(Thesis Abstract)

EMERGENCE OF NEUROINFORMATICS IN INDIA AND ITS SOCIAL CONTEXT

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Research Overview and Approach

Neuroinformatics or NI has been described as the 'the science of informatics relating to brain or behavioural data'.[1] The enhanced ability to study brain function has been aided by a recent spurt in the technological tools available for recording and analysing data. These tools are primarily designed to detect biological changes in the brain. These changes are reflected as variations in electrical impulses, magnetic resonance and ability of biological tissues to detect and absorb positrons, X-rays and so on. These are then translated to visual forms such as EEG or MEG graphs or fMRI, PET and CT images or any combination of these.[2]

Given the increasing diversity and number of such technological devices, some of which (EEG recorders for example) have been in existence for several decades, large amounts of recorded data already exist. To store, share and analyse the increasing volumes of data requires the use of special informatics tools that are capable of making sense of Neurobiological data.[3] The full scope of NI, however, includes creation of mathematical models and simulators, attempts to arrive at standard vocabularies and workbenches, creation

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[1] Koslow, Stephen H, Heurta, Michael F, *Neuroinformatics: An Overview of the Human Brain Project*, National Institute of Mental Health, Lawrence Erlbaum Associates, Publishers, Mahwah, Ed, New Jersey, 1997: Preface. page xi.

[2] Vilringer Arno, Mulert Christoph, Lennieux Loius, 'Principles of Multi-modal Functional Imaging and Data Integration' in, Mulert Christoph, Lennieux Loius Ed, *EEG-fMRI: Physiological Basis, Technique and Applications*, Springer, 2010, Berlin, Heidelberg. Page 4.

[3] Jagaroo Vinoth, *Neuroinformatics for Neuropsychology*, Springer, Dordecht, Heidelberg, London, New York. 2009, pp 19-20.

and maintenance of interoperable databases and the development of collaborative tools to help researchers share data and results.[4]

While the full scope of Neuroinformatics may be larger, this research concerns itself with two interrelated aspects of its emergence. The first involves a better understanding of the brain and behaviour leading to an enhanced ability to identify and diagnose mental disorders. The second involves the creation of newer technologies based on this enhanced understanding.

Addressing mental disorders predicates an understanding of what an “ordered” or “normal” mental state is. Scientifically speaking, while there may be a common anatomy for human brains that may be useful in identifying and treating damaged brains,[5] there seems to be no consensus on what constitutes normal mental function or behaviour. Indeed, in order to assess what constitutes “normal” mental health, apart from noticeable physical damage to the brain, science looks to “socially acceptable” norms and behaviour.[6] Given the general understanding of science as objective and free from bias[7] as opposed to more nebulous social categories, when it comes to mental health, there seem to be several overlaps and intrusions, making it an interesting area of study.

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[4] Arbib, Michael A, Grethe Jeffrey S, *Computing the Brain: A Guide to Neuroinformatics,* Academic Press, California, 2001. Page xi.

[5] Interestingly, Hanna Damasio, Professor of Neurology at the College of Medicine, Univ of Iowa suggests that there may be an ‘average’ neuroanatomic brain common to most people with a large range of variation considered entirely normal.

Damasio Hanna, *Human Brain Anatomy in Computerized Images,* Oxford University Press, 2005. page 47.

[6] Merrell Kenneth W, Walker Hill M, ‘Deconstructing a definition: Social Maladjustment Versus Emotional Disturbance and Moving the EBD field forward’, *Psychology in the Schools,* Wiley Periodicals, Vol 41(8), 2004. Pp 900-910.

[7] Calhoun Craig, ‘Introduction: On Merton’s Legacy and Contemporary Sociology’, in Calhoun Craig Ed, *Sociology of Science and Sociology as Science,* Columbia University Press, New York, Sussex, 2010, pp 1-17.

Put differently, the use of IT tools to analyse brain and behavioural data may lead to the identification of newer categories of mental disorders. The question that arises then, is - how does the potential of NI tools to create these new standards and categories of mental disorders affect social standards and structures? Or in other words, how do we understand these tools from a social standpoint?

A better understanding of brain function also enables the ability to create new technologies or enhance existing ones. Since many of these technologies are often inter-linked, they are seen as happening in 'clusters'. The combination of these technologies results in convergence or synergy so that they have the ability to change human life, sometimes in radical ways. [8] But are these technologies different in any way from earlier technologies? And if so, in what way and what does it mean for us as human beings?

