Issues in Neuro - Management Decision Making

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ABSTRACT

New brain imaging technologies have motivated neuromanagement studies of the internal order of the mind and its links with the spectrum of human decisions from decision making among fixed gambles to decision making mediated by market and other institutional rules. We are only at the beginning of the enterprise, but its promise suggests a fundamental change in how we think, observe and model decision in all its contexts.

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Nobel Laureate (Management, 2002)

I. INTRODUCTION

Decisions are an inevitable part of human activities. Each day life is full of decisions and choices. An important question is how people make (economic) decisions. Specifically, researchers are interested in assumptions, beliefs, habits, and tactics that people use to make decisions. Research suggests that brain considers various sources of information before making a decision. However, how does it do this? In addition, why does the process sometimes go awry, causing us to make impulsive, indecisive and confused decisions; kinds that can lead to risky and potentially dangerous behaviours? Human behaviour is not the product of a single process. To a certain extent it reflects interaction of different specialized subsystems. These systems usually interact seamlessly to determine behaviour, but at times, they compete. Outcome is that brain sometimes argues with itself, as these distinct systems come to different conclusions about what we should do. Human behaviour, in general, is not under constant and detailed control of careful and accurate hedonic calculations. It is product of an unstable and irrational complex of reflex actions, impulses, instincts, habits, customs, fashion and hysteria. For a long time, economists have argued that humans make decisions by obeying laws of rationality.

Expansion of neuroeconomics parallels development of cognitive science. Neuroeconomics has bridged contrasting fields of economics and psychology. Economics, psychology and neuroscience are converging into a single, unified discipline with ultimate aim of providing a general theory of human behaviour. This is the emerging field of Neuroeconomics in which consilience, accordance of two or more inductions drawn from different groups of phenomena, seems to be operating. Economists and psychologists provide conceptual tools for understanding and modeling behaviour. Neurobiologists provide tools for study of mechanism. The goal is to understand processes that connect sensation and action by revealing neurobiological mechanisms by which decisions are made. Such union is exclusively attributable to changes within economics. Neuroeconomics has inspired change because important findings have posed more of a challenge to standard economics perspective. The source of inspiration has been neuro judgment research, which can, in turn, be seen as amalgamation of ideas

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from cognitive science and economics. Neuroeconomics has primarily challenged customary economics postulation that decision-making is a unitary process a simple matter of integrated and coherent utility maximization suggesting instead that it is driven by interaction between automatic and controlled processes.

With different disciplines approaching the problem through characteristically different techniques and substantial advances, question of how we design and how we ought to craft judgments and decisions has engaged researchers for decades. However, neuro - economics decision making has recently emerged as an inter-disciplinary effort to bridge this gap. It seeks to integrate ideas from fields of organisational psychology, neuroscience and neuro - economics in an effort to specify accurate models of decision and decision. Research investigates neural bases of decision predictability and value, central parameters in economics model of expected utility. Neuro - multiple - systems approach to decision - making, in turn, influences economics, a perspective strongly rooted in organisational psychology and neuroscience. Integration of these approaches and methodologies offers exciting potential for construction of near - accurate models of decision - making.

Human performance has been subject of active research from quite a few perspectives. How do we make a decision? Decision makers have a tendency to seek more information than required to make a good decision. When too much information is sought and obtained, one or more of several problems can arise. A delay occurs because of time required to obtain and process extra information. This delay impairs effectiveness of decision or solution. Information overload occurs. In this state, decision-making ability actually declines because information in its entirety can no longer be managed or assessed appropriately. A major problem caused is forgetfulness. When too much information is taken into memory, especially in a short period, some information (often that received early on) will be pushed out. Neuroeconomics seeks to explain human decision-making, ability to process multiple alternatives and choose an optimal course of action. It studies how economics behaviour shape understanding of brain and guide models of economics via. Neuroscience, experimental and neuro economics and cognitive and organisational psychology. As research in decision-making behaviour becomes computational, it incorporates approaches from theoretical biology, computer science and mathematics. Neuroeconomics adds by using methods in understanding interplay between economics behaviour and neural mechanisms. By using tools from various fields, Neuroeconomics offers a more integrative way of understanding decision making.

