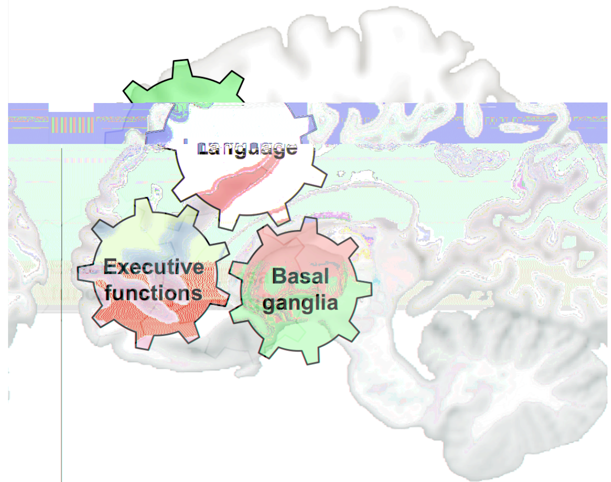
Workshop
New Ideas in Neuropsychology

The role of the basal ganglia in the interaction between language and other cognitive functions

October 13, 2017

Ecole normale supérieure
Salle Dussane, 45 rue d'Ulm

Paris (75005)



Program

9h15 - 9h45 Welcome Breakfast

9h45 - 10h35 Jubin Abutalebi (Università Vita-Salute San Raffaele)
Basal Ganglia and Control of Languages

10h35 - 11h25 Ruth de Diego-Balaguer (ICREA)
Learning to predict in speech: temporal processing, prediction and attention may interface through the striatum

11h25 - 11h40 Coffee break

11h40 - 12h30 Xavier Hinaut (INRIA)
Modelling sentence processing with random recurrent neural networks and applications to robotics

12h30 - 13h20 Michael Schwartze (University of Manchester)
Temporal coding of speech in a subcortical-cortical network

13h20 - 14h30 Lunch

14h30 - 15h20 Christophe Pallier (INSERM-CEA Cognitive Neuroimaging Unit)
The basal ganglia and me

15h20 - 16h10 Bruce Crosson (Emory School of Medicine)
The striatum and thalamus in language: Associations and dissociations

16h10 - 16h25 Coffee break

16h25 - 17h15 Sonja Kotz (University of Manchester)
On the importance of timing and rhythm in motor and non-motor behavior

17h15 - 17h30 Closing remarks

NPI NeuroPsychologie Interventionnelle
IEC Institut d'Etude de la Cognition
ENS
DEC Département d'Études Cognitives

Abstracts
(alphabetical order)

Jubin Abutalebi
Università Vita-Salute San Raffaele

Basal Ganglia and Control of Languages

Speech production and comprehension are governed by control processes. In bilingual and multilingual speakers, unlike monolingual speakers, these control processes must also control the language of use. Language control covers a gamut of processes from the initial selection of the language of use to ones ensuring that only the representations (lexical, grammatical and phonological) of the selected language are finally produced. In recent years the number of structural and functional neuroimaging studies that have addressed how the bilingual control system is implemented in the brain has increased considerably. It is now well established that the architecture of this complex system encompasses brain networks involving cortical (e.g., anterior cingulate cortex, prefrontal cortices) and subcortical structures (e.g., caudate, putamen) each responsible for different cognitive processes such as goal maintenance, conflict monitoring, interference suppression and selective response inhibition.
In the my presentation, I will illustrate the nature and dynamics of language control in bilingual speakers with a key focus on the role of the basal ganglia, and in particular the caudate nuclei and the putamen. Each of these two subcortical structures has a distinct role in bilingual language processing and I will present clinical data (i.e., lesion data from aphasics) and neuroimaging data that highlight the multiple functions of these two nuclei for language control. The role of these nuclei will be finally discussed within the framework of prominent neuro-cognitive models.