The research is seen as falling under the rubric of Science, Technology and Society (STS) studies, of the different approaches that fall under this broad umbrella, this thesis argues that a technoscience approach can help us meaningfully understand and examine the field of neuroinformatics. In other words, neuroinformatics as an upcoming and evolving endeavour, I argue, cannot be meaningfully grasped through the rubrics of technology studies, science studies or as the history of science. The technoscience approach is compelling precisely because it sees science and technology as enmeshed processes, which co-constitute and co-evolve as technoscience possibilities in particular social contexts.

Thesis Outline

The thesis describes how this approach plays out in emergence of the field in India.

[8] Bainbridge, William Sims, 'Cognitive Technologies', in Bainbridge, William Sims and Roco Mihail, Ed, *Managing Nano-Bio-Info-Cogno Innovations: Converging Technologies in Society*, Springer, Dordrecht, The Netherlands, 2006. page 203.

In Chapter 1, I discuss how the field of neuroinformatics emerged through the calibrated bringing together of neuroscience and information technology. The consequences of such a coupling of science (neuroscience) and technology (information technology), I point out, is acutely expressed in the manner in which mental disorders are diagnosed and assessed. At one level, conceptualizing and defining mental disorders is overwhelmingly seen as a science based quest. That is, the protocols and procedures of scientific practice come in to play in the setting up of possibilities for treating and analysing the field of mental health. However, informatics tools have become crucial for identifying patterns in data from people who have been diagnosed with such disorders. The identification and classification of these patterns, is in fact, gaining in importance in dealing with mental health issues. The emphasis on using informatics to assemble and generate data on brain signals has thus become crucial to the task of analysing and assessing mental health. In other others words, the scientific quest to understand and explore the human brain is critically entwined with technical equipment.

On the flip side, being able to relate mental disorders with signals recorded from specific locations in the brain also paves the way for the emergence of newer cognitive technologies based on this knowledge. Chapter 5 in the thesis describes some of these technologies that have wider social applications than limited scientific use. However, since scientific understandings are at the core of these technologies; even minor conceptual differences in the underlying science can result in different technologies. This enmeshing of these otherwise separate domains (science and technology) I suggest, makes the case even more crucial and critical for grasping the entwined nature of neuroinformatics through a technoscience approach.

Chapter 2 provides the background and rehearses some of the debates that help to amplify the claims about the enmeshed and co-evolving nature of neurosciences and information technology. One of the key background concepts discussed in this chapter is the idea of 'convergence'. There are several aspects, I point out in my discussion to these 'emerging' technologies which are not developed in isolation but are evolved in groups or as interrelated technological 'clusters'. One such group is what is often termed and called 'Converging technologies'— Nano, Bio, Information and Cognitive (NBIC).

In the realm of science, fields such as psychology, neurobiology and computational neuroscience have similarly been seen as 'converging' towards reaching a 'shared' understanding of the human brain. And as I then go on to argue, one of the integrating forces that has helped nurture a convergence of these otherwise traditionally distinct and unrelated disciplinary fields (psychology, neurobiology and computational neuroscience) has been the use of NI tools. Put differently, convergence has also been seen as occurring between science and technology, especially in the area of cognition.

Through the course of the thesis, I argue that this 'convergence', is effectively, a co-construction whereby technologies, while they aid scientific exploration, also place constraints as much as they yield possibilities on the nature of the questions that may be asked and the frameworks within which answers may be sought.

Several debates have also been discussed in Chapter 2. The debate on standardisation and personalisation, I suggest, on the one hand, argues that newer standards and categories of mental disorders shape and define classification and diagnosis regimes. On the other hand, I point out, diagnosis based on these quantified standards nevertheless require the use of advanced technological tools. This technological dependence of scientific diagnosis, I argue, brings to light different dimensions of mental health. Firstly, the extensive use of technologies changes the method of diagnosis from a more subjective interaction of trained medical personnel with the patient to the collection and analysis of the patient's biological data; secondly, access to diagnosis and treatment gets linked to the availability and precision of technologically advanced tools that may not always be available across the country.

The debate on post-humanism versus being human outlines the idea of the post-human - or beings so technologically enhanced that the boundary between what constitutes the human and the technological is blurred. Emerging cognitive technologies such as BCI (Brain Computer Interfaces), Prosthetic devices and Brain and Nervous system implants, by mediating in the process of cognition, have the potential to change what has generally been seen as a uniquely human phenomenon. Consequently, I argue, cognitive technologies, in collaboration with the other converging technologies have been seen as playing a transformative role in the emergence of this new ‘golden age’ of so called post-human perfection.