Deciphering brain - environment transactions requires mechanistic understandings of neurobiological processes that implement value-dependent decision-making. There is a crucial difference between ‘thinking about thinking’ and actually enhancing brain and mental processes by developing latent potential of each individual. Theoretical accounts posit that human brain accomplishes this through a series of neural computations, in which expected future reward of different decision options are compared with one another and then option with highest expected value is selected. If human brain is often compared with computer, one aspect is crucially missing. Humans define goals for information processing in computers, whereas goals for biological brains are determined by need for survival in uncertain and competitive environments. How to handle brains behind businesses in age of dramatic change and growing uncertainty? What then are the coherent brain dynamics underlying prediction, control and decision-making?

Quantification of decision is a major area of exploration. This is due to discovery of ‘Matching Law’ that stipulates that relative response rate on concurrently available alternatives ‘match’ available relative reinforcement rates. This theoretical construct describes response allocation in more complex situations. People often fail to design ‘rational’ decisions. Economics agents are subject to multiple biases that affect way they perceive events, act upon them and learn from experience. These behaviours cannot be ignored since they have disastrous consequences. When faced with complex decision, individuals engage in simplifying strategies. Adaptive decision making in real-world contexts relies on strategic simplifications of decision problems. Yet, neural mechanisms that shape these strategies and their implementation remain largely unknown. Although we now know much about how brain encodes specific decision factors, much less is known about how brain selects among multiple strategies for managing computational demands of complex decision-making task.

II. NEURO MANAGEMENT - PERSPECTIVES

Economics have always relied on a careful modeling of decision modeling. To cope with this mismatch, economists have developed theories of decision-making that are a better fit for neuro data than traditional models. Methodology consists in building models to demonstrate relationship between cause and neuro anomaly. Freedom provided by introspection method leads to a model selection problem. Neuro - management decision-making can be regarded as a mental process (cognitive process) resulting in selection of a course of action among several alternative scenarios. Every decision-making process produces a decision. Process must be regarded as a continuous process integrated in interaction with environment. Analysis is concerned with logic of decision making, rationality and invariant decision making it leads to. This reflects more than compensatory interaction of decision making-related regions. Specific brain systems potentiate decision makings depending on strategies, traits and context. Therefore, decision making is a reasoning or emotional process which can be rational or irrational, based on explicit assumptions or tacit assumptions. This leads to formulation of a 'neuro - management decision making paradox'.

Neuromanagement has bridged management and psychology. It challenges standard management assumption that decision making is a unitary process-a simple matter of integrated and coherent utility maximization. The goal is a mathematical theory of how brain implements decisions that is tied to behaviour. This theory is likely to show some decisions for which rational - decision making is a good approximation (particularly for evolutionarily sculpted or highly learned decision makings), provide deeper level of distinction among competing alternatives and provide empirical inspiration to incorporate nuanced ideas about endogeneity of preferences, individual difference, emotions and endogenous regulation. Researches investigate central parameters viz. neural bases of decision predictability and value in theory of expected utility.

This paper starts with the premise that most basic decisions (in form of decision makings or effort allocation) can be traced back in structure of macro-scale brain activity, as measured with modern neuroimaging apparatus. Typically, such responses involve regions in brain whose precise function depends upon specific task the brain is solving. This 'context-dependency' expresses itself through (induced) specific plasticity of networks, in parallel to tonic changes in neuromodulatory activity. In turn, this reconfiguration networks subtends learning and yield (mal) adaptive behaviour. In other words, it is very likely that goal-directed behaviour emerges from interactions that shape spatio - temporal dynamics of macro-scale brain networks. This means that understanding mechanics of multimodal observation of brain activity (electrophysiology, fMRI) and neuro measurements (explicit decision makings, reaction times, autonomic arousal signals, grip force) poses exciting challenge of quantitatively relating information processing to brain effective connectivity.

Decision usually involves three steps: recognition of a need, dissatisfaction within oneself (void or need), decision to change (fill void or need) and conscious dedication to implement the decision. How are decisions carried out in brain? Do we interpret research findings when neurological results conflict with self-report? What are the general implications of neuro management? Central argument is that decision-making is at core of all managerial functions and future of any organization lies on vital decisions made. However, there are certain critical issues coupled with factors such as uncertainties, multiple objectives, interactive complexity and anxiety make decision making process difficult. At times when making a decision is complex or there are many interests at stake, then we realize the need for strategic decision-making. Questions include; how to choose in tough situations where stakes are high and there are multiple conflicting objectives? How should we plan? How can we deal with risks and uncertainties involved in a decision? How can we create options that are better than ones originally available? How can we become better decision makers? What resources will be invested in decision - making? What are the potential responses to a particular problem or opportunity? Who will make this decision? Every prospective action has strengths and weaknesses; how should they be evaluated? How will they decide? Which of the things that could happen would happen? How can we ensure decision will be carried out? These questions are crucial for understanding complex human behaviours.

