When economic theory meets the mind: neuroeconomics as a new approach to psychopathology

Quando la teoria economica incontra la mente: la neuroeconomia come nuovo approccio alla psicopatologia

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Summary

The paper describes the current status of the new interdisciplinary research field of neuroeconomics in relation to psychopathology, giving an account of possible clinical implications for social dysfunction. This is achievable because neuroeconomics join economics, psychology, neuroscience and computational science in order to gain a greater understanding of people decision making. Recent research are using these tasks in association with neuroimaging in order to understand existing discrepancy between the theoretical models and experimental data and to gain more details on the ways people decide and judge within the social context. We report how neuroeconomics paradigms have been recently used to study social interaction in different mental disease conditions such as in borderline personality disorder, externalizing behavior problems, depression, social anxiety, psychopathy, autism and, more recently, psychosis.

Furthermore the paper aims to point out a new set of tools from Economics Theory able to gather human interaction 'in vivo' in a computable way. The challenge of neuroeconomics may be to bring a broad set of tools letting new knowledge on neural computation of social interaction and, extensively, on mental diseases where the social impairment is a core feature.

In conclusion the paper speculates that neuroeconomics is a potential bridge for translational research in psychopathology as it allows to get an objective evaluation of the interpersonal behaviors in a shifting social environment and to combine behavioral with neuroimaging measures, as tools to investigate relationship between neurobiology and behavior.

Key words

Neuroeconomics • Decision making • Psychopathology

Neuroeconomic basis of decision making: from economic theories to real world choices

Neuroeconomics is a new interdisciplinary research field which combines economics, psychology, neurosciences and computational science in order to gain a greater understanding of people decision making (DM). The study of DM has received significant attention from economists and psychologists in the last few decades. These studies provided both cognitive accounts of preferences as well as understanding of the ways in which neural processes mediate risk-taking behaviour that model real-life choices [1].

This emerging discipline is able to connect computational theories, in particular the reinforcement learning, and game theoretical approach to elements of neural circuits underlying social DM variables. Neuroeconomics may offer a broad theory of human behaviour to study learning, social exchange and cooperation, brain reward pathways and neurotransmitter systems, connecting sensations and actions, disclosing their neurobiological substrates [2 3].

If so, neuroeconomics provides a new approach with new experimental paradigms and tools borrowed from economics science supporting the social neuroscience research in its continuous challenge to find the underlying mechanisms responsible for social behaviour. In the real world the ability to understand others' minds and intentions and beliefs (Theory of Mind – ToM), socially relevant stimuli, make interpretations about their meaning and behave according to decisions that are accurate, optimal and adaptive, are essential to successfully navigate ourselves through the social context. In so far, neuroeconomics may turn in an intriguing tool to ascertain the 'social predicting brain' in the more disparate contexts of DM within human interactions [2].

Traditionally, choice behaviours were studied within economic models according to the global DM theories of 'Utility', the ability of the individual to satisfy needs or wants, criterion of the best option and measure of satisfaction. If economists have devised ways of representing and measuring 'Utility' in terms of economic choices that can

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be counted, this computation is not easy in social decision context, in which one needs to infer the probabilities and values of the partner or opponent in attempting to reach the best decision to obtain satisfaction. This aim can be reached by new tools derived from emerging neuroeconomics paradigm.

In a similar way Economics applies Utility Theory, Neuroeconomics uses the mathematical Game Theory giving the opportunity to apply specific models to social exchange exploration. Game Theory aims to capture rational decisions and choice behaviour in simulated social situations. The essence of Game Theory is strategic interpersonal reasoning: in a two player game, one agent chooses among the range of possible moves depending upon the decision of the Second Agent. The Primary Agent has to form mental models regarding what the Second Agent will do based on his prospective or predicted moves and payoffs.

Neuroeconomics uses Game Theory to investigate cooperation, reciprocity, fairness, and altruism as illustrated by the famous games known as the Trust Game and Prisoner's Dilemma Game (PDG) [4 5]. In the former game the player (Investor) decides to invest money through a partner (Trustee) and during the transfer the amount is multiplied by some factors, so that the Trustee may return some, all or any money. Essentially the game is based on trust: if the Trustee respects trust reciprocating money, both players end up with higher payoff. The PDG is a similar paradigm, but both players choose to cooperate or not simultaneously, without knowing what the partner will chose to do. Game Theory predicts that in the former game, if the players consider each single interaction during the game, a *purely* rational Trustee will never reciprocate trust received and the rational Investor, realizing this, should invest zero in the transaction and, in the latter, players immediately will fail to mutual defection. What is further interesting from our perspective is that, despite these rational predictions, most of people playing are more trustfully, cooperative and less selfish than expected.

