International School for Advanced Studies, Trieste
Written Exam for Admission to the Cognitive Neuroscience PhD curriculum
April 14, 2016

Please answer or discuss three (3) of the following questions.
Note: You should not use one publication or experimental paradigm as the central focus of multiple questions.

English is the language strongly preferred by the Commission. However Italian may be used if necessary. Please write clearly, neatly and concisely. The Commission cannot score what it cannot read. Length is not correlated with quality. Help yourself with equations, drawings, diagrams, or plots as needed.

* * * * *

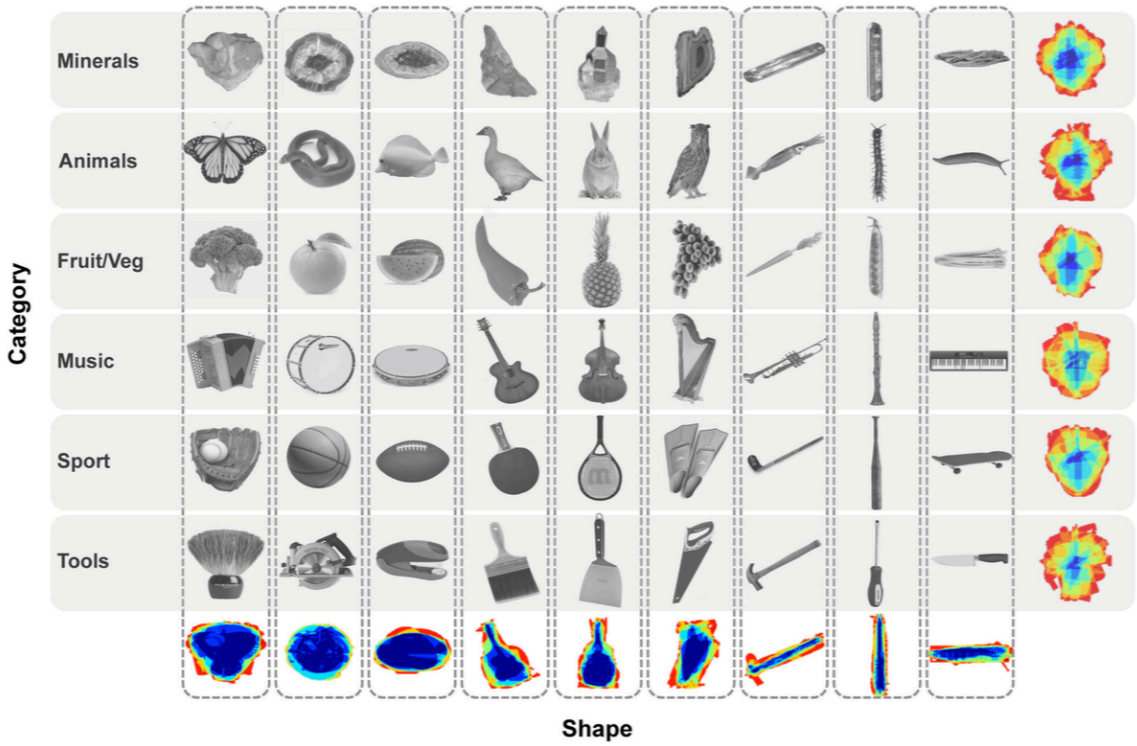
1. It is generally (but not universally) held that human language is an exclusive feature of our species. Illustrate your stand in this respect and argue critically for it.

2. Concisely describe the main organizational principles of the central nervous system.

3. Sensory stimuli, events, and objects are made up of many features bundled together. A visual object for instance can be comprised of shapes, colors, patterns, motion and so on. A tactile object could be comprised of shape, texture, size and so on.
   (a) Do you imagine the neuronal coding of all features to be clustered together in the same population of neurons in cerebral cortex, or else separated into modules? Does the answer to the question vary according to the stage of cortical processing?
   (b) Suppose at the conclusion of a well-controlled sensory stimulus in the laboratory, a subject is asked to report or judge just one of several possible features. How, by what kind of algorithm, do you think the brain could select just one kind of feature to produce an answer? If single neurons encode multiple features, can the subject's answer be *un*influenced by the other ("irrelevant") features?

4. Please sketch a flow chart of the computations that brought you to this room where you are taking the admission exam. Intend "computations" the way you prefer.

5. A long-standing question in visual neuroscience is whether high-level cortical areas in humans and other primates represent strictly visual information only, or also (and perhaps mainly) the categorical (i.e., semantic) membership of visual objects. This image shows the stimulus set used by Bracci and Op De Beeck in a recent human fMRI study investigating this topic.



Please, answer the following questions:

(a) What do you think is the greatest challenge, at the level of stimulus design, to dissociate visual representations from category representations? Do you think that this stimulus set properly addresses this challenge? Why?