III. SOMATIC - MARKER (SMH)

Modern economics theory ignores influence of emotions on decision-making. Emerging neuroscience evidence suggests that sound and rational decision making, in fact, depends on prior accurate emotional processing. The somatic marker hypothesis provides a systems-level neuroanatomical and cognitive framework for decision-making and its influence by emotion. The key idea of this hypothesis is that decision-making is a process that is influenced by marker signals that arise in bio-regulatory processes, including those that express themselves in emotions and feelings. This influence can occur at multiple levels of operation, some of which occur consciously, and some of which occur non-consciously. Here we review studies that confirm various predictions from the hypothesis, and propose a neural model for economics decision, in which emotions are a major factor in the interaction between environmental conditions and human decision processes, with these emotional systems providing valuable implicit or explicit knowledge for making fast and advantageous decisions.

Neuro - economics decision-making occurs in face of uncertainty about whether one's decisions will lead to benefit or harm. Somatic - marker hypothesis is a neurobiological model of how neuro - decisions are made in face of uncertain outcome. This holds that such decisions are aided by emotions, in form of bodily states, elicited during deliberation of future consequences and that mark different options for behaviour as being advantageous or disadvantageous. This involves interplay between neural systems that map these states. Although it is unclear whether models generalize to all processing, there is evidence that volitional movements are initiated, not by conscious decision making self, but by subconscious.

Somatic markers are associations between reinforcing stimuli that induce an associated physiological affective state. SMH proposes mechanism by which emotional processes guide (or bias) behaviour, particularly neuro - economics decision-making. Optimism bias is inconsistent with the independence of decision weights and payoffs found in models of decision under risk, such as expected utility theory and prospect theory. Hence, to explain the evidence suggesting that agents are optimistically biased, we propose an alternative model of risky decision, affective decision making, where decision weights—which we label affective or perceived risk are endogenized. Affective decision making (ADM) is a strategic model of decision under risk where we posit two cognitive processes; 'rational' and the 'emotional' process.

When we design decisions, we must assess incentive value of decisions available, using cognitive and emotional processes. When we face complex and conflicting decisions, we may be unable to decide using only cognitive processes, which become overloaded and unable to help decide. In these cases (and others), somatic markers help to decide. Within brain, somatic markers are processed in ventromedial prefrontal cortex (VMPFC). Somatic - marker associations reoccur during neuro - economics decision-making and bias cognitive processing. When we have to design complex and uncertain decisions, somatic markers are summed to produce net somatic state. This state directs (or biases) neuro - economics decision of how to act. This influence may occur covertly (unconsciously), via brainstem and ventral striatum, or overtly (consciously), engaging higher cortical cognitive processing.

Amygdala is an essential component of this mechanism and therefore damage to either structure will disrupt proposed action in mediating development and action of somatic markers. The amygdala is heavily involved in emotion and learning. This is true especially for negative outcomes. The amygdala is responsible for producing fear responses in us and for the learning associated between particular stimuli and fear responses. It has been shown that the amygdala plays a key role in the representation of utility from a gain or dis-utility from losses. Accordingly, demand for ability to solve complex problems initiated evolutionary trend for increases in brain size. This increase is due to increase in prefrontal cortex volume. Evolution of prefrontal cortex allows thinking and processing information in abstract ways. By tagging particular stimuli, it helps speed up process of decision making when encountered by eliminating unsuitable decisions and ensuring advantageous options. Since interactions are complex, evaluating appropriate neuro response in these situations requires greater brain processing capacity involving multiple brain structures.

IV. REVIEWS

Since ancient times, scholars have studied decision-making. But, in general, study of decision has been partitioned into three main approaches. For most economists, goal of studying decision behaviour is prediction to develop formal mathematical models, typically based on a rigorous axiomatic foundation, which can predict decisions humans do, or should, make. These typically take as inputs state of external world and generate as outputs actual decisions made by human choosers. For an economist, a model is useful if it makes accurate predictions; whether or not the algorithm it employs mimics actual process of decision-making is irrelevant to accomplishing this end. For this, economics studies of decision-making can be viewed as aimed towards achieving compact and abstract models of decision possible. The products are high-level, and often normative, theories that state testable neuro hypotheses.

