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Review article

Neuroeconomics of decision-making during COVID-19 pandemic

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ABSTRACT

The coronavirus disease 2019 (COVID-19) pandemic reveals the decision-making challenges faced by communities, governments, and international organizations, globally. Policymakers are much concerned about protecting the population from the deadly virus while lacking reliable information on the virus and its spread mechanisms and the effectiveness of possible measures and their (direct and indirect) health and socioeconomic costs. This review aims to highlight the various balanced policy decision that would combine the best obtainable scientific evidence characteristically provided by expert opinions and modeling studies. This article's main goal is to summarize the main significant progress in the understanding of neuroeconomics of decision-making and discuss the anatomy of decision making in the light of COVID-19 pandemic.

1. Introduction

1.1. History

In the late 1990s, a new scientific field called neuroeconomics emerged from converging trends in economics, psychology, and neuroscience. Neuroeconomics has evolved primarily with the neuroscientific revolution of the 1990s, which resulted in the development of sophisticated imaging tools, in particular, functional magnetic resonance imaging (fMRI) [1]. The utilization of neuroeconomics in decision-making processes has been a topic of philosophical interest. However, we lack a clear scientific understanding of how people make decisions and how much impact stressful situations have on the quality of decision-making.

1.2. Formulation of choice

A complex neurological network is involved in the formulation of a choice, which aids in decision-making, and promotes the survival of the individual making the choice. Neuroeconomics has also affected the survival and decision-making power amid the coronavirus disease 2019 (COVID-19) pandemic. COVID-19 imposes an emergency on global public health; therefore requires the

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urgency of evident-based knowledge for the decision-making. The ongoing COVID-19 pandemic has significantly affected the decision-making process, making it critical for public health decision-makers. This article aims to review the correlation of neuroscience, psychology, and economics with decision-making and involved neuroanatomical pathways to unveil the intimate knowledge of the neuroeconomics field.

1.3. Role of neuroeconomics

In addition, the role of neuroeconomics in decision-making during the present COVID-19 pandemic will be reviewed and discussed. Firstly going into choice, cognition and uncertainty in order to understand them prior to discussing neuroeconomics; followed by an overview about neuroeconomics and its relationship to neuroscience, economics, and psychology. Moreover, discussing the factors that affect decision-making will be covered.

2. Choice, cognition, and uncertainty

2.1. Definition of choice

A choice is an act of choosing between two or more possibilities. The psychology theories and mental models of choice explore why we subconsciously make the decisions, what inspires those decisions, and what needs these decisions are meant to satisfy. In fact, behind every decision-making process, there are several factors at play. Unless we are forced into making a decision, we have the free will to make the choices that provide us with the best outcome. Many unconscious influences evade our awareness and affect our choices without us even recognizing how those influences have manipulated our reasoning and affected the consequence of our decision. Therefore, the most important question in context is what affects our choice making process?

2.2. What affect choice making process

Human instinctive needs affect choices, decision making, and behavior as proposed by the psychologist [2]. There is a hierarchy of needs which is a set of native needs organized in a pyramid that includes basic needs (food, water, air, and sleep), psychological needs (love and belongings), and self-fulfillment needs (esteem and self-actualization). Every person desires to fulfill needs that also affect behavior and decision-making quality. Most of these needs are essential physiological requisites for survival. We will not be conscious of these influences but will be able to point to them when asked [2]. On the other hand, many cognitive features and mechanisms influence the decision-making process because of the mental pattern for choosing from different options; therefore, important in understanding and predicting human behavior. It is revealed in many behavioral economics studies that decision-making is subject to cognitive elements such as cognitive outline, alternative anchoring, the prototypical degree of alternatives, their memory availability, and the retro-assessment of alternatives [3,4]. Bias not only refers to a belief or judgment about a specific thing but also to behavioral tendencies and influences on decision-making that affect how we reach decisions and ultimately make choices [5]. Many cognitive biases unconsciously affect the way we make decisions.

3. The relationship of neuroscience, economics, and psychology with neuroeconomics

Neuroeconomics being a multi-disciplinary field is considerably associated with different fields of neuroscience, ranging from neuropsychology, computational and theoretical neuroscience, to cognitive and behavioral neuroscience [1]. Cognitive and behavioral neuroscience involves the neural mechanisms of mental and behavioral activities, or, more generally, the relationships among the brain, the mind, and action [6, 7, 23].

3.1. Neuroscience in relation to neuroeconomics

Cognitive and behavioral neuroscience is divided into multiple domains, specifically decision neuroscience (i.e., neuroeconomics), affective neuroscience, and social neuroscience. Furthermore, decision neuroscience is a broad field that unites cognitive neuroscience with decision sciences such as psychology and economics [1]. However, such association is not exclusive, as different disciplines and fields are also correlated and contributed to the emergence of neuroeconomics. As an interdisciplinary field, neuroeconomics utilizes and integrates various pieces of information, from different resources, including knowledge about the structure and organization of the nervous system, the relationships between brain structures and functions, the association between the nervous and hormonal systems, and the underlying mechanisms of brain physiology to inform and articulate economics and decision-making [8].

