Neuron Counts and Uniqueness of the Human Brain

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There is a wide consensus that the human brain is unique. Our accomplishments – language, planes, cities, metaphysics – suggest as much, and our capacities for problem-solving and abstraction are worlds ahead of those observed in other animals. This report will examine this consensus in light of some new research, and attempt to provide some idea of what it is that differentiates our brains from those of other animals.

1) The Old Consensus

Neuroscientists have suggested a number of answers as to what makes out brains different. [2] Until recently, it was believed that human brains contained around 100 Billion neurons and roughly ten times as many glial cells. Both numbers, but especially the latter, were much larger than those of other animal brains that had been studied, and so those were considered likely causes for our greater intelligence. Neuronal counts have long been considered a proxy for intelligence, and it seems reasonable to think that large numbers of glial cells would increase myelination and thus the speed of thought.

Secondly, the human cerebral cortex is unusually large, and it was believed that cortical neurons were largely responsible for higher brain functions. Also in humans, 20% of total energy use goes to the brain, though it is only 2% of body mass, and this ratio is larger than for many other mammals. Finally, the human brain is one of the largest among land animals, and extremely large in proportion to our body size. The combination of all of these seemingly unique traits seemed to indicate a reasonable basis for viewing the human brain as an aberration among known species.

2) New Knowledge

Recently, new developments in techniques for estimating neuron numbers have called these theories into question. There has long been a belief that the relation between brain size and number of neurons is more or less constant between species, at least among mammals. However, a new study shows that in rodents, it is the size and not the number of neurons that increases most with brain size. [3] Therefore, the overall number of neurons in a rodent does not increase as fast as brain size does. Primates, in contrast, tend to have similarly sized neurons regardless of brain size, and as a result even smaller primate brain contain many more neurons than comparable rodent brains.

The takeaways from this study are twofold. First, size is not a consistent indicator of the number of neurons in a brain. This also calls into question the validity of using brain size alone and the ratio between brain size and body size as approximations of intellectual capability. Second, perhaps it is not the human brain that is qualitatively unique, but the primate brain. Another study, this time conducted on human brains, confirmed that hypothesis. [4] An average adult male brain was found to contain roughly 85 Billion neurons, and a similar number of glial cells. As well as disproving theories about unusually large glial cell concentrations, this showed that the human brain has very close to (< 10% difference) the number of neurons that would be expected in the brain of a human-sized primate, based on extrapolation from other primate species. Also, the study found that while the cerebral cortex was proportionately larger in humans, it contained only the number of neurons that would be expected based on scaling up from other primate brains.

In other words, the uniqueness of the human brain is real, but it is perhaps not as much of a qualitative difference as previously thought, at least with respect to our closest relatives. Primate brains in general seem to be much more efficiently structured (in terms of neurons/size) than those of other mammals, and humans possess significantly larger brains than other primates. In terms of proportions and overall structure, however, our brains are very similar to those of other primates.

3) Research Technique

These findings were generated using a new technique called the Isotropic Fractionator. [5] Essentially, the idea is that instead of trying to count cells, which come in many different shapes and sizes, researchers should count neurons, which are much easier to deal with. The assumption is that every cell in the brain has exactly one nucleus, and, since neuronal nuclei can be distinguished fairly easily from other types, counting nuclei is an efficient proxy for counting cells. Once the nuclei are separated, they are stained with an antibody that colors neuronal nuclei, and they can be counted using a microscope. Once enough samples have been counted, they are used to generate an approximation of cell numbers for the entire section of the brain under examination.

4) Implications

The distinguishing features of the human brain are of interest to AI researchers for obvious reasons. Humans are the most intelligent animals we are aware of, so understanding our brains appears to be the most straightforward way to understand how intelligence works in nature. The results of the studies described above show that the singular distinguishing feature of human (and primate) brains is not size or specific structural differences, but the total number of neurons the brains contain. In this vein, the large percentage energy usage observed in human brains is actually not anomalous: brain energy use may vary across species, but brain energy use per neuron is fixed. [1] In other words, humans use more energy in our brains because we have more neurons in our brains.

If neuronal number is the primary divider in nature between the intelligent and the unintelligent, that seems to have some significant consequences for AI. A gorilla has a brain 1/3 the size of a human, and, while data are not yet available, as a primate seems likely to have roughly 1/3 the number of neurons. As computer scientists we tend to focus on better algorithms and asymptotic size comparisons. We would not expect a 3 to 1 increase in storage and processing power to be vastly significant, yet in nature it clearly is. Perhaps, then, one problem with the AI project at this point is that computers do not yet have the processing power that our brains do (One rough estimate calculates 100 Billion neurons * 200 impulses/s * 1000 connections/neuron = 2E16 calculations/s; Wikipedia reports that the fastest computer today does 8E15 floating point operations/s, so we may be getting close [6] [7]). Another, related implication is that perhaps it is too early to give up on artificial neural networks' capacity to produce human-level intelligence – like gorilla brains, they may simply need to be a bit larger.

References:

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