Over the course of the last three centuries, social and natural scientists have tried to understand how we make decisions, but using entirely different strategies. Since late 1990s, groups of interdisciplinary scholars have begun to combine social and natural scientific approaches to study of decision into an emerging synthetic discipline (Neuroeconomics. The central assumption is that by combining both theoretical and empirical tools from neuroscience, psychology and economics into a single approach, resulting synthesis will provide insights valuable to all parent disciplines. Studies conducted to date seem to support the conclusion. Theories from economics and psychology have already begun to restructure neurobiological understanding of decision-making. Recent findings are beginning to suggest constraints on theoretical models in economics and psychological domains.

At a lower level of reduction, psychologists studying mechanisms of judgment and decision seek to understand mental constructs that guide decision making at a more process-based level of analysis. Mental processes like fear of losses or human tendency to overestimate low probabilities form algorithmic components of psychological models of decision. These models seek not just to predict behaviour but to capture accurately mental events that precede decision. As such, they are much more complicated that economics models. Although this mental complexity often makes them more realistic it does so at a cost, because these models are so complicated they can often be hard to test completely. At a yet lower level of reduction, neurobiologists have been trying to understand neural pathways and computations that give rise to decision-making behaviour. These natural scientists have sought to understand, at a physical level, how it is that brain achieves decision by studying computational architecture of the brain. Of course, the challenge neuroscientist's face is one of scale. Understanding how decisions are made simply by tracing neural pathways has constrained neurobiologists to studying only very simple decisions, decisions that an economist or psychologist would consider uninteresting.

During the past ten years, empirical studies of human choices in which uncertainty, inconsistency and incomplete information are present have produced a rich collection of findings which are beginning to be organized under broad generalizations. Since late 90s, interdisciplinary scholars have begun to combine social and natural scientific approaches to study of decision making into an emerging synthetic discipline called Neuromanagement. In 1998, less than 20 papers a year were published that included both 'brain' and 'decision-making' as keywords. Since 2008, nearly 200 articles bearing those keywords have been published. In all probability, the first paper to openly combine neuroscientific data and mathematical theory was 'On neural computation of Utility'of Shizgal and Kent Conover's in 1996. The paper sought to describe neurobiological substrate for decision making using normative theory. In 1999 this was followed by Platt and Glimcher's publication of 'Neural correlates of decision variables in parietal cortex' which argued that: 'Neurobiologists have begun to focus increasingly on study of sensory-motor processing, but many describe these processes remain rooted in classic reflex' and went on to 'describe a formal management-mathematical approach for physiological study of sensory-motor process, or decision-making'. Within neurobiological circles this paper was rapidly followed by a suite of papers uniting both management and psychological theories of decision making with measurements in human brains.

The first formal paper in neuromanagement was published in 2001. The paper appeared in Journal Neuron (Breiter 2001) and reflected collaboration between Breiter, Shizgal and Kahneman. The paper employed psychological Prospect theory of decision making developed by Kahneman and Tverskyin and brain scanning experiment. The scanning experiment revealed that brain activation in ventral striatum matched predicted subjective valuations. The second reflected collaboration between McCabe and Smith. This represented use of game theory in human neurobiological experiment data. Critical insight was that decision-making systems of brain can be viewed as fundamentally two-part system. Areas in frontal cortex and basal ganglia form first of these two parts. These areas learn and compute values of available actions and are a set of valuation structures that these areas principally contribute to decision-making. Outputs of these then appear to pass to fronto-parietal circuits that actually 'decide' between options based on these antecedent valuations and pass these decisions on to motor system for implementation. Subsequent studies have largely supported segregation of neural architecture into valuation and decision making systems, although levels of interconnection between these two are being explored.

In 2003, Glimcher directed that reviewed history of neuroscience and argued that history was striking in its lack of normative models for higher cognitive function. Glimcher proposed that management could serve as source for normative theory. Shortly thereafter Camerer, Loewenstein and Prelec published Neuromanagement: How neuroscience can inform management (2005) which served as a manifesto. Camerer argued that failure of traditional management to make accurate predictions reflected inattention to mechanism. Understanding how decisions are made, they proposed, would yield algorithmic alternatives to neoclassical theory with enhanced predictive power. Noting that, Faruk Gul and Pesendorfer published in 2008 'The Case for Mindless Management'. First, they suggested that neurobiological measurements, per se, lay entirely outside the province of management. Second, they argued that while reductionist approaches that seek to link mechanistic insights to larger theoretical frameworks have been successful in natural sciences, these same reductionist approaches are unlikely to be able to relate natural scientific phenomena to social scientific theory. In essence, they argued that insights into biological mechanism are unlikely to have much impact on management theory.

