections with the neurobiological mechanisms that may underlie experience-dependent effects in audition in hopes of stimulating discussion about what the challenges of speech perception contribute to understanding of auditory processing, more generally.

Time in recognition of speech

Hynek Hermansky

Temporal context has a significant role in recognition of speech. Coarticulation with neighboring speech sounds brings influence of immediate temporal context. Among longer temporal effects belongs changing acoustics of communication environment. Very powerful is the effect of very long temporal context, the knowledge of a language. All of these temporal effects are well handled and utilized in human speech communication. The talk will discuss our efforts for handling and utilizing temporal context in recognition of speech by a machine.

Language-dependant context effects in speech perception: how the distant past affects the present,

Emmanuel Dupoux

During early childhood, infants learn to tune in the language(s) spoken in their linguistic environment. These early acquisitions have a powerful and lasting influence on the perception and production of speech sounds as attested by the foreign accent syndrome which affects adults in both modalities. We will review some of the well documented effects in perception with an eye on identifying the potential computational mechanisms underlying them. In particular, we will review three classes of phenomena: the retuning of perceptual dimensions, phonological and phonotactic illusions and compensation for phonological/phonetic rules. Each of these phenomena will be analysed in terms of their profiles of acquisition/reacquisition, as well as of a possible computational implementation.

Two behavioral tasks to probe auditory memory and context effects

Daniel Pressnitzer

There is growing evidence that a key aspect of listening is the ability to rapidly adapt, online, to the sounds and tasks at hand. Here I will describe two behavioural paradigms intended to probe what may be termed "adaptive audition". First I will summarize a line of work where we used random signals, such as white noise, to observe the formation of new auditory memories. Results show that incidental learning of complex sounds can be surprisingly rapid and robust. Then I will describe recent data where ambiguous stimuli were used to highlight the influence of the immediate acoustic context on perceptual judgments. Both tasks provide behavioural demonstrations, above threshold and with large effect sizes, of adaptive processes in mid-level audition. They should thus be suitable for future investigations using animal models, brain imaging or computational modelling.

Stimulus specific adaptation and unsupervised sound learning,

Leila Khouri,
Bshara Awwad, Israel Nelken

To survive in an ever-changing environment, humans and animals alike, rely on their stunning capacity to extract rules and patterns from their dynamic surroundings. However, the neural processes underlying this capacity to extract and store relevant sensory infomation remain poorly understood. To shed light on the neuronal correlates of auditory learning and memory, we used Stimulus Specific Adaptation (SSA) paradigms and animal electrophysiology. An important determinant of relevance for external stimuli is their probability of occurence, making oddball (SSA) sequences an attractive tool to investigate sensory learning in the Auditory System. In our experiments, SSA sequences were built from tone clouds. Each tone cloud consists of 36 (6*6) tones spanning 6 octaves and 6 time bins. Within each 1/6 of an octave and 16 ms time bin, frequency and onset of the tone are chosen randomly and independently for each of the tone clouds. The sequences employed consisted either of (1) repeated presentations of different clouds with equal probability, (2) pairs of clouds one common and the other one rare (oddball sequences) or (3) a set of several different tone clouds among which one is repeated (diverse sequence). Neural responses to tone clouds were recorded from AC and IC of anaesthetized rats. AC and IC responses to oddball sequences, were smaller to the common tone cloud (standard) than to the rare (deviant) tone cloud. When time course of standard and deviant responses was analysed, standard responses were found to decrease over time. Strikingly, however, in AC but not IC neurons, deviant responses were found to increase over time. The finding of increasing responses to the deviant sound is absolutely novel and could result from one of two scenarios: the increase in response to the deviant cloud could indicate (1) violation of the expectation created by the standard, or (2) learning of the deviant cloud. To test both possiblities, a set of diverse sequences was presented to the animals. These sequences consisted of one repeating tone cloud among several intermittent novel tone clouds. Average responses to the repeated clouds in these sequences were smaller than average responses to non-repeated clouds. The divergence in response resulted solely from decreased responses to the repeated tone cloud. No consistent change in reponse to the diverse clouds was evident. Consequently, Auditory Cortex neurons retain a memory specific to deviant and standard tone clouds. This finding constitutes evidence for sensory learning of complex non-sense sounds occurring as early as the AC, but after inferior collicular processing.