Another interesting set of tasks derived from Game Theory is bargaining games, in particular The Dictator and Ultimatum Games used to study behaviours of equality and inequality. In the former one player (Proposer) decides how much offer to the other player (Responder), in the second game the players need to divide a sum of money in order to both have a payoff, with the Proposal deciding the amount and the Responder accepting or not the offer: in case of rejection both players gain zero. According to the rational prediction the Responder should accept any offer and the Proposer should offer the smallest amount possible.

Again, differently from theoretical predictions, observed behaviours show that low offers than 20% of the total amount are rejected about half of the time, underlining a trend to altruistic punishment where the Responder prefers to get no money rather than a miserable offer.

Recent research are using these tasks in association with neuroimaging in order to understand this discrepancy between the theoretical models and experimental data and to gain more details on the ways people decide and judge within the social context.

How psychopathology is using neuroeconomics

Economic theories allow to study different interacting factors in the framework of a single model taking into account motivational drives. This feature is of interest for disciplines as psychiatry and clinical psychology that need real world approaches to study the interplay of social, psychological and biological factors underlying psychopathology.

By varying task characteristics (e.g., strategies, payoffs, and structural features of interactions, such as context and communication between players), simple games can be adapted to probe a remarkable range of social phenomena, including social influence, prosocial behaviour, trust, social-norm violations, social-cognitive biases, group dynamics, and higher-order social cognition [6 7].

Neuroeconomic paradigms have been recently used to study social interaction in different mental disease conditions: borderline personality disorder (BPD), externalizing behaviour problems, depression, social anxiety, psychopathy, autism and, more recently, psychosis.

King-Casas et al. [8] used the iterated version of the Trust task to examine trust in adults with BPD. When cooperation began to falter in the iterated interactions but cooperation is hoped, BPD subjects showed an insensitivity of anterior insular cortex in comparison to healthy subjects. A similar result was achieved by Unoka et al. [9] who found that decreased trust was specific to borderline patients, as opposed to depressed patients, exclusively when the risk -taking is social. These results can be ascribed to an abnormal social input perception in BPD.

Sharp et al. [10] instead used the trust game under the two conditions of anonymous and known-identity to study externalizing behaviour problems in adolescence. Prior social and moral information about partners (i.e., reputations) modulated reward responses in the adolescent brain, where a reduced reciprocity was shown during social reasoning independently from ToM functioning. These results are in line with findings from studies with adults [11].

Monterosso et al. [12] provided evidences in the addiction area studying how people value the near-term and medium-term future in relation to prediction-error signalling and the connected neural substrates.

Ernst [13] reviewed reward-related and goal-directed pro-

cessing in relation to symptoms of depression providing a possible map and connection of the DM processing to neural dysfunction. In the context of social anxiety the major result reported diminished activity for social than to nonsocial partners (i.e. a computer) in a region of medial PFC implicated in ToM.

Findings from a study on psychopaths showed that different patterns of activity in brain areas associated with social emotion regulation (e.g., the dorsolateral prefrontal cortex) were achieved during Prisoner's Dilemma (PD) game with high non-cooperative responses [14]. A general tendency to competitive behaviours, non fairness and exploitation of partners in criminal psychopaths [15] and a comparable level of non-cooperation in psychopaths to those of patients with frontal-cortex lesions as investigated by the Dictator Game [16] were also observed.

Fett et al. [17] using Trust Game showed that patients with psychosis and healthy relatives with a heightened risk for the illness exhibit lower baseline levels of trust compared to healthy controls.

In autism a study using Dictator Game, showed a specific insensitivity to social reputation of autistic subjects when observed by others during charity donation.

All these results demonstrated a validity of neuroeconomics tools, with their specific adaptations to each context, to investigate and discriminate psychiatric disorders.

