International Journal of School and Cognitive Psychology

Leon-Dominguez U, Int J Sch Cog Psychol 2014, 1:2
DOI: 10.4172/2469-9837.1000e103

Editorial Open Access

Neural Challenges for the 21st Century

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Received date: March 24, 2014 **Accepted date:** March 28, 2014 **Published date:** April 5, 2014

Editorial

As we enter the 21st century, the rise and growing use of neuroimaging techniques in brain research provides us with the unique opportunity to discuss the real state of cerebral functioning. Cerebral function is what ultimately defines the human condition, and it is the tool we use to understand the cosmos as well as ourselves. The comprehension of neural mechanisms underlying cerebral function has become a theme of great interest, proof of which can be found in the economic investment of the U.S. and Europe in ambitious research programs aimed at deciphering and simulating the functioning of the brain. These bold initiatives hold tremendous potential for fields ranging from medicine and psychopathology to artificial intelligence and philosophy. Both projects are enormously complex, given that the technical and theoretical elements needed for their development stretch beyond the limits of human knowledge.

The principal limitation, in technical terms, is that no existing computer can simulate the interaction produced between more than 100 billion neurons. The complexity of this task increases exponentially when an attempt is also made to simulate potential interaction between these neurons. In terms of scale, there are more neural interactions (or possible content of consciousness) in the human brain than there are particles in the universe [1].

One example of the magnitude of this task can be found in an experiment by German and Japanese scientists which attempts to simulate human brain activity using one of the most potent supercomputers of our time. It "only" took them 40 minutes to simulate one second of activity in 1% of our brain [2]. Attempts at brain activity simulation also face challenges regarding the exact calculations needed to attain this simulation. The sheer number of interactions that must be calculated borders on absolute chaos. From a mathematical perspective, the brain can only function by means of incomputable determinist laws or determined chaos (read more in Gödel's incompleteness theorems, 1930).

Apart from technical challenges, there are theoretical issues that need to be resolved, namely the "binding problem" and "hard problem" of consciousness. The first to discuss the binding problem of consciousness was Christof von der Mahlsburg [3], who theorized that neural mechanisms mediated in the unity of our experience. This cognitive binding is thought to occur at virtually all levels of cognitive processing and is considered a crucial event for consciousness itself [4]. Singer [5] proposed that brain network integration was caused by transient synchronization of discharges at millisecond precision. At the cellular level, interneurons deal with the binding problem. Researchers have suggested that this cell, along with its inhibitory activity, is primarily responsible for neural coupling or synchronization between different neural networks [6,7]. Thus, synchronization, and in particular, interneuron activity, could act as the physiological mechanism that triggers dynamic neuronal self-organization and leads to the emergence of different contents of consciousness [8]. The binding problem proposed in the 1990's may finally begin to be resolved, two decades later.

Neuroscientists must also face the daunting theoretical challenge posed by the hard problem of consciousness, the conversion of nervous activity in cerebral networks to subjective experience, or qualia [9,10]. Here we encounter the grand mystery of the neurosciences, and in theoretical terms, one of the main obstacles to the scientific study of subjective experience [11]. Some authors suggest that the components of qualia are unconscious associations whose brain structures are comprised of neural networks linked to these same associations [12,13]. Others theorize that consciousness as a whole represents a complex neural pattern that misperceives some of its highly complex properties as monadic and qualitative [14].

At this juncture, it may help to step back and contemplate this issue from a different perspective. The best option, in my opinion, is from the theoretical standpoint of Emergentism. This theory maintains that a complex system or metacharacteristic, which cannot be explained by the properties of its individual elements, emerges from synchronized interaction among a vast number of elements. The integration of billions of neurons into neural networks, which integrate into even greater neural networks, allows consciousness to emerge [8,15-18].

The study of complex systems follows certain thermodynamic rules and equations, and may provide a scientific approach to addressing the hard problem of consciousness [19]. This approach can be applied to society as a whole. The Internet and cellular devices allow us to stay connected online. When an event goes viral through social networking, a global consciousness appears to emerge, pushing for resolution and accountability. In today's high-tech world, consciousness could be one the best examples of emergentist properties.

The technological revolution and rapid scientific advances of this century could lead to a paradigm change or the start of singularity. A better understanding of the brain requires a better understanding of us as human beings, and of our universe. The scientific field's best equipped to lead this transition--physics and neuroscience--have already found some common ground [20,21]. In the face of these formidable challenges, the neurosciences are being called up to lead this paradigm change with other scientific and social players of the 21st century.

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Citation: Umberto León Domínguez (2014) Neural Challenges for the 21st Century. Int J Sch Cog Psychol 1: e103. doi: 10.4172/2469-9837.1000e103

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