3.2. Economics in relation to neuroeconomics

Economics is the science of choices, and choices are constricted by limited resources and institutional structures. Neuroeconomics agrees with economics that non-choice measurement was restricted by technology in the past but it has become easier nowadays. Therefore, we can now observe multiple biological correlates of choice, which are causally influenced in ways that are new in scientific history. Therefore, if technology was constricting the focus on choices, then advances in technology make this an appropriate time to investigate the neural mechanisms of choice [9,10]. Therefore, the flexibility of the human brain and its ability to undertake intricate

patterns of social cognition are important considerations in this field. For example, social neuroeconomics addresses decisions made in social contexts and it aims to explain prosocial behaviors, such as trust [1,11–14]. This field relies in part on the findings of social neuroscience regarding the neural networks responsible for interpreting other people's feelings and thoughts, sympathizing with another's state of mind, and acting morally.

4. Neuroeconomics and decision making

The goal of neuroeconomics is to understand human decision-making processes and the mental consideration of multiple outcomes that may be triggered by specific actions [15]. All neurological processes in the brain are driven by logic, which supports optimal decision-making. However, sometimes, this optimal decision-making pathway is hindered, leading to illogical decisions [16]. A central question in neuroeconomics concerns the disparate roles of intuitive, emotional responses and controlled, cognitive responses. Value-based economic decision-making depends on the action of dopaminergic neurons in the midbrain that is responsible for memory formation and retrieval [17]. Neuroeconomics deals with all the processes involved in decision making, which occurs in response to certain known and unknown stimuli. The field of neuroeconomics seeks to identify specific areas of the brain that are responsible for optimal or suboptimal decisions.

4.1. Research domains of neuroeconomics

Several areas of research fall under the domain of neuroeconomics. These include economic decision-making in the face of an unknown situation or an uncertain threat; loss of aversion or sense of control; sexual and social decision making; and intertemporal decision making [18]. Most decisions involve some degree of economic, social, or moral uncertainty or ambiguity. Economic decisions, in particular, are affected by a variety of contextual factors and emotions [19]. Several studies have suggested that the key brain regions involved in these kinds of decisions are the medial prefrontal cortex (ventromedial aspect) and the striatum [20,21]; Q [22].

5. Neuroanatomy of decision making

To understand the decision-making process in more depth, it is necessary to understand the neuroanatomy involved in it. Decision-making is the process by which individuals choose from among different available options. The process of decision-making is dependent on the prefrontal cortex and hippocampus and is done in four steps; firstly, sensory inputs produce an initial stimulus, which excites a set of hippocampal neurons, secondly, another set of secondary stimuli arrives within the hippocampus where the stimulus neuron response is then produced as initial information. Thirdly, this initial information is delivered to the prefrontal cortex, which then determines the additional information needed and retrieves it from the hippocampus [23]; X.-J. [7]; lastly, the prefrontal cortex reaches a proposed controlling process. Multiple neurotransmitters, such as dopamine, serotonin, cortisol, oxytocin, and prolactin, play a huge role in decision-making [10]. These neurotransmitters stimulate the brain to undertake specific tasks [10,17]; but they are still not fully understood (X.-J [7]. Dopamine also plays a role in decisions involving a delayed benefit [10,24]. The left hemisphere of the brain is abundant in dopamine, which is responsible for concentration and attention, both of which are crucial to decision making. The left hemisphere controls the right hemisphere of the brain by inhibiting actions that would be socially improper. If the right hemisphere controls an individual's personality, that person is vulnerable to their impulses and emotions in decision-making [10,25]. The decision-making process occurs in the dorsolateral prefrontal cortex, where the information relevant to the decision is collected [10,26] and then stored and processed ([10,27, 86]. Other functions of the forebrain include attention, executive control, working memory, planning, sequencing, and finally, emotional and motivational significance [28–31]. Studies of focal lesions using functional imaging have noted that the orbitofrontal and anterior cingulate are also critical to decision making [32]. The relationships between specific prefrontal regions and specific complex processes have been demonstrated behaviorally, psychologically, and via neuro-imaging. For example, the caudal prefrontal region has been noted to play a role in attentional mechanisms [29,33,34]. The ventrolateral prefrontal cortex seems to help regulate response inhibition [29,35,36]. The ventromedial prefrontal region encompasses two fundamental moieties: the paleo- and arch cortical trends. It is also characterized by a relatively analogous laminar pattern; therefore, given its subserving functions, it is crucial to adaptive behavior and decision making [29]. The prefrontal cortex includes more differentiated regions, the lateral and caudal portions, which provide more insight into the decision-making process. There are bidirectional, interrelated, intrinsic connections from the ventral and medial prefrontal areas to the lateral and caudal regions; this indicates that the latter may contribute in many ways to the decision-making process; these contributions may include response modulation, planning, and sequencing [29]. The limbic system, however, is not particularly involved in decisions about immediate options (i.e., immediate benefits or losses [10,17]. During decisions involving immediate benefits, the most activity has been observed in the ventral striatum and the posterior and anterior cingulate cortex [10,37]; those structures also play a role in decisions involving delayed benefits, but they are much less active during such decisions than during those involving immediate benefits [10].

