The Ethical and Technological Aspects: Neuroscience

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Abstract — The paper review about the some breakthroughs like (Broca's region, Alzheimer's diseas, Neuroimagin)and technological advancements(fMRI, brainiacs, Gallvin approach, Dr. Pam Schiller's approach) in the field of neuroscience. The brain contains about 100 billion neurons! Mapping them and finding out just what it is they actually do and how they function, is by no means a trivial task. Subsequent section of the paper focuses about the Human Brain Project (HBP), along with a few recent research studies, their findings/accomplishments, the future prospects and possible applications. At last the paper analyzes the aspect of ethical issues that are becoming the challenge to deal with, with the emergence of neuroscience along with the UAE aspect of the Neuroscience.

Index Terms— Neuron, HBP, Human Brain and Neuroethics

I. Introduction

Neuroscience is all about the study of neurons and the functioning of the nervous system. It implements the principles of various fields such as physics, mathematics, chemistry, biology, computer science, and electronics to make postulate appropriate theories and test them out experimentally in order to understand the workings of the brain and its neural networks [6].

Neuroscience is a fairly broad term; it can be branched into other disciplines: developmental, computational, structural, evolutionary, and functional, to name a few. Its prime objectives are the innovation of modern technologies, and to diagnose, combat and preferably cure brain/neuron related disorders.

Growth of neuroscience in the past:

The field of neuroscience has been one of the pioneering fields to ask questions of our very existence and even our nature and to try and attempt to answer them. The turning point was the development and research in Brain-Computer Interface (BCI) or Mind Machine Interface (MMI). This is quite simply (as the name suggests) the combination of computer/computing technology and of course the unsurpassable and often pliable human brain; in its implementation the immense adaptability of the brain and the improvements in electronic devices help the disabled people in overcoming and even alleviating their disabilities.

The Jens Naumann [12] case was an essential step forward in the realization of an improved "brave new world", one in which disability was no longer permanent but merely a case of study and research in the right direction to successively eradicate our so called shortcomings. Jens Naumann lost his sight in his adulthood but thanks to modern technological advancements and the study of the human brain (neurology) scientists and doctors alike were able to restore his sight to a certain extent. The technique/method used was one put forward by a renowned biomedical researcher named William H. Dobelle. His model was one which consisted of a mounted camera on a pair of glasses and electrodes directly implanted into the brain which stimulated the vision center. That's the basic functioning of the technology, although a lot of time, effort and research went into its implementation putting it into words makes it sound perhaps, quite less glamorous than it actually is and only someone with an in depth knowledge of the subject can truly appreciate the complexity and beauty of this ingenious approach towards restoring sight. However the mere thought of helping someone regain their sight (one of our most key feature; frequently taken for granted) by the application of some key principles in the field of computation, neurology, and electronics, never ceases to baffle and/or astound. Jens' implant was put in place in the year 2002, over a decade ago!

Breakthroughs:

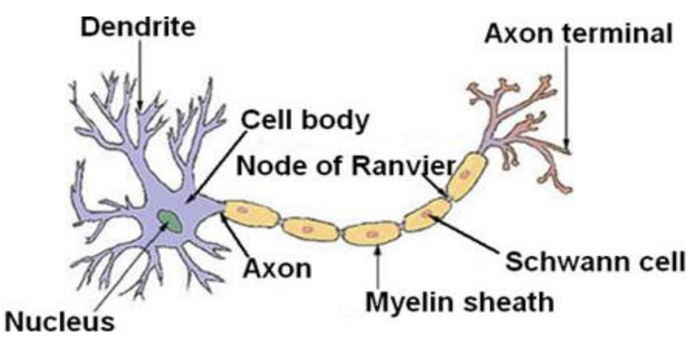
Broca's region: Paul Broca was a surgeon of French descent. In the 1860s he discovered a correlation between the left frontal lobe and speech. He documented and considered that lesions and/or damage in the left frontal lobe of patients may be held responsible for their speech impediments. This in turn formed the basis that the brain's regions specialize in unique tasks and each part of the brain may be attributed to different abilities and skills. This was a discovery which is now central to all neurological studies and is to date considered one of the most important discoveries in the field of neuroscience.