On the opposite side of this polarised debate is the notion of the natural human being – using technologies rather than in danger of being made extinct by them. This viewpoint argues that a different conceptualisation of technologies, one embedded in social and environmental realities may lead to a future different from a post-human one. These technologies - based on a different understanding of cognition and the role of technologies in human activity - have traditionally included ‘intermediate’ and ‘appropriate’ technologies and are also reflected in the spirit of more recent trends such as the open source and free software movements in the field of IT.

The scientific understanding of cognition or our ability to rationalise and analyse has generally been understood as being ‘disembodied’ or distinct from bodily concerns. Most contemporary technologies, including the NBIC technologies are based on this disembodied notion. An embodied understanding of cognition, till recently, has been as scientifically marginal or ‘nomadic’ or unestablished. These two notions represent the different scientific understanding on which the two opposing points of view are based.

The third debate - on expert-knowledge versus common sense - discusses the Weberian notion of contemporary society which relies heavily on experts and expert-knowledge. In an increasingly complex world, this view argues that understanding and addressing problems requires a level of technical skill and detailed scientific knowledge that are beyond the reach of non-experts. Decision-making is therefore best left to the experts. The opposing point of view suggests that science is too abstract and generic; being traditionally laboratory-based, it suggests, science has little to do with real-world practicalities. Technologies on the other hand, are seen as too focussed on the efficiency of specific tasks to take note of their larger social and environmental significance. In this situation, it argues, while science and technology may indeed be in position to provide solutions to social problems, they need to be tempered with a more common sense approach. The technoscience approach, by bringing forth the more practical, engineering aspects of science, and the more general concepts underlying of task oriented technologies, also helps us grapple with and find overlaps with the otherwise sharp divide between the expert and the non-expert frames.

How a technoscientific approach helps in arriving at a social understanding of NI is described in Chapter 3 (Co-Construction in NI) which discusses the fieldwork and methodology. The fieldwork is methodologically based on the effort to initiate an ethnography of neuroscientists and software engineers, in order to document and take stock of their viewpoints. The transcribed interactions with them include questions and responses on topics ranging from general concerns about science and technology to specific issues related to neuroscience and information technology as well questions based on the background and experience of the individual. Based on the responses of the experts, a subset of simpler questions with multiple choice answers have been put to other English-speaking, internet-savvy professionals. These responses, furthermore, for my study also form the 'non-expert' or general view as well.

The neuroscientists and researchers analysing brain and behaviour data are of the view that while the quest for generalised 'laws of brain' cannot be ruled out, research emphasis was more on the search for patterns in data corresponding to particular brain functions. Based on the metaphor of the brain as machine, this search for common patterns of functioning or behaviour over more generalised laws suggests a notably engineering approach towards this scientific quest. This highlights the dual nature of Neuroinformatics as an intertwined combination of science and technology.

On the technology front, most IT professionals interviewed agreed that depending on technology/design choices and project management techniques offered several possible pathways in which software development efforts could evolve. While the predominant design and development paradigm of object-orientation was based on the representation of real world-objects as software abstractions, most engineers seemed unaware of the underlying, scientific (disembodied) notion of cognition on which it was based. Thus, the technoscientific perspective also brings forth the scientific concepts underlying the technology development paradigm. As chapter 5 points out, there also exist a different set of software practices that are seen as based on a more 'embodied' idea of cognition.

A study of the transcripts and an analysis of the responses to the multiple-choice, poll-type questions suggests that there may not be a single view representative of the expert opinion just as there seemed to be no single 'general' view. Rather, there were a diversity of expert opinions in both neurosciences and information technology some of which shared sufficient overlap with other general or non-expert view to be acceptable to both. Thus, Chapter 3 suggests that rather than a pure science studies or technologies studies approach, a combination of these perspectives can lead to a mutually acceptable, yet socially robust viewpoint.

Chapter 4 discusses the engineering aspects inherent in the scientific search for patterns of mental disorders using NI based statistical tools. These tools are based on the understanding of the brain as an information processing *machine*; accordingly the mechanistic or engineering perspective plays an important role in it. In tune with the engineering perspective, the idea is not to seek a generalised design or law applicable to all brains, but more to identify and distinguish similarities in their functioning.

One of the characteristics of statistical tools such as the ones used to identify new categories based on similarities in brain signals is the quantification of the margin of error for observation and analysis. These tools attempt to take on board possible inaccuracies in observations and measurements, and suggest that the outcomes of their calculations may not be predicted with complete certainty but only with a quantified degree of accuracy. In other words, implicit in the statistical approach is the idea of a less deterministic, *contingent* view of the universe. In other words, it is not a nomological quest for a universal scientific law, instead that the effort brings together engineering and scientific sensibilities in an *technoscientific* approach.