It is noteworthy to mention that there is some causal evidence that the roles of intuitive, emotional responses and controlled cognitive processes in optimal decisions involve tension between utilitarian principles (cost-benefit analyses aimed at promoting the greater good) and deontological principles (concerning the rights and obligations of individuals). The common hypothesis suggests that utilitarian judgments are supported by regions of the dorsolateral prefrontal cortex and the parietal lobes that are associated with reasoning and cognitive control, while deontological judgments are supported by regions of the medial prefrontal cortex, medial parietal cortex, and superior temporal sulcus/temporoparietal junction that are associated with emotion and social cognition. This hypothesis is supported by previous correlational fMRI studies [20,21]; Q [22]. and lesion studies [38]. Lesion studies have provided

causal evidence for the location of emotional processes that support deontological judgments in the medial prefrontal cortex.

Furthermore, for proper neurochemical functioning, the right concentration of glucose must be present in the brain. A glucose deficit can lead to anxiety, agitation, and aggressive behavior. Therefore, the functional state of the brain and the condition of the whole body are both vital to proper decision-making. For example, fatigue, exhaustion, dehydration, and imbalance in homeostasis can all lead to poor choices [10].

6. Factors affecting the neuroeconomics of decision making

6.1. Knowledge

Knowledge is information about the world and how it works. Individuals need sufficient knowledge to make good decisions. This sometimes requires advice from qualified experts [39], which some individuals believe will help them make better decisions [40–42]. For instance, an individual may need opinions on the best sub-characteristics in terms of the future workload from their seniors (experts) for choosing a future sub-attribute. In addition, the sharing of wisdom enhances the performance of knowledge management through constant learning [43]. Although, memory and learning are the fundamental basis of knowledge [44]; however, the neural basis of the learning process is still elusive.

6.2. Inner resources

Inner resources are beliefs acquired during development that determine psychological wellbeing, including pleasure, happiness, and a hopeful outlook. Emotions are strong and predictable drivers of decision-making; for example, if an individual feels anxious about the outcome of a risky choice, they may opt for a safer option. Emotions have a promising approach to decision-making and survival [45]. Therefore, emotions gain insights into neuroeconomics [44]. However, emotions can also debase decision-making [46, 47]. Decisions are influenced by emotions and partially based on the assumption that the decider can predict others' behaviors; empathy plays a role in decisions as well. These abilities (predictions and empathy) stem from the individual's preferences and beliefs. Studies on empathy have noted that the same effective brain neural circuits are automatically activated when we are in pain and when we see another in pain. Therefore, empathy directs our emotions towards other people when we make decisions [10]. Empathy positively contributes to the individual's positive well-being. Different brain structures and neural networks would be associated with decision-making, which could be significant for neuroeconomics [44]. Moreover, affective forecasting is a mental process of predicting emotional states about the future events [48]. Affective forecasting not influences the behavior and preferences of an individuals but also decision. Although affective forecasting determines behavior, judgements, and decision, but cannot be always accurate [49].

6.3. Social support

Humans have a basic need to interact with each other socially. Social interactions affect the individual's health and help to cope with stress or depression [50]. Social support is the interpersonal system that we have developed and participates in. Social support can be care, love, respect, value, networking, communication, etc. [51]. As an example, individuals with stronger social support experience fewer difficulties when making career-related decisions [52]. Such as, having to travel across the world for a job and having your family and friends' support. Also, cultural products symbolizing wealth and social dominance activate the reward-related neural correlates [53]. Therefore, self-interest and social behavior also impact the neuroeconomics of decision-making [44]. Social exclusion may exert negative effects on the behavior and cognition of an individual. However, emotional support and appraisal/informational support could be effective in decreasing the negative motions [54]. Such social support also regulates the neurobiological correlates and neurophysiological effects. However, cultural differences influence the different types of social support networks [50]. Social support can beneficially reduce the chances of illness, speed recovery from illness, and decreases mortality from diseases [50].

6.4. Spirituality and religious beliefs

Spirituality is the belief in purpose, order, and morality. Spirituality can help reduce conflicts and challenges around decisions and increase satisfaction with decisions [55,56]. Spirituality and religion also help people in stressful conditions and the negative consequences of illness [57]. Spirituality could aid in mental relaxation during life problems and illnesses. Understanding religion and economics is also influenced by neuroeconomics. Religions provide social support, create positive emotions, and facilitate behavior and spirituality at times of bereavement and crisis. In addition, the majority of internal medicine specialists agree that religious and spiritual beliefs have a positive correlation with mental health [58]. [59] reported that young adults attending religious ceremonies have higher life satisfaction. Early research revealed that people who have higher education are more likely to rely on religious beliefs in decision-making [60]. However, recent studies reported a negative association between higher education and religious interference in decision-making [61]. Therefore, neuroeconomics could be influenced by the status of beliefs in an individual's decision-making.

6.5. Anatomical dysfunction

Anatomical dysfunction is caused by disorders or injuries. For example, frontostriatal dysfunction can lead to substantial changes in cognition and action. This can be seen in various disorders that disrupt this circuitry, including Parkinson's disease, schizophrenia,

attention-deficit/hyperactivity disorder, and addiction [18, 85]. Frontal-like deficits may occur because low striatal dopamine, which occurs in Parkinson's disease, leads to diminished "go signals" and difficulty updating prefrontal representations [62–65].