Several recent advances in Neuroeconomics, however, may challenge this conclusion. Glimcher and colleagues (2007), for example, measured human brain activity while subjects made decisions between monetary gains of different sizes that would become available to them at different times. They found that the brain activations observed under these conditions were incompatible with an algorithmic interpretation of an important theory of intertemporal decision in use by many economists. The problem with Glimcher's argument, however, is that the economics theory describes a mechanism that is not really hypothesized to be instantiated in the brain. Demonstrating that the mathematically specified mechanism does not exist thus only weakly contravenes the theory. A much more compelling reply to this critique would be to demonstrate that a neurobiological observation suggested a testable modification to standard economics theory. While there is one candidate demonstration of this type emerging in the literature authored by Mauricio Delgado, Erkut Ozbay, Andrew Schotter and Elizabeth Phelps (2008), the demonstration that neurobiological data can shape economics theories of behaviour remains incomplete.

In addition to these research centers, The Society for Neuroeconomics serves as a central focus for the emerging discipline. The society was founded in 2005 and hosts an annual meeting at which scholars from around the world present recent scientific findings. In 2009, the Society published, in collaboration with Academic Press, 'Neuroeconomics: Decision-Making and the Brain'. This edited volume serves both as a textbook for many graduate and upper level undergraduate courses in Neuroeconomics and as a Handbook of Neuroeconomics for researchers in the field. It summarizes current advances and controversies in the field and should serve as a starting point for anyone interested in learning more about this academic discipline.

Probably the original publication to explicitly merge neuroscientific data and rigorous mathematical model was Shizgal and Conover (1996) review in Current Directions in Psychological Science: 'On the neural computation of Utility'. The publication sought to describe neurobiological substrate for decision using normative economics model. This was followed by Platt and Glimcher(1996) publication of 'Neural correlates of decision variables in parietal cortex' which argued that: 'Neurobiologists have begun to focus increasingly on study of sensory-motor processing, but models used to describe these processes remain rooted in classic reflex' and went on to 'describe a formal economics-mathematical approach for physiological study of sensory-motor process, or decision-making'. Empirically, the publication demonstrated that activity of individual neurons in posterior parietal cortex encoded both probability and magnitude of reward as would be predicted by most economics theories if these neurons participated in decision-making. Within neurobiological circles this publication, which sought to use economics approaches to studying decision, was rapidly followed by a suite of publications in economics and psychological theories of decision with measurements in human brains.

V. PROBLEM STATEMENT

Making a decision implies that there are alternative decisions to be considered. In such a case we want not only to identify as many of these alternatives as possible but to choose the one that;

- Has the highest probability of success or effectiveness, and
- Best fits with our goals, desires, lifestyle, values, and so on.

Emerging neuroscience evidence suggests that sound and rational neuro - economics decision making depends on prior accurate emotional processing. Somatic marker hypothesis provides a systems-level neuroanatomical and cognitive framework for neuro - economics decision making and its influence by emotion. Key idea is that neuro - economics decision-making is a process influenced by marker signals. This influence can occur at multiple levels of operation, some of which occur consciously and some occur non-consciously. The issues, because modern models ignore influence of emotions on neuro - economics decision-making, that crop up is;

- What happens when we change our minds and what are the algorithms?
- What computational mechanisms allow brain to adapt to changing circumstances and remain fault-tolerant and robust?
- How (and where) are value and probability combined in brain and what is the dynamics?
- To what extent do tracking utility computations generalize tasks that are more complex?
- Does an unmet need generate a tonic and progressively increasing signal (amounting 'drive') or does it manifest as a recurring episodic / phasic signal with increasing amplitude?

- Do higher-level deliberative processes rely similarly on multiple mechanisms, or a single, more tightly integrated (unitary) set of mechanisms?

Every decision is made within a decision environment, which is defined as collection of information, alternatives, values and preferences available at time of decision. Neuroscience evidence suggests that sound and rational neuro - management decision making depends on prior accurate emotional processing. An ideal decision environment would include all possible information, all of it accurate, and every possible alternative. However, both information and alternatives are constrained because time and effort to gain information or identify alternatives are limited. Time constraint simply means that a decision must be made by a certain time. An understanding of what decision-making involves, together with a few effective techniques, will help produce better decisions.