Bruce Crosson
Departments of Neurology and Radiology, Emory University; Department of Psychology, Georgia State University; Center for Visual and Neurocognitive Rehabilitation, Atlanta Veterans Affairs Medical Center, Atlanta, Georgia, USA

The striatum and thalamus in language: Associations and dissociations

In their seminal review, Alexander, DeLong, and Strick (1986) provided evidence for five basal ganglia loops, originating and terminating primarily in frontal cortex. Since that time, additional frontal-basal ganglia loops have been defined (e.g., Middleton & Strick, 2000), and three closely related “sub-loops” have been identified, each with thalamocortical projections influencing the frontal component the loop (e.g., Mink, 1996; Nambu et al., 2002). Evidence suggests that thalamic nuclei and the basal ganglia work together to increase the processing efficiency by increasing signal for actions selected for execution and suppressing noise from competing actions (e.g., Nambu et al., 2002). We recently have traced frontostriatal (Ford et al., 2013) and thalamocortical (Bohsali et al., 2015) fiber tracts for Broca's area (pars triangularis and pars opercularis), providing anatomic evidence for Broca's area-basal ganglia loops. Yet, most thalamic nuclei are not part of basal ganglia loops. For example, we also have traced fiber tracts between Broca's area and the pulvinar (Bohsali et al., 2015), which does not have direct connectivity with the basal ganglia. Hence, some thalamic nuclei may influence language-related processes independent of the basal ganglia. Studies indicate that thalamic mechanisms both engage neural systems to enable high-resolution information processing and participate in information transfer between cortical areas during such processing (Sherman & Guillery, 2006). During this presentation, we will integrate these anatomic data with functional neuroimaging data that highlight three basal ganglia loops: (1) a pre-SMA loop participating in lexical selection (Crosson et al., 2003), plus (2) a Broca's area and (3) a dorsolateral prefrontal loop participating in lexical-semantic encoding during working memory (Moore et al., 2013). We will further integrate anatomic data with two independent thalamic mechanisms (1) a cortico-pulvinar mechanism binding features during semantic processing (e.g., Kraut et al., 2003), and (2) paraventricular thalamic mechanism that becomes active during the retention phase of lexical-semantic working memory (Moore et al., 2013). Theoretical implications of basal ganglia loops and independent thalamocortical mechanisms will be discussed.

Ruth de Diego-Balaguer
ICREA, University of Barcelona; Cognition and Brain Plasticity Unit, IDIBELL, L'Hospitalet de Ll.; Neuroscience Institute, University of Barcelona.

Learning to predict in speech: temporal processing, prediction and attention may interface through the striatum

Speech processing is inherently temporal. It is composed of phonemes, syllables, words and phrases with different durations and onset times. In the process of learning infants and adults confronted with this complex stimulation need to extract these units tuning to these temporal frames. Prosody, which is characterised by introducing a rhythm by changes in pitch, vowel duration and pauses is also an intrinsic characteristic of all languages. It has a key role helping in the process of learning words and rule dependencies in language. In our recent investigations we have studied how prosody helps word segmentation by attracting exogenous attention and rule learning by guiding endogenous attention to the relevant elements predicting the associated dependencies. Interestingly this endogenous attention appears to involve a predictive component rather automatic that recruits a ventral fronto-parietal system left lateralised that is shared between language and attention and a more controlled goal-directed system that recruits more dorsal areas of the fronto-parietal network that are shared with executive functions. I will review ongoing developmental work and research on Huntington's disease patients pointing to the possible role of the striatum in the link between those predictive mechanisms and goal-directed attention systems given its role in the adaptation of behaviour to prediction errors detected in the learning process.

Xavier Hinaut
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Modeling sentence processing with random recurrent neural networks and applications to robotics

Primates can learn complex sequences that can be represented in the form of abstract categories, and even more abstract hierarchical structures such as language. In order to study how these abstractions are formed and because of the highly recurrent connectivity in prefrontal cortex (PFC) we model part of it using recurrent neural networks. Particularly, we use the Reservoir Computing paradigm to model PFC and part of the basal ganglia: a recurrent neural network with random connections kept constant models the prefrontal cortex, and a read-out layer (i.e. output layer) models the striatum. This model was trained to perform language syntactic processing; in particular, thematic role assignment: for a given sentence this corresponds to answer the question "Who did what to whom?". Inspiring from language acquisition theories (Tomasello 2003), the model processes categories (i.e. abstractions) of sentences which are called "grammatical constructions" (Goldberg 1995). After training, it is able to (1) process correctly the majority of the grammatical constructions that were not learned, demonstrating generalization capabilities, and (2) to make online predictions (of thematic roles) while processing a grammatical construction. Moreover, we observed that when the model processes less frequent constructions an important shift in output predictions occurs. It is proposed that a significant modification of predictions in a short period of time is responsible for generating Evoked-Related Potentials (ERP) such as the P600 which typically occurs when unusual sentences structures are processed (Hinaut & Dominey 2013). Subsequently, to show the ability of the model to deal with a real-world application, the model was successfully applied in the framework of human-robot interaction for both sentence comprehension and production (Hinaut et al, 2014). Recently, we showed that the very same instance of reservoir could learn both English and French sentences at the same time, suggesting that a common "output" (striatal) representations could be used even in the case of different languages (Hinaut et al, 2015). Moreover, the model is able to learn small corpora in fifteen European or Asian languages with different word order (Hinaut et al, in revision). In a nutshell, this suggests that a random neural network with no prewired structure seems enough to learn the syntax of languages different in structure and in word order.