6.6. Confidence

Decision confidence is the feeling in an individual that he or she has done something correctly or not. Confidence in decision-making increases the chances of correct decisions and decreases the probabilities of error [38]. Critical thinking and confidence exert a positive correlation with an individual's decision-making attitude, resulting in effective and appropriate decision-making [66, 67]. However, when an individual experiences lack of confidence he or she may require further knowledge or assistance from experts to make a confident decision [68]. On the contrary, overconfidence might result in poor decisions and consequently disaster [69]. Over-confidence also negatively impacts the expected clinical outcomes. For instance, in the Swiss Hypertension and Risk Factor Program (SHARP), practitioners' higher level of confidence (65%–69%) was not significantly associated with patients' blood pressure (30%–35%) [70].

Factor	Definition	How it affects decision making
Knowledge	is information about the world and how it works.	Individuals need sufficient knowledge to make good decisions. This sometimes requires advice from qualified experts
Inner resources	beliefs acquired during development that determine psychological wellbeing, including pleasure, happiness, and a hopeful outlook	decisions are influenced by emotions and partially based on the assumption that the decider can predict others' behaviors; empathy plays a role in decisions as well.
Social support	the interpersonal system that we have developed and participates in	Social interactions affect the individual's health and help to cope with stress or depression
Spirituality and religious beliefs	Spirituality is the belief in purpose, order, and morality.	Spirituality can help reduce conflicts and challenges around decisions and increase satisfaction with decisions
Anatomical dysfunction	caused by disorders or injuries	frontostriatal dysfunction can lead to substantial changes in cognition and action, which hinder decision making process
Confidence	the feeling in an individual that he or she has done something correctly or not	increases the chances of correct decisions and decreases the probabilities of error

7. Neuroeconomics and pandemic situations

When a pathogen attacks the body, the body recognizes it as a foreign particle and sends signals to the hypothalamic-pituitary-adrenal axis of the brain, which activates the endocrine system, ultimately triggering the immune system to kill the pathogen and store information about it in memory cells for future action against that pathogen [71]. The immune system also releases certain cytokines and chemokines required for normal brain function and maintenance [72]. All these processes are undoubtedly important for the survival of an individual in society. Neuroeconomics deals with the study of such behaviors and their underlying mechanisms to promote a better understanding of certain kinds of behavioral responses and to formulate possible treatments for different psychiatric and neurological diseases. In addition to the danger of accidents and natural or man-made disasters, we are all almost continuously exposed to germs, chemicals, or toxins that can cause disease. Even within our bodies, cells are continuously changing and can even transform into malignant cells that can subsequently form tumors.

Social and behavioral factors considerably contribute to the spread of infectious disease transmission. Human behaviors with social, psychological, economical, and environmental determinants affect the curse, duration, and outcomes of outbreaks [73]. Sense of responsibility and anticipatory behavior of individuals and communities have considerable influence on the survival of the population and transmission of the outbreak [87]. Social and behavioral determinants intertwined with non-pharmaceutical interventions, including social distancing, hygiene practices, and respiratory etiquettes, potentially improves the survival rates during large-scale epidemics, including Black Plague, Influenza, Ebola, SARS, MERS, COVID-19, etc. In the 14th century, the Black Plague killed nearly two-thirds of the population of Europe and over 75 million people worldwide (of an estimated total population of 350 million), but some individuals who seemed "magically protected" managed to survive it [74]. Furthermore, decision-making under uncertain conditions may be improved by moderately acute stress [75]. Incorporating behavior with epidemic models has been of significant importance for public health strategies. Behavioral models shows that during initial waves of 2009 A/H1N1 (swine) influenza pandemic, social distancing behavior significantly reduces the transmission of diseases [76]. COVID-19 pandemic has forced individuals and responsible parties to make their decisions under some sense of uncertainty. This pandemic has put every single person's decision-making skills to the test, whether they're a leader responsible for millions of people, or a member of the community, all were faced with the need to take quick action to ensure the safety of themselves and others [77]. Furthermore, as the COVID-19 cases continued to increase, anxiety-related decision-making increased as well. However, certain people remained healthy in most situations. For example, Park et al. found that stress due to COVID-19 was high among participants, but adherence to CDC guidelines was high as well [78]. This could indicate that decision-making improves under stressful conditions. However, Starcke et al. found that stress hinders and deteriorates the decision-making process [79]. Cesari et al. note that the ongoing ageism (where an age criterion was implemented to follow the decisional algorithm for allocating scarce resources to the patients) that has overtaken the decision-making process is problematic and should be reviewed; clinical decisions should be made on an individual basis [80]. Therefore, a balance must be present to ensure proper and logical decision-making, which, during the pandemic, was the responsibility of the authorities to

ensure the wellbeing of their population.

In summary, decision-making is affected by many factors, which can be physiological, social, psychological, etc. They play both a conscious and subconscious role in decision-making and by optimizing the external and internal factors we can enhance our decision-making process and choose the best possible options by utilizing all these factors to develop our judgement.