Alzheimer's disease: Alois Alzheimer theorized the increasing chance of dementia with age. In the year 1906 he described the disease and its potential to inhibit brain function and affect memory. He worked with a woman named Auguste D who had several of the symptoms now known to be an essential tool in the diagnosis of the disease. He interviewed the woman on many occasions and came to a few crucial hypotheses which are still currently being studied by doctors and scientists to find a cure for the dreaded disease [11].

Neuroimaging: Technologies such as CAT (computerized axial tomography), PET (positron emission tomography), MRI (magnetic resonance imaging), fMRI (functional MRI), EEG (electroencephalography) have given us a firsthand look directly into the brain as and when it functions, in real time! These technologies have been of great importance in the advancements of the field in the recent past. They have essentially provided us with a "road-map" view of the brain and allowed us to localize different parts of the brain to different functions [1].

*Human brain, neurons and their functioning**:*** The nervous system is made up of interconnections of many neurons arranged together to form a network (called the neural network). Neurons specialize in carrying information in the form of electrical impulses. They consist of a cell body within which cell structures/organelles such as the mitochondria (the energy center), nucleus (carries genetic information), Nissil's granules, etc. exists

Neurons have elongated projections called axons and dendrons. Axons carry the electrical signals away from the cell body, whilst dendrons carry them toward the cell body. Vertebrate neurons are usually encased within myelin sheaths. The main purpose of the myelin sheath is to protect the nerves and speed up the propagation of impulses [5].



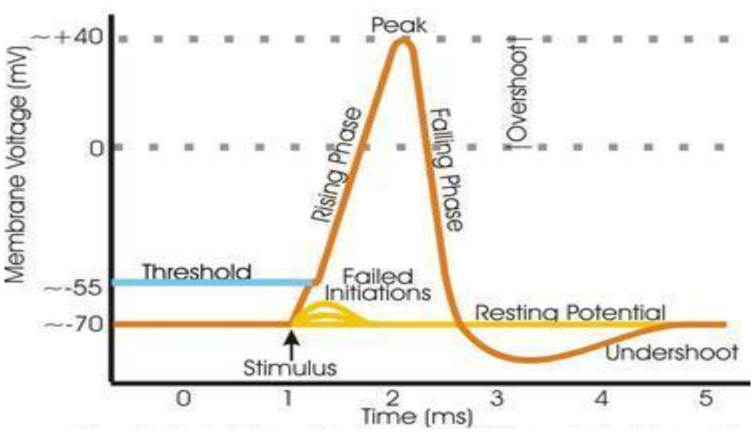
Structure of a Neuron

Axons carry electrical impulses by a process called 'the action potential'. This is accomplished by manipulating the concentration of potassium ions (K^+) and sodium ions (Na^+) inside and outside the membrane. Na^+/K^+ gates embedded in the membrane make this process possible. On resting potential (-70mV polarized) there is a higher concentration of Na^+ outside the cell than the inside, and vice versa for K^+. In the event of an action potential (when small amounts of depolarization reaches a threshold), the Na^+ channel/gate opens up to allow Na^+ ions to flow along the concentration gradient and makes the inside of the cell positive (about +40mV), this is the depolarization part of the progression. Next, the Na+ channel closes up and the K+ channel opens up, allowing the K+ ions to flow along the concentration gradient and causes the potential within the cell to drop once again but the K+ channel opens and closes very slowly therefore the potential drops to below resting potential. This is repolarization. Finally the K+ channel closes and hyperpolarization is corrected and the resting potential is reached yet again. Resting potential is maintained by K+/Na+ pumps; this is an active process and requires energy in the form of ATP (adenosine triphosphate).

These breakthroughs in the field may not have been possible if not for the need/want for constant progress of the human condition. Every science dependent discipline is an arms race between growing need and satisfying these needs adequately. Neuroscience is no different; the need for its existence is preliminary to understanding more about the human brain and assist with abolishing the diseases related to it. This is further discussed in the section below

II. NEED FOR NEUROSCIENCE

Modern research in the field neuroscience aims to find out why the brain works the way it does, how it works, what are possible cures for its disorders and/or degeneration. Like with any scientific research the first step is discovery, and from there on the path to innovation can be paved. The scientist and professionals at CERN (Council European Organization for Nuclear Research) are an excellent example of research intertwined with implementation and innovation.