Neuromechanistic models for perceptual dynamics with adaptation

John Rinzel

The impact of recent trials on perceptual accuracy in the general population

and in Dyslexia, Merav Ahissar

Pure tone frequency discrimination is traditionally viewed as a simple discrimination task, where performance is dictated by sensory resolution. However, a detailed trial-by-trial analysis shows that performance is substantially affected by recent trials (Raviv, Ahissar & Loewestein, 2012). Thus, listeners compare the 2nd tone in each trial to a combined representation of the 1st tone in this trial and their estimated prior for this first tone (~average frequency of 1st tones). This implicit strategy is expected from a Bayesian perspective since the representation of the 1st tone is noisy by the time the 2nd tone is presented. Moreover, individuals with a noisier system are expected to allocate a larger weight to previous trials compared to the current trial. This is indeed the case in the general population. However, dyslexic individuals put a lower weight on recent trials even though their sensory system tends to be noisier. ERP measurements suggest that in the general population the auditory system tracks and averages across the first stimulus in each trial. This automatic tracking mechanism is impaired in Dyslexia, degrading the ability to form an effective prior. The resulting sub-optimal dynamics of perception may account for Dyslexic's poor performance in a range of perceptual, memory and reading tasks.

Spectral and spectral-motion context effects with speech and non-speech sounds

Andrew Oxenham

We will review some recent work from our lab involving context effects induced by steady or gliding tones. Several studies have reported effects of the preceding long-term average power spectrum on the perception of speech sounds; less is known about effects produced by spectral motion. In the first series of experiments, we explore the potential role of spectral motion aftereffects on the perception of speech-like and non-speech sounds. In the second series of experiments, we examine context effects on a simple frequency discrimination task, involving the ability of listeners to discriminate the frequency of two successive sinusoids. A recent study demonstrated a dramatic effect of previous sounds on listeners' judgments in a simple 2-alternative forced-choice frequency-discrimination task (Raviv et al., 2012). One puzzling aspect was the large average JND of unpracticed subjects, which was more than an order of magnitude greater than that observed in earlier studies. To test for the influence of practice, we replicated the experiment, and compared initial performance with performance after more extended practice. To test for potential task confusion or response bias, we ran the experiment with alternative instructions (select the lower of the two tones, instead of selecting the higher). JNDs in our subjects were between 1 and 2%, even in the unpracticed condition, and improved somewhat with practice. The bias was observed in all conditions, consistent with the original report, and remained substantial even after practice. Both JNDs and bias were similar in both tasks (selecting lower or higher tone). The results demonstrate the potential importance of both static and dynamic spectral context effects, and suggest that they remain robust even after extensive practice.

Changing responses in auditory cortex on multiple time scales,

Patrick Kanold

Using neuroimaging and multi-voxel pattern analysis to study the neural representations of sounds during auditory short-term memory and imagery

Annika Linke

Neuroimaging in humans has shown that auditory short-term memory and imagery recruit similar regions of the brain as the perception of sound. This has commonly been taken to reflect sustained encoding or reactivation of the same information as during perception. Even in sensory regions, however, it is not clear that such a direct mapping between common regional activation and the informational content of neural representations can easily be made. Higher-level representations reflecting more abstract categorical information emerge rapidly and electrophysiology has shown that neural coding in auditory cortex is highly plastic depending on a sound's behavioural relevance. It is thus likely that top-down processing influences neural representations in auditory cortex during memory maintenance and imagery. Voxel averaging - the most common analysis method for functional magnetic resonance imaging (fMRI) - decreases the chances of detecting such subtle differences in neural information coding when the same brain region is activated. In this work we therefore use fMRI and multi-voxel pattern analysis to directly test the content of neural representations in auditory cortex during auditory perception, imagery and short-term memory of simple and complex natural sounds. We show that which information about the same sounds is encoded in auditory cortex is highly flexible and depending on the task demands, with representations being abstracted during imagery but not during perception or short-term memory maintenance.