From a social standpoint, the identification of standards and categories of mental disorders based on an analysis of data signals from the brain, in effect, translates into finding biological parameters for behavioural disorders. The DSM-V, the clinical manual for diagnosing mental disorders suggests that while the search for quantifiable biological parameters for behavioural disorder is the goal, till now, it has not yielded any clinically usable outcomes. Once identified, these newer parameters have the potential to influence *social* standards and categories of the “new” normal. From a decision-making perspective, it implies that decisions made on the basis of similar statistical analysis must keep in mind the possibilities of errors and corrections. Thus, bringing forth the engineering aspects of errors and breakdown to the more deterministic scientific perspective as an outcome of their co-construction, also suggests the possibility of feedback and course corrections.

If Chapter 4 engaged with one part of the technoscience approach ─ the technological aspects visible in the scientific quest ─ in chapter 5 I deal with the reverse; i.e. it brings forth the scientific understandings of cognition underlying technologies in general and information technologies in particular. . Technologies act as mediators between mental processes and the external world so that eventually they become part of the internalised cognitive process. The design and development of information technologies, on the other hand, involve cognitive activities such as analysis, reasoning and decision-making which are themselves aided by IT tools. The mutually reinforcing nature of this relation between cognition and information technologies is thus reflected in the predominant metaphor of the brain as an information processing machine. However it does not end there. Since information processing involves the manipulation of abstract signs and symbols, it may be no surprise that the underlying understanding of cognition is also based on the idea that the external world is represented inside the brain as abstract signs and symbols. This view, known as *disembodied* cognition, seems to be implicit in the traditional conceptualisation and design of information systems and indeed in the textbook Software Development Life Cycle (SDLC). As I point out, cognitive models and patterns such as source-path-goal, containment and the link or association patterns seem to bear a resemblance to software design patterns.

A more *embodied* notion of cognition, one that has recently been gaining in popularity in mainstream neuroscientific circles is the idea that cognition may be based on the direct (embodied) experiences of living in a social and physical world. This divergent conceptual understanding also suggests a different set of technological practices, ones in which engineers or technologists may approach design and development by directly experiencing the physical, cultural and social environment where the technology is to function, rather than working with abstract symbols and imaginations. Thus, the deeply intertwined nature of the science of cognition and the technologies of information processing strengthens the case for a technoscientific understanding of the field.

Conclusion

To summarise, the study of NI using the TechnoScientific approach appears to refine the understanding of both science and engineering as an affect of their co-construction. It seems to suggest that in the case of NI, there may be elements of engineering in science just as there may be scientific aspects in engineering practice.

The questions asked at the outset and the responses that are drawn from the thesis are outlined below:

- How does the potential of NI tools to identify and diagnose mental disorders affect society and its structures?
  - How do we understand NI tools from a social standpoint?

As mentioned in “Mining for Categories” in Chapter 4, NI tools may potentially help in identifying and diagnosing mental disorders by classifying or categorising patterns in data known to come from people with disorders and then searching for similar patterns in generic data. These NI based categories may either overlap with existing social categories or create entirely new standards of categorisation. Being scientifically validated, these categories may end up consolidating social hierarchies and relations of power if they are in agreement with existing social categories or else lead to social changes if they differ.

Additionally, the tools used to identify categories and standards of mental disorders may also be similarly used to identify patterns in other kinds of data. In social issues such as those of governance and markets, newer ways of categorisation and standardisation may be especially significant. The identification of scientifically validated categories may thus influence both formal rules such as those of laws and governance as well as implicit or informal arrangements related to culture, religion and other social etiquette.

Regarding emerging technologies and their relationship to the social, the thesis examined following questions

- Are emerging technologies based on newer understandings of the brain different in any way from earlier technologies?
    - If so how?

As pointed out, there are several important differences between emerging technologies and the 'industrial' or production oriented technologies of earlier times. Indeed, these technologies have been classified as 'meta-technologies' based on their potential to influence other areas and disciplines and to effect social relations of power and notions of identity in more significant ways. The predominant perspective of disembodied cognition underlies the idea of abstract signs and symbols as representations of real-world objects that form a part of text book software design and development practices. A more embodied approach has been associated with a different set of software tools and practices that attempt to arrive at technological systems based on a more direct experience of the social and physical world.