(b) How would you use this stimulus set (or another set, if you think it would be more appropriate) to understand how visual and semantic information is coded in visual cortex? Imagine you could run a human fMRI experiment or a monkey electrophysiology experiment, in which you can record the activity of one or more neuronal populations (from one or more visual cortical areas):

(b1) What kind of stimulus presentation protocol would you use? Would you require the subject to perform a task or just passively fixate the stimuli?

(b2) From which area (or areas) would you record neuronal population(s)?

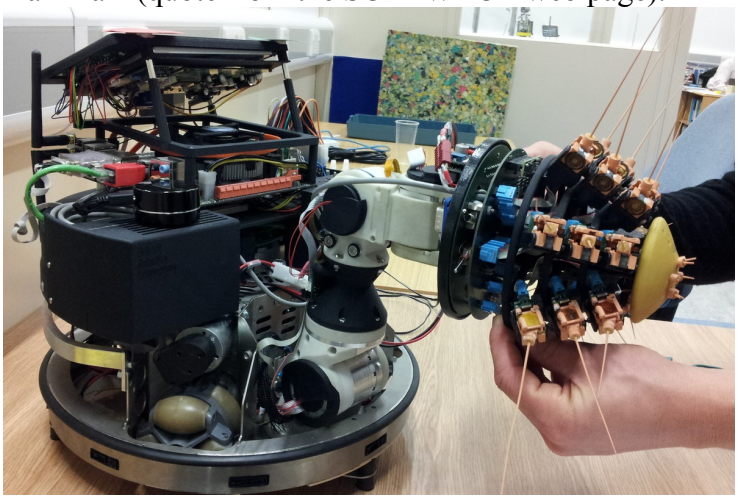
(b3) What kind of alternative hypotheses exactly would you test? What do these hypotheses predict at the level of neuronal representations?

(b4) What kind of analyses would you perform to understand the nature of the object representation(s) in each area(s)?

6. Mr. Fortunato Di Domenica has had a stroke on Monday, four weeks before coming to your attention. He's well oriented in time and space, but clearly struggles in talking to you. He seems to understand what you ask, with some uncertainty; has clear word finding difficulties; and his articulation is imprecise at times. As it often happens in small hospitals, you have no CT scan; but you know that the CVA was due to a haemorrhage in the left middle cerebral artery.
   Research in your department focuses particularly on phonology and morphology. Do you flag this patient to your colleagues' attention? If you're not sure, how would you ascertain whether it's worth to do so?

7. Would you be interested in studying gender in language? If so, what do you find interesting in this domain?

8. A branch of computational neuroscience is actively engaged in building robots to better simulate and understand cognitive functions, such as perception, decision making, etc. For instance, the image below shows the picture of the SCREWBOT, a mobile whiskered robot developed at the University of Sheffield to serve as an "embodied model of a small whiskered mammal" (quote from the SCREWBOT web page).



Please, answer the following questions:

(a) What do you think "embodied model of a small whiskered mammal" means? In other words, what kind of elements (at the mechanical and algorithmic level) do you imagine Sheffield scientists and engineers have incorporated in this robot, so as to make it a model of whisker-mediated somatosensation? And what kind of interaction do you think may have taken place between neuroscientists and engineers to build such a robot?

(b) What goals do you think may be served by building robots such as this to study how the brain mediates sensation and perception? In other words, what computational questions do you think you may ask, using a robot, which you could not ask by simply simulating sensory functions with a computer.

(c) Do you think it would be equally interesting to build a similar model for the visual modality (i.e., replace the artificial whiskers with a digital camera)? Or, instead, you think that developing such robots is uniquely useful for studying somatosensation?

9. Functional Magnetic Resonance Imaging, Transcranial Magnetic Stimulation and Electroencephalography: discuss the merits and the limitations of these techniques as tools for cognitive neuroscience.

10. Being the brilliant young neuroscientist that you are, you must have certainly read countless interesting articles and books about your preferred topic in the field. Among all the material you have read, choose the article (or book) that you found most intriguing and inspiring. Summarize the motivations, methodological approaches, results and conclusions of the article (or book) and explain why you consider it special. Finally, describe what kind of study you would carry out using this article (or book) as the starting point. To answer this question, take a step away from your own history of research: please avoid discussing your Master's thesis and the background related to it. The commission will be disappointed if the answer to this problem resembles the introduction to your thesis!

11. An incidental finding in some previous research that you've done is that seeing a word like DEALER makes it easier to subsequently process a word like DEAL. Can you interpret this result linguistically in an unambiguous way? If not, what kind of experiment would you design to adjudicate between alternative accounts?

12. The sad situation in Syria is akin to what in statistical physics would be called a complex disordered system, with frustration. Try to delineate a mathematical description (do not worry about political correctness – it will play no role in assessing your attempt).