General shape of an Action Potential propagating down a logigo axon.

III. SOME RECENT STUDIES

1). *Researcher at the University of Western Ontario* have been able to predict a person's actions moments before they actually execute them just by looking at the parts of their brain where activity seems to be localized in an fMRI scan (while, or rather just before their thoughts are converted into physical action). Basic principle is based on the fact that different regions of our brain "light" up when thinking/doing different things.

For instance the parts of the brain that are active when we move our hands are different from the ones when we move our legs; similar theory applies to thoughts as well.

Bringing the real world into the brain scanner, researchers at The University of Western Ontario from The Centre for Brain and Mind can now determine the action a person was planning, mere moments before that action is actually executed. [13]

According to Gallivan : The new findings could also have important clinical implications: "Being able to predict a human's desired movements using brain signals takes us one step closer to using those signals to control prosthetic limbs in movement-impaired patient populations, like those who suffer from spinal cord injuries or locked-in syndrome."

2). *Similar approach has also been adopted by the "brainiacs" at another University:* The researchers/scientists at University of California Berkeley have succeeded in reading peoples' minds, well nearly. What they have done, is essentially created a computer algorithm that couples with the brain scans of the visual cortex of volunteers using MRI (Magnetic Resonance Imaging) to recreate their thoughts in the form of movies which can be displayed on a screen and recognized (albeit vaguely, but is distinguishable to a decent extent) by us.

This could be of immense importance in sleep study research, assisting in shedding light as to what happens to our brain in the state of coma, etc.

The technology works by taking MRI scans, which images the brain of the volunteers while they are shown a movie or video clip. The idea is that, by using a sophisticated computer algorithm which "reads" the MRI scans of the volunteers, it can to a certain degree recreate the images (in the form of a video) seen by them and display these computer generated images on a screen.

3) *"Free Will" or "Forced Execution"*: .This one is right out of science fiction. It brings into perspective the age old question of "free will" or "forced execution". Is it really us who are in control of our brain and thus our action is it the other way round? Scientists have been working on this very subject for some time now. New evidence shows that (as mentioned in study-1) a person's brain shows what they are about to do right before they do it, often without even their knowledge. This begs the question: is it possible to "program" someone's brain and have them perform tasks without their possible consent, and if so, what implications would this have on the ethical implementations of such technology.

Researchers have been able to identify the precise moment when a network of nerve cells (neurons) in the brain creates the signal to perform an action, before a person is even aware of deciding to take that action. Now they are building on this work to make initial attempts to interfere with consciously made decisions by decoding the pattern of brain activity in real time before an action is taken. [14]

Normally it is difficult to research the activity of neurons in the brain because it involves implanting electrodes - an invasive procedure that would not be ethical to do simply for scientific curiosity alone.

4) *Dr. Pam Schiller's on Early Brain Development:* The entanglement of nature and nurture has long been the subject of biological research, new evidence in neuroscience exhibits that these might be more closely linked than you previously imagined. In early brain development, children have a highly active brain. It lies in a constant state of dynamic change, in which the brain makes new connections and learns new skills.

These skills later prove to be of utmost importance in the individuals' daily interaction and to a certain extent his/her survival. After a child is born, needless to say the brain is not fully developed; the higher regions of the brain (cerebellum) aren't yet "wired". The connections it makes is highly dependent on the environment the child is exposed to, which is inclusive of all the factors which are external to the child i.e. the nurture part of the entanglement, whereas the genes he/she possesses is the nature part.

Although all the essential components necessary for the brain to make connections is present at the time of birth, the quality of the "brain wiring" depends heavily on the external as mentioned. Scientists speculate that the majority of our genetic expression may be dependent on our environment. The external world is interpreted by the child and his/her outlook depends on the experiences he/she has at an early age. Some of the crucial skills acquired at this stage of early development are – social interaction, language, reasoning, etc. There are brief periods known as "windows of opportunity" in which the child's brain is especially fertile to acquiring certain skills [2].