8. Conclusion

We need to learn from the previous pandemic to better prepare for future challenges; during the crisis, countries, and individuals have behaved in various ways that we can learn from to better prepare for the future. The collective decision-making was based initially on scientific observations made and slowly, as we became more knowledgeable, science aided in making better decisions. Integrating local and collective decision-making will ultimately lead to better outcomes. Our thoughts, emotions, and beliefs can affect our health, our wellbeing, and even our chances of survival. We still have a long way to go in order to fully understand how individuals make decisions and more research should be done on the matter in order to understand how all those factors and challenges [81,82] that come into play affect us and our decision making process and how to utilize them in a way that can benefit us rather than hinder our decision making process.

The effective and transparent communication between politicians and experts for establishing evidence-based and comprehensive systematically relevant risk management plans and strategies is very critical in such pandemic or crisis [82]. As minimizing the economic, societal and psychological costs is the key, we must educate the public and raise their awareness about the neuroeconomics and its vast dimensions to help them boost their decision-making process and make the best out of their given situations and available choices [83,84]. Large collaborative studies should be implemented in the field of neuroeconomics to explore this field further and make the most of it.

Conflicts of interest

Authors declare no conflict of interest.

Ethical approval

Not required.

References

[1] D. Serra, Neuroeconomics and Modern Neuroscience, 2019.
[2] A.H. Maslow, Motivation and Personality, Prabhat Prakashan, 1981.
[3] A. Tversky, D. Kahneman, The framing of decisions and the psychology of choice, Science 211 (4481) (1981) 453–458, https://doi.org/10.1126/science.7455683.
[4] J. Veldwijk, B.A. Essers, M.S. Lambooij, C.D. Dirksen, H.A. Smit, G.A. de Wit, Survival or mortality: does risk attribute framing influence decision-making behavior in a discrete choice experiment? Value Health 19 (2) (2016) 202–209, https://doi.org/10.1016/j.jval.2015.11.004.
[5] K.E. Stanovich, R.F. West, On the relative independence of thinking biases and cognitive ability, J. Pers. Soc. Psychol. 94 (4) (2008) 672–695, https://doi.org/10.1037/0022-3514.94.4.672.
[6] M.S. Gazzaniga, The Cognitive Neurosciences, fifth ed., MIT press, 2009.
[7] X.-J. Wang, Decision making in recurrent neuronal circuits, Neuron 60 (2) (2008) 215–234, https://doi.org/10.1016/j.neuron.2008.09.034.
[8] P.W. Glimcher, Foundations of Neuroeconomic Analysis, OUP, USA, 2011.
[9] C. Camerer, Goals, methods and progress in neuroeconomics. Annual Review of Economics, Ann. Rev. Econ. 5 (2013) 425–455, https://doi.org/10.1146/annurev-economics-082012-123040, 2013.
[10] A. Potemkowski, Neurobiology of decision making: methodology in decision-making research. Neuroanatomical and neurobiochemical fundamentals, in: Neuroeconomic and Behavioral Aspects of Decision Making, Springer, 2017, pp. 3–18.
[11] J.B. Engelmann, E. Fehr, The neurobiology of trust and social decision-making: the important role of emotions, in: Trust in Social Dilemmas, Oxford University Press, New York, NY, US, 2017, pp. 33–56.
[12] E. Fehr, C.F. Camerer, Social neuroeconomics: the neural circuitry of social preferences, Trends Cognit. Sci. 11 (10) (2007) 419–427.
[13] E. Fehr, I. Krajbich, Chapter 11 - social preferences and the brain, in: P.W. Glimcher, E. Fehr (Eds.), Neuroeconomics, second ed., Academic Press, San Diego, 2014, pp. 193–218.
[14] J.K. Rilling, A.G. Sanfey, The neuroscience of social decision-making, Annu. Rev. Psychol. 62 (2011) 23–48, https://doi.org/10.1146/annurev.psych.121208.131647.
[15] B. Christiansen, Neuroeconomics and the Decision-Making Process, IGI Global, 2016.
[16] A. Rustichini, Neuroeconomics: what have we found, and what should we search for, Curr. Opin. Neurobiol. 19 (6) (2009) 672–677, https://doi.org/10.1016/j.conb.2009.09.012.
[17] H.M. Bayer, B. Lau, P.W. Glimcher, Statistics of midbrain dopamine neuron spike trains in the awake primate, J. Neurophysiol. 98 (3) (2007) 1428–1439, https://doi.org/10.1152/jn.01140.2006.
[18] [a] G. Moretto, Cognitive and Affective Processes in Social Actions and Decisions, Dissertation thesis, Studiorum Università di Bologna, 2010;
[b] A. Nieoullon, Dopamine and the regulation of cognition and attention, Prog. Neurobiol. 67 (1) (2002) 53–83, https://doi.org/10.1016/s0301-0082(02)00011-4.
[19] P. Mongin, Expected utility theory, in: J. Davis, W. Hands, U. Maki (Eds.), Handbook of Economic Methodology, Edward Elgar, 1998, pp. 342–350.
[20] B. Knutson, M.R. Delgado, P.E.M. Phillips, Chapter 25 - representation of subjective value in the striatum, in: P.W. Glimcher, C.F. Camerer, E. Fehr, R. A. Poldrack (Eds.), Neuroeconomics, Academic Press, London, 2009, pp. 389–406.
[21] J. Peters, C. Büchel, Neural representations of subjective reward value, Behav. Brain Res. 213 (2) (2010) 135–141, https://doi.org/10.1016/j.bbr.2010.04.031.
[22] Q. Wang, S. Luo, J. Monterosso, J. Zhang, X. Fang, Q. Dong, G. Xue, Distributed value representation in the medial prefrontal cortex during intertemporal choices, J. Neurosci. 34 (22) (2014) 7522–7530, https://doi.org/10.1523/jneurosci.0351-14.2014.
[23] S. Saberi Moghadam, F. Samsami Khodadad, V. Khazaeinezhad, An algorithmic model of decision making in the human brain, Basic Clin. Neurosci. 10 (5) (2019) 443–449, https://doi.org/10.32598/bcn.9.10.395.

