



International School for Advanced Studies, Trieste

Admission to the Cognitive Neuroscience PhD curriculum

April 23, 2014

Please answer or discuss three (3) among the following 11 questions.

Note: You should not use one publication or experimental paradigms 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.

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1. Assume a typical neuroscientist can be represented as a node in a network, with strong links to one's PhD advisor, postdoc mentor, to n own students and to m postdoc trainees. What would give such a network the character of a small world? Define on this network measures analogous to the clustering coefficient and mean shortest path length (possibly several such measures) and roughly estimate them for the world neuroscience network. Even wild estimates would be interesting.
2. A long-standing debate exists in the system/computational neuroscience community about how sparse the neuronal activity underlying perception, action and memory might be. Terms such as "distributed code", "sparse representation" and "grand-mother cells" are routinely used and debated in the community. Explain what these terms mean to you, and discuss at least one relevant example of neuronal representation. Finally, describe an experiment and the analyses that you would carry out to figure out how distributed (or how sparse) a given neuronal code is (e.g., the representation of a sensory stimulus, such as an image, a sound, or an odor).
3. Neuroscientists know that the hippocampal formation is critical for learning, experiencing, and recalling spatial relations – in short, for navigation. The hippocampus is also important for learning, experiencing, and recalling facts, events, episodes (in rats the first function seems to be predominant, in primates the functions are more evenly balanced.). The ancient Greek and Roman mnemonic device known as "The Method of Loci" helps a person store long lists of information by associating each item with a place, such as a room in a home. The person then navigates through the home to recall the stored information. Focusing on the hippocampus, try to explain how the Method of Loci might work.
4. The impairment of action-verb processing in patients with praxic deficits has been interpreted as being due to the deterioration of motor representations, held to be the core of action concepts. However, grammatical and semantic deficits have been recurrently confused in the context of verb-noun dissociations. In fact, in all published studies, the verb-noun dissociation has been assessed using action-verbs vs. object-nouns, leaving unclear whether the reported deficits impinged the lexical category of verbs, the semantic category of actions, or both. Design a neuropsychological study that removes this confound and clarifies the functional locus of the action-verb impairment.
5. In the visual cortex of primates, two visual pathways have been characterized: the ventral pathway and the dorsal pathway. Recent studies speculate that homologous pathways

also exist in rodents (mice and rats), but empirical evidence is still quite scarce. Propose an experiment to test the existence of these pathways in rodents. You may rely on any combination of behavioral testing, invasive monitoring of neuronal activity (e.g., extracellular recordings using electrode arrays), and tools to artificially excite/inhibit cortical neurons (e.g., optogenetics).

6. Speculate on what might be the brain mechanisms at work when you compare two things. The things can be two stimuli perceived sequentially, for instance. How is the comparison accomplished?

7. Somebody has developed a virus-based technology to transiently enhance, for half an hour, the excitability of a very specific population of neurons of your choice; by about a factor of two. Think of a neuroscience question and sketch an experiment that would address it, using such a technology.

8. Reading/writing abilities are unlikely to be the product of selective pressure. Rather, they seem relatively recent cultural objects, acquired by learning. From this premise, some anthropologists, sociologists, psychologists have jumped to the conclusion that the cultural competence of the human species must have arisen from the novel emergence of a vastly flexible domain-general learning capacity. This hypothesis is consistent with the neuroscientific view of the cortical surface as being largely equipotential and free of domain-specific structure. In contrast, Stanislas Dehaene and Laurent Cohen proposed the Neuronal Recycling Hypothesis whereby the major domains of human cultural variability – including reading/writing – are tightly constrained by our prior evolution and brain organization. Thus, in all cultures, these domains of knowledge seem to map onto remarkably invariant brain structures that they call “cultural maps,” with only small cross-cultural variations. What is your take on this issue? Can you provide arguments and facts in favor or against these two viewpoints?

9. Visual object recognition (the ability to extract the identity/category of visual objects from visual scenes) is a crucial cognitive function and it has proven extremely challenging to emulate in man-made computers. Please explain why, in your view, object recognition represents such a computational challenge.

10. Consider an experiment in which brain activity is recorded while the subject (a human or an animal) carries out some sort of task. When brain activity is compared to the parameters present in the task, relationships are found between the task parameter values and the measures of brain activity. What criteria should an investigator use in order to argue that the the measured brain activity is actually carrying information used by the subject in the task? For instance, if the brain activity is a BOLD signal acquired by fMRI, would the investigator claim that blood oxygenation level is a coding mechanism? Why or why not? Consider additional forms of brain activity besides BOLD and apply the same criteria.

11. Those below are the original opening of T.S.Eliot’s *The Waste Land* and the same lines translated by Google Translate into Hungarian, then into Japanese and back into English. Despite Google Translate’s remarkable performance, some remaining hiccups are noticeable. How would you characterize them?

<p>BREEDING in April, is the cruellest month Of the land of the dead, lilac, mixed Memory and desire, stirring Dull roots with spring rain. Winter are keeping warm us Earth forgetful snow, feeding Tubers were dried life a little </p>	<p>APRIL is the cruellest month, breeding Lilacs out of the dead land, mixing Memory and desire, stirring Dull roots with spring rain. Winter kept us warm, covering Earth in forgetful snow, feeding A little life with dried tubers. </p>
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