A correlation has been linked between music and language centers of the brain. Music is in fact so important that it is critical in the language development in babies. Just as notes combined together form a melody, phrases combined together for sentences. It has been observed that people who speak Asian languages (natively) are more prone to having perfect pitch. Speech itself has a natural melody called prosody. It changes with emotions, if the speaker is excited it translates into a faster rhythm in prosody. And it is more prominent when speaking to infants. This phenomenon is also observed in the cry of infants (even before they develop the ability to speak), there is a distinct melody to it and is relatable to the language native to the child's parents [3].

Below is a table which displays different “windows of opportunity” (and the time associated with it) in different aspects of learning new behavior/skills:

Window	Wiring Opportunity	Greatest Enhancement
Social Development	0-48 months	4 years to puberty
Attachment	0-12 months	
Independence	18-36 months	
Cooperation	24-48 months	
Emotional Intelligence	0-48 months	4 years to puberty
Trust	0-14 months	
Impulse Control	16-48 months	
Motor Development	0-24 months	2 years to puberty
Vision	0-24 months	2 years to puberty
Thinking Skills	0-48 months	4 years to puberty
Cause and Effect	16-48 months	
Problem-Solving	0-16 months	
Language Skills	0-24 months	2-7 years
Early Sounds	0-24 months	8 months to puberty
Vocabulary	4-8 months	2-5 years

Windows of Opportunity

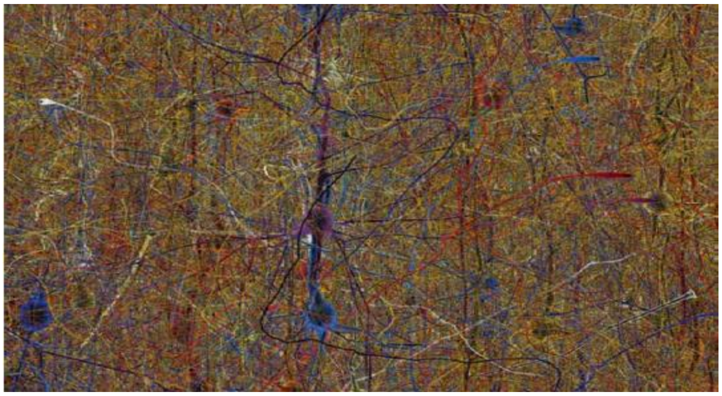
IV. THE HUMAN BRAIN PROJECT (HBP)

This is one of the biggest neuroscience project to emerge in the past few decades (arguable the most significant project). Majority of the funding for the project is done by the European Commission. It aims at modeling the structure and function of the human brain using advanced Information Communication Technology (ICT). Essentially it will be a computerized model of the biological workings of the brain (and its constituents i.e. neurons/neurotransmitters/receptors/etc.) [9] This would have applications in the likes of medicine, artificial intelligence, high performance computation, neuromorphic computing systems, to name just a few. The project intends on adopting a three phase approach over the course of ten years. Namely:

- Phase one – “ramp up” (first two and a half years).
- Phase two – “operational phase” (following four years).
- Phase three – “sustainability phase” (last three years).

As the names suggest, the first phase is inclusive of setting up the required ICT platforms which will be used to assist with the project, the second would be the research and data assessment (inclusive of data recording/sorting, experimentation, etc.), the third phase would be to gain financial self-sustainability so that the findings of the study and can appropriately progress and allow future growth.

To give a slight idea on how complex the internal “wiring” of the brain is, here is a picture of a biologically detailed cortical microcircuit reconstructed and simulated by the Blue Brain Project.