[24] S. Kobayashi, R. Kawagoe, Y. Takikawa, M. Koizumi, M. Sakagami, O. Hikosaka, Functional differences between macaque prefrontal cortex and caudate nucleus during eye movements with and without reward, Exp. Brain Res. 176 (2) (2007) 341–355, https://doi.org/10.1007/s00221-006-0622-4.
[25] F. Denk, M.E. Walton, K.A. Jennings, T. Sharp, M.F. Rushworth, D.M. Bannerman, Differential involvement of serotonin and dopamine systems in cost-benefit decisions about delay or effort, Psychopharmacology (Berl) 179 (3) (2005) 587–596, https://doi.org/10.1007/s00213-004-2059-4.
[26] D.C. Krawczyk, Contributions of the prefrontal cortex to the neural basis of human decision making, Neurosci. Biobehav. Rev. 26 (6) (2002) 631–664, https://doi.org/10.1016/s0149-7634(02)00021-0.
[27] D. Lee, H. Seo, Mechanisms of reinforcement learning and decision making in the primate dorsolateral prefrontal cortex, Ann. N. Y. Acad. Sci. 1104 (2007) 108–122, https://doi.org/10.1196/annals.1390.007.
[28] H.A. Crystal, Book reviews: the frontal lobes. Donald T. Stuss and D. Frank benson. Raven press, New York, NY, 303, J. Neurologic. Rehab. 1 (3) (1987) 147, https://doi.org/10.1177/136140968700100309, 147.
[29] A.R. Damasio, H. Damasio, Neurobiology of Decision-Making, Springer Science & Business Media, 2012.
[30] P.S. Goldman-Rakic, Circuitry of primate prefrontal cortex and regulation of behavior by representational memory, in: Comprehensive Physiology, 2011, pp. 373–417.
[31] T.W. Robbins, The prefrontal cortex, 2nd edn. J. M. Fuster. Raven Press, New York, 1989. Price:$86.50, Int. J. Geriat 5 (5) (1990) 348, https://doi.org/10.1002/gps.930050518, 348.
[32] M.H. Rosenbloom, J.D. Schmahmann, B.H. Price, The functional neuroanatomy of decision-making, J. Neuropsychiatry Clin. Neurosci. 24 (3) (2012) 266–277, https://doi.org/10.1176/appi.neuropsych.11060139.
[33] K.M. Heilman, D.N. Pandya, N. Geschwind, Trimodal inattention following parietal lobe ablations, Trans. Am. Neurol. Assoc. 95 (1970) 259–261.
[34] K. Welch, P. Stuteville, Experimental production of unilateral neglect in monkeys, Brain 81 (3) (1958) 341–347, https://doi.org/10.1093/brain/81.3.341.
[35] S.D. Iversen, M. Mishkin, Perseverative interference in monkeys following selective lesions of the inferior prefrontal convexity, Exp. Brain Res. 11 (4) (1970) 376–386, https://doi.org/10.1007/bf00237911.
[36] J.S. Stamm, Functional dissociation between the inferior and arcuate segments of dorsolateral prefrontal cortex in the monkey, Neuropsychologia 11 (2) (1973) 181–190.
[37] J.W. Kable, P.W. Glimcher, The neural correlates of subjective value during intertemporal choice, Nat. Neurosci. 10 (12) (2007) 1625–1633, https://doi.org/10.1038/nn2007.
[38] I. Levy, J. Snell, A.J. Nelson, A. Rustichini, P.W. Glimcher, Neural representation of subjective value under risk and ambiguity, J. Neurophysiol. 103 (2) (2010) 1036–1047, https://doi.org/10.1152/jn.00853.2009.
[39] W.T. Fagan, Decision Making and Depth of Knowledge. *Newfoundland and Labrador*, Memorial University, Canada, 2012.
[40] N. Harvey, I. Fischer, Taking advice: accepting help, improving judgment, and sharing responsibility, Organ. Behav. Hum. Decis. Process. 70 (2) (1997) 117–133, https://doi.org/10.1006/obhd.1997.2697.
[41] H. Jungermann, K. Fischer, Using expertise and experience for giving and taking advice, in: The Routines of Decision Making, 2005, pp. 157–173.
[42] D. Meshi, G. Biele, C.W. Korn, H.R. Heekeren, How expert advice influences decision making, PLoS One 7 (11) (2012) e49748, https://doi.org/10.1371/journal.pone.0049748, e49748.
[43] J.C. Hong, C.L. Kuo, Knowledge Management in the Learning Organization, Leadership & Organization Development Journal, 1999.
[44] P. Kenning, H. Plassmann, NeuroEconomics: an overview from an economic perspective, Brain Res. Bull. 67 (5) (2005) 343–354, https://doi.org/10.1016/j.brainresbull.2005.07.006.
[45] A. Bechara, A.R. Damasio, The somatic marker hypothesis: a neural theory of economic decision, Game. Econ. Behav. 52 (2) (2005) 336–372.
[46] J.S. Lerner, Y. Li, P. Valdesolo, K.S. Kassam, Emotion and decision making, Annu. Rev. Psychol. 66 (2015) 799–823.
[47] B. Shiv, G. Loewenstein, A. Bechara, H. Damasio, A.R. Damasio, Investment behavior and the negative side of emotion, Psychol. Sci. 16 (6) (2005) 435–439, https://doi.org/10.1111/j.0956-7976.2005.01553.x.
[48] D.T. Gilbert, T.D. Wilson, Prospection: experiencing the future, Science 317 (5843) (2007) 1351–1354.
[49] T.D. Wilson, D.T. Gilbert, Affective forecasting, Adv. Exp. Soc. Psychol. 35 (2003) 345–411.