VI. PROPOSITION

Somatic - Markers, as platform of decision-making, are indispensable to dynamics of neuro - economics decision modeling.

6.1 Aim and Objectives

In organisational sciences, study of decision-making is an important preliminary step to provide sound foundation for analysis of equilibrium in organisational systems. Neuroeconomics analysis has been a fruitful development in this direction. In recent past, a new direction of research has emerged, studying interplay of decision making of single individual with business environment that surrounds him. Principal aim of proposed study is to model computational and neurobiological basis of value-based decision making by using tools from Neuro-economics and cognitive neuroscience. Study of decision-making is an important step to provide sound foundation for analysis of equilibrium in organisational systems. Principal aim of proposed study is to model computational and neurobiological basis of value-based decision making by using tools from Neuro - management and cognitive neuroscience. This paper aims at specific ways in incorporating neuroscience, organisational psychology and management modeling approach involved in decision-making. Research fails to demonstrate distinctiveness by obtaining convergent and discriminate validity measures. Purpose is to elucidate principles and decision - making mechanism in brain. There are two basic mechanisms for decision-making; model - free mechanism (reactive / habitual) and model - based (predictive / flexible).

This paper aims at two specific ways in which neuroeconomics modeling can endeavour towards decision - making; first, incorporate neuroscience and organisational psychology of formal, rigorous economics modeling approach, and secondly, awareness of evidences for multiple systems involved in decision-making. Previous research has demonstrated that judgments of intent were significantly related to attitudinal, normative and affective components of decision-making. The research failed, however, to demonstrate the distinctiveness of the three components by obtaining convergent and discriminant validity measures. This limitation needs to be addressed. Purpose of this research is to elucidate principles and decision - making mechanism in the brain. There are two basic mechanisms for decision-making; model - free mechanism that is reactive, habitual, and model - based mechanism that is predictive and flexible.

- Through innovative experimental and computational approaches, attempt will be to clarify how mechanisms are selected or combined, how neural circuits realize 'mental simulation' for prediction of action outcome in model-based decision-making. And, how mechanisms are regulated of human decision making (through combination of theories in logics and statistical inference), analyses of human behaviours / functional brain imaging, measurement and manipulation of brain activities.
- This research ventures to speculate on neurobiological data and offer a model about relationship between human rationality, emotions

and underlying neuro-economics. Emotions and neuroeconomics underpinnings involved in decision - making would provide scaffolding for construction of cognition and for self-processes which undergird consciousness.

- This paper would examine and compare tools of neural network modeling.
- Objective is to put forward a model for neuro - management decision, in which interaction between variables of neuro - management decision processes. The precise **research questions** are;

- Develop and examine computational models on how we make decisions and choices through decision network modeling.
- Characterize how human brain computes decisions using functional neuroimaging (fMRI)methodologies.
- Integrate interdisciplinary econometric approaches towards contributing to decision neuroscience**.**

Focal point is to understand;

- Neural processes underlying how we craft decisions and decisions.
- Understand mechanisms of decision-making using functional neuroimaging methodologies.
- Integrating interdisciplinary research towards contributing to decision neuroscience.
- Objective is to put forward a model for neuro - economics decision, in which interaction between variables of neuro - economics decision processes are addressed via;
- How does brain assign value to different options under consideration?
- How does brain compare assigned values in order to design a decision?
- How is 'process of valuation' changed when control is exerted?
- How is value computed in complex / abstract domains?
- How can Neuro - economics be applied to design solutions to real - time problems?

Subsequent issues are,

- There is a need to attend as to how neuroscience can, and already has, benefited from Neuro - economics' unitary perspective, and
- How neuroscience has been enriched by taking account multiple specialized neural systems with potential research directions.