Simulated view of internal wiring of human brain

Clearly, understanding the brain requires a lot of coherent and sorted data to be organized into efficient "bite-sized" chunks. Although there is an abundance of data resulting from numerous neurological studies, their reliability has been a subject of heated debate of late. The reason for this can and has been attributed to a disorganized method of research ideologies. There are several independent research firms, doing their part in the fight for science and knowledge but the fact that their data remains majorly undistributed (in the large scale) and unstudied, hampers the efforts of professionals [8]. This project will be highly based on an organized approach to sorting data; ICT will play an essential role in this regard. The majority of the scientific world faces the challenges associated with having access to huge amounts of data on demand. This is especially true for neuroscience as there are various different research methods and a vast variety of sources from very many regions of the world. If a centralized access to the multitude of these data could be made available to different labs, the challenge of "decoding" the brain would become a lot easier (as the saying goes "two brains are better than one"). This is another one of the project's aim/goal.

Many of the findings from the HBP will undoubtedly be of great use to the scientific community and prove to be of key importance in new and improved technology. These have the potential to become integrated into our lives and perhaps even our existence in the long run [10].

V. NEUROETHICS

Fast paced advancements in neuroscience has changed the outlook of people, and the professionals associated with neurology/psychology/neuroscience are under immense pressure to keep improving technologies in the field and cure the vast variety of brain/neuron related diseases/disorders that still remain persistent in the world today [4]. This has also brought into light the different approaches adopted by scientists and industry professionals in order to keep up-to-date with the latest research and satisfy the needs and/or growing demands of disease stricken patients and their families. Some of these approaches and their ethical impact will be discussed in the section below.

Basic criteria that should be satisfied include performing clinical trials with care, avoid any harm to individuals, and look out for the law and general ethical standards of the nation in which the research is being undertaken in. The brain is the most complex organ. Its ability to perform task and function adequately under any circumstance makes it a uniquely versatile tool for survival.

However, its complexity and interconnections makes it a virtually impossible practice to try and alter just one particular function (or ability) in its core. Due to its tightly packed structure and highly interconnected and branched build, just a single point in the brain may (and usually are) be responsible for doing numerous different things.

Therefore just the tiniest of probing into its structure and/or even slight intended intervention in its functioning can result in alterations in other functions, which aren't desirable. Great care must be taken and all possible safety precautions should be studied to avoid these outcomes [7].
Few of the questions asked by the scientific community and are hoping to address is that "are we in the process of altering the intentions of Mother Nature?" and if so, "are we prepared to deal with the consequences?".

As theory goes, “humans are animals too”. This is the adaptation in scientific research and clinical trials, however taking the analogy “not all fruits are mangoes” apply to the aforementioned humans as animals. There are considerably and significant differences in the biological systems of different species of animals (seems like an obvious statement) but the implications this would have in the real-world are dire. Although scientists do their best to try and interpret animal studies and data obtained from various animal trials (or tests) and link them to human subjects and employ the safest way to integrate them into possible treatments which would be of great use to us, there are further safety measures that can be implemented to ensure healthy results and human wellbeing.

Neuroscience research is aims to improve our ability to predict future health conditions and behavior and our knowledge of how to modify both. Studies are based on large groups to whom a specific treatment is given (various precautions such as control groups, and double blind tests are taken), however, conclusions are made which are more closely related to being assumptions rather than actual conclusions; the results from the studies are extrapolated and decisions are made on success-rate percentages and not treatments designed specific to individuals. For the greater part of the century, this seemed to be enough to implement treatments and the results were satisfactory enough in relation to the technology (and drugs) that was available at the time. But in recent times, a growing need for individual treatments (as not everyone’s immune system is the same and different treatments have acquired different results depending on the person’s genetic build-up) have been addressed and projects such as the “Human Genome Project”, a project responsible to map out the entire human genome had been set and this had implications in individual specific treatment.

Neurological research is put under scrutiny by the same ethical guidelines and regulations as any other field of research with humans. These include regulations of confidentiality, governing conflicts of interest, data and safety monitoring of clinical trials, institutional review boards, and informed consent. These issues have been taken into consideration and have been debated, argued, and well thought out before putting forward a new study or research and to the best of their ability try to abide by the aforementioned ethical guidelines.