Neuroeconomics for the social exchange real-world discovery

Why this kind of computational approaches are of interest for psychopathology?

The answer rises from the gap existing in psychology and in psychiatry due to a lack of adequate intermediate levels of description between the neural level and the phenotype, such as mental illness. This is especially true for the understanding of social behaviour impairments specific of some disorders, such as schizophrenia.

The neuroeconomics approach may be relevant for the study of interpersonal dysfunction in psychiatric diseases, where a biological understanding has been achievable only in recent decades, due to the great difficulty in quantifying and parameterizing social cues. Indeed economic games provide the cognitive science with tools of new ecological validity, studying the interaction *in vivo* rather than through static stimuli as face, stories, cartoon comprehension or reasoning and judging about hypothetical scenarios.

The challenge of neuroeconomics may be to bring a broad set of tools letting new knowledge on neural computation of social interaction and, extensively, on mental diseases where the social impairment is a core feature.

The point is that to understand the neurobiology of social dysfunction, one must measure neural activity when participants engage in social interaction or make social decisions. Neuroimaging allows to face this challenge by 'hyperscanning' technology that may image brain functions during partners interaction, simultaneously, using network connections between two separate scanners. Two other interesting methods involves the manipulation of specific neurotransmitter systems with the examination of consequent effects on game-playing behaviour and the use of transcranial magnetic stimulation to activate and disactivate specific brain regions, with the aim to examine the effects on social decision making [18].

However social interaction and psychiatric illness are difficult to assess because of the vast state space of social behaviours and the few external indicators of psychopathology beyond self-report and symptoms ascertained through clinical interviews or behavioural observation to aid in objective psychiatric diagnosis [6 19]. Multiplayer economic games provide a tool to evoke, monitor and measure the degree and type of social impairment in distinct psychiatric illnesses.

Conclusion remarks and future directions

Neuroeconomics approach offers an exciting chance for computing and quantifying social cues allowing a more extensive measurement of interpersonal dysfunction in mental diseases. It is a potential bridge for translational research in psychopathology as it allows to get an objective evaluation of the interpersonal behaviours in a shifting social environment and to combine behavioural with neuroimaging–measures, as tools to investigate relationship between neurobiology and behaviour. Further it permits the development of a common language among the multilevel research paradigms from economics, neurosciences, psychology and psychiatry disciplines to investigate social DM in mental diseases. If so neuroeconomics may be also useful for the study of possible endophenotypes.

Moreover it is important to underline that in any way this approach aims to supplant existing nosologies. Although these models are still quite simple and need many changes to work well in the complexity of human interactions, they may represent an useful add-on for further interpretation of mental functions. So far, evidences from studies on mental disorders using neuroeconomics are encouraging.

Future research may deepen social interaction investigation especially when interpersonal dysfunction is a core feature. This may be achieved for he social difficulties of mood and anxiety disorders that may lie in social probability distortion that prejudice social learning and disrupt social functioning (e.g., social anhedonia). Multi-agent game theoretic paradigms that vary the probability and valence of specific interpersonal gestures may be a useful starting point from which these issues can be examined

and validated. The investigation through neuroeconomics paradigms could be of interest also for the study of vulnerability and resilience to peers influence for risk-taking behaviours in adolescence groups.

Within this framework social valuation (i.e., how much does one value specific social gestures), social risk preferences (i.e., how sensitive is one to social uncertainty), and social inference (i.e., how competent is one at inferring the intentions of social others) may provide unique discriminating vectors among distinct psychopathologies [6].

As social anhedonia seen in depression may signal diminished value from social interactions (whereas susceptibility to peer influence may signal excessive value), the fear of embarrassment in social anxiety may reflect impaired social risk assessment, and in autism, impairments in social inference may manifest as a lack of social reciprocity. Of interest is also the possibility to investigate subtypes of psychotic experiences, such as paranoia using a trust paradigm [20].

Finally, interactive games from economics theories joined to neuroimaging and computational learning theory, provide a paradigm that can be used to study the underlying neurobiology and genetic correlates of social behaviour. They can help in differentiate diagnostic categories or assess criteria, provide bio-behavioural targets for novel strategies treatment of interpersonal difficulties, bridging in some way the existing gap between neurobiology and behaviour.

Conflict of interests

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