[50] D.K. Sherman, H.S. Kim, S.E. Taylor, Culture and social support: neural bases and biological impact, Prog. Brain Res. 178 (2009) 227–237.
[51] S. Cohen, T.A. Wills, Stress, social support, and the buffering hypothesis, Psychol. Bull. 98 (2) (1985) 310–357.
[52] Y.I. Li, The Impact of Social Support on Career Decision-Making: the Role of Relational Self-Concept. (Doctor of Philosphy Dissertation), Penn State University, Penn State University Libraries, 2014.
[53] S. Erk, M. Spitzer, A.P. Wunderlich, L. Galley, H. Walter, Cultural objects modulate reward circuitry, Neuroreport 13 (18) (2002) 2499–2503.
[54] R. Morese, C. Lamm, F.M. Bosco, M.C. Valentini, G. Silani, Social support modulates the neural correlates underlying social exclusion, Soc. Cognit. Affect Neurosci. 14 (6) (2019) 633–643, https://doi.org/10.1093/scan/nsz033%J (Social Cognitive and Affective Neuroscience).
[55] M.A. Mollica, W. Underwood 3rd, G.G. Homish, D.L. Homish, H. Orom, Spirituality is associated with better prostate cancer treatment decision making experiences, J. Behav. Med. 39 (1) (2016) 161–169, https://doi.org/10.1007/s10865-015-9662-1.
[56] F. Rego, F. Gonçalves, S. Moutinho, L. Castro, R. Nunes, The influence of spirituality on decision-making in palliative care outpatients: a cross-sectional study, BMC Palliat. Care 19 (1) (2020) 22, https://doi.org/10.1186/s12904-020-0525-3.
[57] K.I. Pargament, B.W. Smith, H.G. Koenig, L. Perez, Patterns of positive and negative religious coping with major life stressors, J. Sci. Stud. Relig. (1998) 710–724.
[58] G.M. Piscitello, S. Martin, Spirituality, religion, and medicine education for internal medicine residents, Am. J. Hospice Palliat. Med. 37 (4) (2019) 272–277, https://doi.org/10.1177/1049909119872752.
[59] Y. Chen, T.J. VanderWeele, Associations of religious upbringing with subsequent health and well-being from adolescence to young adulthood: an outcome-wide analysis, Am. J. Epidemiol. 187 (11) (2018) 2355–2364, https://doi.org/10.1093/aje/kwy142.
[60] H. Cantril, Educational and economic composition of religious groups: an analysis of poll data, Am. J. Sociol. 48 (5) (1943) 574–579.
[61] S. Schieman, Education and the importance of religion in decision making: do other dimensions of religiousness matter? J. Sci. Stud. Relig. 50 (3) (2011) 570–587, https://doi.org/10.1111/j.1468-5906.2011.01583.x.
[62] M.J. Frank, Dynamic dopamine modulation in the basal ganglia: a neurocomputational account of cognitive deficits in medicated and nonmedicated Parkinsonism, J. Cognit. Neurosci. 17 (1) (2005) 51–72, https://doi.org/10.1162/0898929052880093.
[63] M.J. Frank, R.C. O'Reilly, A mechanistic account of striatal dopamine function in human cognition: psychopharmacological studies with cabergoline and haloperidol, Behav. Neurosci. 120 (3) (2006) 497–517, https://doi.org/10.1037/0735-7044.120.3.497.
[64] T.E. Hazy, M.J. Frank, R.C. O'Reilly, Towards an executive without a homunculus: computational models of the prefrontal cortex/basal ganglia system, Philos. Trans. R. Soc. Lond. B Biol. Sci. 362 (1485) (2007) 1601–1613, https://doi.org/10.1098/rstb.2007.2055.
[65] R.C. O'Reilly, M.J. Frank, Making working memory work: a computational model of learning in the prefrontal cortex and basal ganglia, Neural Comput. 18 (2) (2006) 283–328, https://doi.org/10.1162/089976606775093909.
[66] K. Hoffman, C. Elwin, The relationship between critical thinking and confidence in decision making, Aust. J. Adv. Nurs. 22 (1) (2004) 8–12.
[67] S.A. Jackson, S. Kleitman, Individual differences in decision-making and confidence: capturing decision tendencies in a fictitious medical test, Metacognition and Learning 9 (1) (2014) 25–49, https://doi.org/10.1007/s11409-013-9110-y.
[68] K. Desender, A. Boldt, N. Yeung, Subjective confidence predicts information seeking in decision making, Psychol. Sci. 29 (5) (2018) 761–778.
[69] J.A. Sniezek, Groups under uncertainty: an examination of confidence in group decision making, Organ. Behav. Hum. Decis. Process. 52 (1) (1992) 124–155.
[70] A. Pechère-bertschi, P. Greminger, L. Hess, J. Philippe, P. Ferrari, Swiss Hypertension and Risk Factor Program (SHARP): cardiovascular risk factors management in patients with type 2 diabetes in Switzerland, Blood Pres. 14 (6) (2005) 337–344.
[71] R. Dantzer, Neuroimmune interactions: from the brain to the immune system and vice versa, Physiol. Rev. 98 (1) (2018) 477–504, https://doi.org/10.1152/physrev.00039.2016, del Castillo.