When comes to understanding the drawbacks of testing and getting consent of patients for carrying out a new type of treatment/therapy on them, it is absolutely crucial to educate them fully of all the probable risks at hand. The problem here lies in the fact that it may be quite difficult to get consent from patients with mental illnesses that compromise their intellect and emotions, as they may not be in the appropriate mental condition to make adequate decisions, let alone a life altering one which requires full understanding of the volunteer. In these cases, examiners frequently secure permission through a responsible family member or a specially appointed surrogate or proxy for the impaired person.

VI. CONTROVERSIAL APPROACH

An area of research involves the use of neurostimulation such as transcranial direct-current stimulation (tDCS) or transcranial magnetic stimulation (TMS). While tDCS and TMS function somewhat differently, they're both capable of increasing or decreasing activity in different parts of the brain. [15]

These technologies have been used as treatment for a wide variety of problems including migraines, Parkinson's disease and to aid in recovery from strokes. They've also shown some promise in enhancing certain cognitive abilities like memory and problem solving, and are preferred to many other treatments given that they're non-invasive and relatively safe, especially compared to procedures such as electroshock therapy (shock treatment).

Although tDCS and TMS are not currently employed in the treatment of offenders (criminals), one can conceive of their being used to turn off — or at least tone down — troublesome areas of the brains of individuals with impulse control problems.

That will no doubt prove controversial, but a third area — psychosurgery — has been and continues to be by far the most controversial means of controlling behaviour, given its invasive nature and potential for serious complications.

Needless to say, such procedures raise serious ethical issues. But in fact all procedures, be they surgical, pharmaceutical or electrical, raise many important ethical questions, questions that ought to be asked and answered before we employ them in treating offenders.

At this point, research on many of the proposed methods for treating offenders remains in its infancy, and hence it's too early to conclude that they work. That fact alone should discourage us from employing the procedures, since they might achieve nothing positive but might in fact produce serious side effects.

But the more difficult question arises when evidence suggests certain procedures do work at, for example, reducing violent behaviour in individuals with impulse control problems, which, incidentally, includes the majority of the prison population.

Despite the benefits such procedures could offer both the offenders and society, many people are understandably hesitant to sanction making changes in someone's brain, especially without the person's consent — something British Columbia Court of Appeal Justice Ian Donald calls "a terrifying prospect."

Yet Greely notes that "now we send people to prison, and prison changes their brains" — and one might add that it rarely changes anyone's brain for the better. Greely further argues that when we send people to prison, or impose any other sanction on them, "we want to change their brains." And ideally, we want to change their brains in a way that gives offenders better control over their impulses that makes them more responsible.

VII. Neuroscience in U.A.E

U.A.E is still in the preliminary stages of neuroscientific research and development, but UAE is very well on our way with various labs and research facilities being set up. New York University Abu Dhabi (NYUAD) has set up a neuroscience language research lab. They will be working on the human language aspect of neuroscience and trying to establish brain regions responsible for learning/understanding language. Below is the press release of this initiative. The lab has signed a partnership agreement with UAE University Linguistics' Neuroscience of Language Laboratory, committing to share resources and technical expertise, and to collaborate on research projects. The Department of Linguistics at UAE University (UAEU) has an established team of researchers working on Arabic and other languages from formal, neuropsychological and developmental perspectives; the collaboration between the two labs aims to position the UAE as a leader in neurolinguistic research.[16]

"This partnership between the labs at UAEU and NYUAD will help us achieve our common goals of further developing scientific theory, and testing hypothesis in the field of linguistics.

VIII. Conclusion

With bold and brave new research prospects (the likes of HBP etc.), the world of neuroscience is an exciting one to be a part of. If the few kinks (anomalous data and incoherent research) are rectified in the near future with a unified "world lab", the applications and benefits of the field are boundless. It looks as though the scientific community is well on their way to greater and enhanced views of development in computation and technology.

The step of problem identification has already been acknowledged and addressed; now the only task is to solve these underlying problems.

The issues involved with neuroethics (human experimentation, thought control, technology assisted behavior alteration, etc.) are currently being addressed and are in the process being resolved (or at the very least, refined). Once these ethical boundaries are firmly established, the progress of neuroscience will be inevitable and the aforementioned technologies related to the likes of neuromorphic computation will not be a mere theory, but an actual scientific fact upon which our very lives will be centered.

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