Thursday, June 26th

Symposium 3:

Abstract hierarchical models in linguistics

and their relevance for cognition and behaviour

Given the physicalist stance taken by modern day cognitive science, theorizing about the mind must be grounded in our current understanding of physical systems, normally focusing on the brain and nervous systems. Since the advent of modern day cognitive science, much important progress has been made in attempting to locate where certain cognitive processes may take place in the brain. However, although the nature of psychological processes and fine-grained details of neurons as biological entities are well known, discovering how these two aspects of cognitive processes are linked remains an outstanding question.

The Neurophotonics Lab at the University of Nottingham is currently developing the Simple Living Artificial Brain system (SLAB), in order to provide the experimental means to investigate the links between low-level neural activity and cognitive and behavioural processes. The SLAB is simple enough so that accurate physical data can be recorded from the system, while having enough complexity in order that it can produce meaningful examples of behaviour.

One of the goals of the SLAB project is to create an abstract conceptual framework linking the physical activity within the neuronal system and the environment with which it interacts with higher-level notions such as cognition and behaviour. This framework must consist of multiple levels of representation or abstraction, be contextualized, capture the continual interaction between neurons and an environment and link form and function. These are also properties of some models of language in linguistic theories. Therefore, this symposium will explore the possibility that ideas from linguistic theory can be usefully applied in this new context, not because of what they tell us about language, but what they tell us about hierarchies within complex abstract systems in general.

The first paper will introduce the SLAB system itself, as well as how this approach shifts attention from solely on the brain to considering the brain as one part of a wider system, which contains the brain, body and the wider environment. The second paper will discuss abstract modeling of language as found in the theory of Systemic Functional Linguistics, specifically focusing on the notions of system, instance, stratification and the notion of 'appliable linguistics'. The final paper will put forward a novel research program, linking the content of the previous presentations, by showing how modeling traditions from within linguistic theory can be applied in useful ways to a new context, that of neuronal computation and its links to behaviour.

1. What's on the SLAB? - Building a Simple Living Artificial Brain

The Neurophotonics Lab is a multidisciplinary research group at the University of Nottingham with the goal of understanding fundamental aspects of information processing in the brain.

In order to understand how information is encoded and processed by a network of neurons it is thought to be necessary to be able to monitor and control all action potential activity, in particular, within the network for an extended period of time. Furthermore, the interaction between an organism and its environment is also essential for a meaningful description of information processing within the network. The continual flow of information from the network to the environment and back again allows the organism to explore, learn, and form a synergy with its environment.

Unfortunately, even in extremely simple organisms, it is not possible to monitor all the action potential activity, let alone the environmental signals, due to limitations in available technology. In order to overcome the complexities of real organisms the Neurophotonics Lab is developing a simple experimental system in which a small network of cultured neurons continuously exchanges information with a virtual environment implemented on a real-time computer; analogous to how a real organism interacts with its environment.

The intention is that this minimalist, but non-reductionist, experimental system will contribute to theoretical neuroscience by enabling the underlying cellular and molecular activity to be related to higher-level cognitive and behaviour events. Importantly it will allow a much closer correspondence between the experimental system and the mathematical models that describe it than is currently possible, which should aid the development of theory.

The theoretical challenges are still considerable however. In particular an abstract conceptual framework is required with which to link the low-level physical activity within a neuronal system and the body and environment that it is embedded in with higher-level notions such as cognition and behaviour. Theoretical linguistics may provide such a framework.

It is postulated that the resulting system, a Simple Living Artificial Brain (SLAB), contains the minimal, but essential, components required by a cognitive organism, while being technically feasible, experimentally accessible, mathematically formalisable and physiologically relevant to cognition at an elemental level.

This talk will cover the progress that has been made in developing the basic technology required to realise this ambitious goal and explore the theoretical challenges that relate to the use of this tool.

2. Developing an Appliable Model of Language: the approach of systemic functional linguistics

In line with the theme of the conference, this paper will examine the ways in which the theoretical model of systemic functional linguistics (SFL) interacts with notions of system, instance, and abstraction. In doing so, it will provide a framework with which to explore the ideas of practice and representation as they pertain specifically to the potential output of the Simple Living Artificial Brain (SLAB) project at the University of Nottingham.

First, it will introduce the stratificational model as typically depicted by Martin and Matthiessen (1991) via Halliday (1976), as influenced by Hjelmslev (1963/1943). This particular model holds as the primary visual depiction of language as a system of systems in the SFL tradition, and is still frequently used by scholars today in a number of different applications. This model will therefore then be explored to point out the qualities which have made it significant in the multi-faceted fields of Applied Linguistics. Such qualities are its holistic nature, enabling users to link language production, content, and context; its bi-directionality, enabling users to theorise how various strata interact in terms of realisiation; and its relationship to language in use, enabling users to demonstrate how the entire model can be seen to simultaneously instatiate in terms of texts.

Next, it will reiterate the SFL call for an "Appliable Linguistics" (Mahboob and Knight 2010, following Halliday 1985). Such an approach involves the cartography of the system to have room for both application of theory to real-world language contexts, but also the feedback of those contexts back into the system: as a correlate, our understanding of language and means of describing it should be flexible enough to include *all* instances of language. Finally, it will sketch out what this appliability might mean from the perspective of language as residing in the brain itself, taking the notion of "appliability" to challenging extremes.

3. Using linguistic theory to aid the modeling of the physiological basis of the mind

This paper puts forward the hypothesis that ideas from the modeling of language in Systemic Functional Linguistics (SFL) can be meaningfully applied in the development of an abstract model of cognitive and behavioural processes as being grounded in physical properties of neural systems. Although much progress has been made in recent decades to locate where certain cognitive or behavioural processes may reside in the brain, one important question remains: how do low-level physical properties of neural networks link to notions such as cognition and behaviour? In order to shed light on this question, an abstract model is needed.

The Simple Living Artifical Brain (SLAB) project, currently under development at the University of Nottingham, will provide the experimental means to inquire on the nature of such a model. As will be discussed, many of the properties required in this abstract model are also found in models of language in linguistic theory. These include the following: being multi-leveled, describing the influence of the environment and showing how spatially and temporally localized units relate to non-localized higher-level notions. This talk will put forward the claim that this fact opens up the intriguing possibility that what has been discovered about complex, multi-leveled systems in linguistics can provide clues to how such a framework may be applied in neuroscience.

This talk will focus on two aspects of the model, and explore why they are important to the modeling of cognitive behaviour. Firstly, the idea of stratification in a neural context will be discussed. This provides a multi-leveled model of increasing abstraction, with no necessary causal links between the levels (Halliday, 1991). Stratification captures the idea that cognitive behaviour is not the cause of the physiological state of the system, or vice-versa, but both are the same phenomenon but described at different levels of abstraction. Secondly, the notion of the *cline of instantiation* (Halliday, 1994) provides a way of thinking about the relationship between the underlying system under investigation and instances of that system as seen in observed behaviour. In a neuronal context, this notion offers a way to consider the feedback between individual instances of an organism interacting with the environment and the organism's potential for exhibiting certain behaviours in certain situations.

This presentation introduces a novel inter-disciplinary research approach, whereby ideas within abstract modeling in linguistic theory can be applied to neuroscience to further our understanding of the physical basis of behaviour and cognition.