[72] G.T. Norris, J. Kipnis, Immune cells and CNS physiology: microglia and beyond, J. Exp. Med. 216 (1) (2018) 60–70, 10.1084/jem.20180199 %J Journal of Experimental Medicine.
[73] J. Bedson, L.A. Skrip, D. Pedi, S. Abramowitz, S. Carter, M.F. Jalloh, B.M. Althouse, A review and agenda for integrated disease models including social and behavioural factors, Nat. Human Behav. 5 (7) (2021) 834–846, https://doi.org/10.1038/s41562-021-01136-2.
[74] G.E. Bolton, A Comparative Model of Bargaining: Theory and Evidence, The American Economic Review, 1991, pp. 1096–1136.
[75] K.A. Byrne, A.C. Cornwall, D.A. Worthy, Acute stress improves long-term reward maximization in decision-making under uncertainty, Brain Cognit. 133 (2019) 84–93.
[76] M. Springborn, G. Chowell, M. MacLachlan, E.P. Fenichel, Accounting for behavioral responses during a flu epidemic using home television viewing, BMC Infect. Dis. 15 (1) (2015) 21, https://doi.org/10.1186/s12879-014-0691-0.
[77] O.O. Ogunleye, D. Basu, D. Mueller, J. Sneddon, R.A. Seaton, A.F. Yinka-Ogunleye, G.M. Rwegerera, Response to the novel corona virus (COVID-19) pandemic across Africa: successes, challenges, and implications for the future, Front. Pharmacol. (2020) 1205.
[78] C.L. Park, B.S. Russell, M. Fendrich, L. Finkelstein-Fox, M. Hutchison, J. Becker, Americans' COVID-19 stress, coping, and adherence to CDC guidelines, J. Gen. Intern. Med. 35 (8) (2020) 2296–2303.
[79] K. Starcke, M. Brand, Effects of stress on decisions under uncertainty: a meta-analysis, Psychol. Bull. 142 (9) (2016) 909.
[80] M. Cesari, M. Proietti, COVID-19 in Italy: ageism and decision making in a pandemic, J. Am. Med. Dir. Assoc. 21 (5) (2020) 576.
[81] J.B. Dennison, D. Sazhin, D.V. Smith, Decision neuroscience and neuroeconomics: recent progress and ongoing challenges, WIREs Cog. Sci. 13 (3) (2022) e1589, https://doi.org/10.1002/wcs.1589.
[82] E.N. Iftekhar, V. Priesemann, R. Balling, S. Bauer, P. Beutels, A. Calero Valdez, P. Willeit, A look into the future of the COVID-19 pandemic in Europe: an expert consultation, Lancet Reg. Health Eur. 8 (2021), 100185, https://doi.org/10.1016/j.lanepe.2021.100185.
[83] V. Priesemann, R. Balling, S. Bauer, P. Beutels, A.C. Valdez, S. Cuschieri, P. Willeit, Towards a European strategy to address the COVID-19 pandemic, Lancet 398 (10303) (2021) 838–839, https://doi.org/10.1016/s0140-6736(21)01808-0.
[84] A. F, Health, spirituality and covid-19: themes and insights, J. Publ. Health 43 (2) (2020) e254–e255, 10.1093/pubmed/fdaa185 %J Journal of Public Health.
[85] M.J. Frank, A. Scheres, S.J. Sherman, Understanding decision-making deficits in neurological conditions: insights from models of natural action selection, Phil. Trans. Biol. Sci. 362 (1485) (2007) 1641–1654, https://doi.org/10.1098/rstb.2007.2058.
[86] S. Goldman-Rakic Patricia, Regional and cellular fractionation of working memory, Proc. Natl. Acad. Sci. USA 93 (24) (1996) 13473–13480, https://doi.org/10.1073/pnas.93.24.13473.
[87] J. Raude, M.C. K, C. Flamand, T. Apostolidis, Understanding health behaviour changes in response to outbreaks: findings from a longitudinal study of a large epidemic of mosquito-borne disease, Soc. Sci. Med. 230 (2019) 184–193, https://doi.org/10.1016/j.socscimed.2019.04.009.