6.2 Research Methodology

In the past few years, methods used in understanding brain patterns and neural activity have advanced tremendously. In light of discussing some of these theories and applications of neuroscience in decision making, it is important to see what techniques are being used to study the brain. On a very primitive level, many physiological responses can be easily measured by just observing. In recent years, techniques include Electroencephalograph (EEG), Magnetic Resonance Imaging (MRI) and Magneto encephalography which measure changes in electrical current in brain using different techniques viz. MRI and MEG use magnets to measure brain waves while EEG's use electrodes which are attached to the outside of head. Next, Computerized Tomography (CT), which takes X-ray images of the brain; Positron Emission Tomography (PET) which measures emissions from radioactive particles in the blood. The last two are the most sophisticated methods – Functional Magnetic Resonance Imaging (fMRI) – that rely on magnetic properties to measure blood flow and the Single Neuron Measurement where tiny electrodes are inserted into the brain to measure the responses of single neurons. Single Neuron Measurement is a very invasive procedure and is currently used only on animals. Looking at the above techniques, we can see that the techniques used to study the human brain have come a long way. Each of these techniques has different benefits and have some costs associated with them.

Research demonstrates that brain cannot encode all information. Decision is triggered when 'enough' information supporting one alternative is obtained and brain uses a variety of biological mechanisms to filter information in a constrained optimal way. Neuro data reports precisely that individuals stick too often to first impressions. These confirmatory biases may emerge from same set of physiological information processing constraints. Further work in this direction help uncover causes of other biases and determine whether they are all related to same physiological limitations. Methodology used in neuroeconomics model has two advantages. Primarily, evidence from brain sciences provides precise guidelines for constraints that should be imposed on decision-making processes. This help uncover 'true' motivations for 'wrong' decisions and improve predictive power of the model. Neuro theories that account for biases in judgment build on specific models of preferences over beliefs or non-Bayesian updating processes. Rather than guessing a cause for biases, neuroeconomics model builds a model based on existing physiological properties underlying learning and belief formation. In principle, this can help pinpoint biological foundations for anomalous decisions. The second advantage is that by explicitly modelling physiological properties, it is possible to provide foundations for elements of preferences traditionally considered exogenous. Decisions involving risk, uncertainty, or time delays may require complex trade-offs.

The proposed methodology is to develop theoretical foundations, models and algorithms to support timely, robust, near-optimal decision making in highly complex, dynamic systems, operating in uncertain, resource-constrained environments with incomplete information against a competent thinking adversary. Although, based on operations research methodologies such as modeling, simulation and numerical optimization, this paper is expected to include multi-disciplinary emphasis to accommodate complex, multi-dimensional decision frameworks. Methodology includes use of neuro decision tasks and application of neuroscientific analyses and functional neuro-imaging techniques (fMRI). Attempt to combine somatic marker hypothesis with coherence model of neuro - economics decision would be a major initiative. Juxtaposition of Damasio's hypothesis with a cognitive model of neuro - economics decision making is preliminary to a possible model of emotional neuro - economics decision making.

Research directions include;

- Modeling and simulation with objective of decision support,
- Fundamental graph model and network analysis in support of modeling complex systems behaviours,
- Numerical optimization and modeling for behaviours,
- Evidential reasoning and fusion approaches to model real-time information,
- Sequential dynamic decision making approaches, and
- Algorithms and simulation into modeling of decision-making.

6.3 Rationale for Research

Goal of studying human decision behaviour is prediction. This research seeks to expand models, typically based on a rigorous axiomatic foundation, which can predict decisions humans. These models typically would take as inputs state of external world and generate as outputs actual decisions made. For this reason, studies can be viewed as aimed towards achieving both compact and most abstract models of decision possible. To date, economics model of decision has not been informed by the way brain functions, although literature contains numerous papers on Neuroeconomics. By economics model, we mean one that disciplines analysis of observations by assumption of optimization that presumes that economics agent has mechanism for processing information (Bayes' rule) to arrive at decision based on utility function. Observations include not only decision between options, per se, but additional data, including length of time it takes to make decisions, number of errors in decisions and psychophysical measurements such as functional magnetic resonance imaging (fMRI).

Including more than just observed decisions allows data to have an additional disciplining effect on theory. We extend this assumption of optimal behaviour to analysis of brain process producing a decision. To do this, we assume that there is an unobservable decision that an agent makes, consequences of which are reflected in all observable data that can be measured in decision process. That decision is strength of effort devoted to processing information in reaching a decision between options. As a conclusion, we propose a model that joins predictions of traditional psychological observations (time to decide and error rate) and predictions of relative brain activation (as measured by fMRI) dependent on exogenous characteristics of decision environment.