Sonja A. Kotz
Faculty of Psychology and Neuroscience, Dept. of Neuropsychology and Psychopharmacology, Maastricht Universtiy, The Netherlands & Max Planck Institute for Human Cognitive and Brain Sciences, Dept. of Neuropsychology, Leipzig, Germany

On the importance of timing and rhythm in motor and non-motor behavior

Neural correlates of motor and non-motor behavior such as speech and language as well as their dysfunctions are well documented in neuroscience and neuropsychology respectively. However, while the critical influence of timing and rhythm in motor behaviour is clearly recognized, there is very little evidence on their impact in speech and language research (see Kotz & Schwartze, 2010). This is surprising as rhythm and timing (i) play a crucial role in speech and language learning, (ii) can compensate developmental and acquired speech and language disorders, and (iii) further our understanding of subcortical contributions to linguistic and non-linguistic functions. For example, recent neuroimaging and clinical evidence has confirmed the contributions of classical motor control areas (cerebellum (CE), basal ganglia (BG), supplementary motor area (SMA)) in timing, rhythm, music, and speech perception (Chen et al., 2008; Grahn et al., 2007; Geiser et al., 2009; Kotz et al., 2009; Kotz & Schwartze, 2011). We consider serial order and temporal precision to be the mechanisms that are shared in simple and complex motor behaviour (e.g. Salinas, 2009), but also in higher order cognitive functions such as speech and language (Kotz & Schwartze, 2010; 2015). In my talk I will present behavioral and neuroimaging evidence on the role of timing and rhythm in motor behaviour, language learning, speech comprehension, and the compensation of both motor and speech behaviour in clinical populations and embed this evidence in a cortico-subcortical framework encompassing action-perception coupling.

Christophe Pallier
INSERM-CEA Cognitive Neuroimaging Unit

The basal ganglia and me

In the introduction of one of the most famous paper in cognitive sciences, George Miller wrote 'My problem is that I have been persecuted by an integer. For seven years this number has followed me around, has intruded in my most private data, and has assaulted me from the pages of our most public journals.' In a similar vein, I could write that I have been persecuted by the basal ganglia. Although in my neuroimaging studies on language processing I have never directly focused on trying to understand their specific role, activations in the basal ganglia often crept in the functional maps. During my talks, I will present the results of these experiments in the hope that other participants will be able to provide some explanations. In particular, I am particularly intrigued by a recent experiment conducted with deaf participants which highlighted the role of the basal ganglia in syntactic processing of sign language.

Michael Schwartze
Faculty of Psychology and Neuroscience, Dept. of Neuropsychology and Psychopharmacology, Maastricht University, The Netherlands

Temporal coding of speech in a subcortical-cortical network

Our sense of hearing rests on the processing of events unfolding in time. Acoustic events form patterns of continuous changes from the clicks of a metronome via morse-code to music, song, and speech. The temporal structure of these events, i.e., their rate and rhythm, gives rise to the concepts of succession and duration. Importantly, temporal structure conveys information that is to some extent independent of the formal structure of the same events, i.e., characteristics such as pitch, timbre, or loudness. Both sources may be used separately as well as in conjunction with each other to optimize auditory processing, and speech processing in particular. For example, regularity in either dimension can be used to generate predictions about the timing and the type of future events. Such prediction instantiates a powerful mechanism that allows for proactive neurocognitive behaviour in audition, which may in turn facilitate the perceptual integration of speech. To achieve these ends, speech processing may interface with dedicated temporal processing systems of the brain, including the cerebellum, the supplementary motor area, and the basal ganglia in order to exploit temporal structure in a constant drive to predict the temporal locus of salient events. The talk will describe the subcortico-cortical network that may engage in these processes. This approach offers a novel perspective on speech processing as an inherently dynamic process, with implications for the development and optimization, as well as the functional loss of speech processing capacities.