Even as it is recognized that brain (and consequent behaviour) does not operate perfectly optimally, there are several reasons why these assumptions can nevertheless be valuable. First, although complex forms of behaviour might not be optimal, simpler evolutionarily conserved mechanisms might prove to be closer to optimal, or at least to have been so in the environment in which they evolved. Second, an assumption of optimality can be a crucial step in development of formal model, as it is often easiest to define and precisely characterize optimal behaviour of a system. Formal model, in turn, enables generation of precise, testable predictions about system's behaviour. Finally, even when behaviour (or neural function) turns suboptimal, defining optimal performance can provide useful benchmark against which to compare actual behaviour. Identifying ways in which behaviour systematically deviates from optimality can generate new insights into underlying mechanisms.

Neuroeconomics model will soon play a crucial role in building of new reliable theories capable of explaining and predicting individual behaviour and strategic decisions. Main message is that individual is not one coherent body. Brain is a multi-system entity (with conflicting objectives, restricted information, etc.) and therefore decision-maker must be modelled. Before the modern model, organisations were modelled as individual players characterised by an input-output production function. Systematic study of interactions between agents and decision processes within organisations (acknowledging informational asymmetries, incentive problems, restricted communications channels, hierarchical structures, etc.) led to novel insights. Applying a similar methodology to study individual decision-making is the way to understand bounds of rationality.

6.4 Probable Limitations

Until now, research has not systematically integrated influence of emotions on decision-making. Since evidence from neuroscience suggests that decision-making depends on prior emotional processing, interdisciplinary research under label of 'Neuroeconomics' arose. The key idea is to employ recent neuroscientific methods in order to analyze relevant brain processes. Due to its multidisciplinary nature, this investigation is subject to several kinds of misconceptions. Is neuroeconomics study of decision-making processes relevant for economics? Depending on how we define '(neuro) economics', it may or may not be relevant. The debate, however, seems futile. This research does not take a stand on that issue. Instead, it argues that question is of scientific interest and tools from economics theory are well adapted to address it.

- While there are several benefits of using neuroscience techniques in understanding human behaviour and decision making, there are some questions that neuroscience cannot answer by itself and needs help of experimental methodology and theories to understand why we behave in the manner that we do. The key limitation of neuroscience techniques, aside from being expensive, is that it is able to identify that different regions of our brain are activated when we are in certain situations. These techniques are not able to provide an explanation or a reason (neuro) as to why we respond in the manner that we do.
- What happens in brain or what is activated when we make decisions or are in the process of making decisions or responding to outcomes? It does not give us any insight into why we make these decisions and why we respond in the manner that we do. This is where experimental methodology would help bolster understanding as to why people

make decisions that they do. A synergy between neuroscience techniques and neuro experiments will provide tremendous insight into understanding human behaviour and decision making.

- Is the neuromanagement study of decision-making processes relevant for management? Until now, research has not systematically integrated influence of emotions on decision-making. Depending on debate, it is argued that question is of scientific interest and tools from management theory are well adapted to address it. Evidence suggests that decision-making depends on prior emotional processing. Due to its multidisciplinary nature, this investigation is subject to several kinds of misconceptions.

6.5 Likely Contributions

The study of decision making require extensive empirical study and setting for basic research on how ill-structured problems are, and can be, solved. Neuroeconomics offers a solution through an additional set of data obtained via a series of measurements of brain activity at the time of decisions. The likely contributions are;

- Provides a conceptual and philosophical framework for understanding and conducting neuroeconomics research at the intersection of neuroscience, economics and psychology,
- Describes a standard model for decision process that links and spans neurobiological, psychological and economics levels of analysis,
- Applies neuroscience to neuro-economics and ties both fields to biological constraints in how we judge relative value and make decisions,
- An important resource for researchers in interdisciplinary research,
- Shed light on causes of behaviour (and therefore of neuro anomalies) and help build new theories capable of explaining and predicting decisions,
- Measurement of brain activity provides information about the underlying mechanisms used by the brain during decision processes, In particular, it shows which brain regions are activated when a decision is made and how these regions interact with each other, This knowledge can then be used to build a model that represents this particular mechanism,
- Mismatch would yield emotion ,
- Neuro - economics decision juncture would cause simulation to occur

The present attempt would (perhaps) contribute towards existing scholarship in following mode;

- Provide a conceptual framework for understanding and conducting neuromanagement research at intersection of neuroscience, management and psychology,
- Offer a solution through an additional set of data obtained via a series of measurements of brain activity at the time of decisions,
- Describe the first standard model for decision making process with the intention of linking and spanning neurobiological, psychological and management levels of analysis,
- Attempt to build brain-based models capable of predicting observed behaviour,

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