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KORTİZOLÜN NÖROFİNANSAL KODLARI

Yusuf POLAT[1]

REVIEW ARTICLE / DERLEME MAKALE

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Özet

İnsanların biyolojik ve psikolojik açıdan strese yanıt olarak ürettiği kortizolün etkileri, bir stres hormonu şeklinde anılmasından öte bir olgudur. Kortizole ilişkin özellikler, stres altındaki bireylerin finansal davranışlarını anlamada ve incelemede bilimsel bir araç olarak kullanılmasını mümkün kılar. Kortizolün ölçülebilir olması ve laboratuvar ortamında deneysel olarak manipüle edilebilmesi nörofinans alanında kayda değer bir imkân yaratmaktadır. Ayrıca kortizol düzeylerindeki varyasyonların karar verme mekanizmaları üzerindeki etkileri gerçekçi ve kapsamlı modeller geliştirilmesine olanak tanır. Böylece stresin finansal davranışlar üzerindeki biyolojik temelleri daha iyi anlaşılabilir ve piyasa dinamiklerine ilişkin öngörüler güçlendirilir. Bu çalışmada da kortizolün, bireylerin ekonomik ve finansal karar verme süreçlerinde, özellikle risk ve belirsizlik durumlarında nasıl rol oynadığı; ödül ve ceza öğrenme merkezli süreçlerin ya da yaklaşımın bilişsel işlevler, motivasyon ve prososyal davranışlar üzerindeki etkileri ele alınmaktadır. Nitekim beynin bu süreçlerde kritik bir biyokimyasal modülatör olduğu, kararların hızını, kalitesini ve risk algısını etkileyerek ekonomik ajanın davranışlarında dikkate değer değişikliklere yol açtığı vurgulanmaktadır.

Anahtar Kelimeler: Nörofinans, Kortizol, Kortikostereoid, Risk, Biliş.

NEUROFINANCIAL CODES OF CORTISOL

Abstract

The effects of cortisol, produced by humans as a biological and psychological response to stress, go beyond being merely known as a stress hormone. The characteristics of cortisol enable its use as a scientific tool to understand and examine the financial behaviors of individuals under stress. The fact that cortisol can be measured and experimentally manipulated in laboratory settings creates a significant opportunity in the field of neurofinance. Additionally, variations in cortisol levels allow for the development of realistic and comprehensive models that explain their impact on decision-making mechanisms. Thus, the biological foundations of stress on financial behaviors can be better understood, and predictions regarding market dynamics can be strengthened. This study also addresses how cortisol plays a role in individuals' economic and financial decision-making processes, especially under conditions of risk and uncertainty; its effects on reward- and punishment-based learning; cognitive functions, motivation, and prosocial behaviors. It is emphasized that the brain acts as a critical biochemical modulator in these processes, influencing the speed, quality, and risk perception of decisions, leading to notable changes in the behavior of economic agents.

Keywords: Neurofinance, Cortisol, Corticosteroid, Risk, Cognition.

[1] Asst. Prof. Dr., Aksaray University, Faculty of Economics and Administrative Sciences [https://ror.org/026db3d50], yusufpolat@aksaray.edu.tr, ORCID: 0000-0002-2255-0658

1. Introduction

Cortisol is a key biological mediator of the stress response and is therefore commonly referred to in the literature as the “stress hormone” (Soares et al., 2012). It is an important biological marker secreted during stressful situations, assisting organism in coping with stress (Forbes et al., 2024a). However, cortisol functions are not limited to this: cortisol plays a critical role in evolutionary processes related to survival and adaptation by enabling an organism to make optimal decisions under uncertainty, preventing the loss of control and distraction caused by stress, pressure, and panic, and supporting the proper functioning of cognitive system. This makes it not only an endocrine hormone associated with biological processes but also a functional mechanism at behavioral and psychological levels (Waismel-Manor et al., 2011). Cortisol is associated with alterations in functional connectivity between the hippocampus and the brain’s default mode network during resting states, which may have implications for monitoring, alertness, and decision-making processes under stress (Thomason et al., 2013). The effects of cortisol on stress response are genomic and non-genomic, and can vary depending on factors such as age, gender, and anxiety (Duque et al., 2022). Additionally, cortisol is known to be highly influential in areas such as addiction, relapse, habit formation, behavioral conservatism, and caution (Sinha, 2008). Cortisol also plays an important role in acquiring social status and determining individuals' positions in social hierarchy (Sherman et al., 2016). Furthermore, cortisol is a significant factor in determining individuals' levels of impatience, especially when making decisions about the future (Riis-Vestergaard et al., 2018). Stress-related cortisol activity has been shown to modulate moral and ethical decision-making, particularly in contexts involving reward and punishment (Selart & Johansen, 2011). Furthermore, acute stress–related cortisol activity has been associated with increased impulsive choice, leading individuals to place lower value on future rewards and favor immediate gratification (Kimura et al., 2013). This can also hinder strategic thinking and the ability to conduct deep analysis (Leder et al., 2013). Additionally, cortisol elevations may be associated with issues such as self-regulation, emotional modulation, and eating disorders. This hormone also functions as a key neuroendocrine signal that shapes individuals' internal thought processes, beliefs, and self-concept. Therefore, in daily life and particularly in relation to cognition, impulsivity, loss risk-uncertainty, reward-punishment-learning, motivation, and prosocial behavior, cortisol has positive or negative relationships with the fundamental research problems of behavioral economics and neurofinance. This study presents an overview of introductory and explanatory information and findings within this context. Building upon this foundation, the overarching subject of this comprehensive literature review is to evaluate the complex effects of cortisol - the primary hormone produced during the human stress response - on economic and financial behavior, specifically from a neurofinance perspective. The primary objective is to elucidate stress-related decision-making processes by synthesizing evidence on cortisol’s role under conditions of risk and uncertainty, its influence on reward–punishment learning, and its downstream effects on cognitive functions, motivation, and prosocial behavior. This work emphasizes how the measurable and experimentally manipulable characteristics of cortisol offer significant opportunities to understand and examine financial behaviors under stress, ultimately allowing for the development of realistic and comprehensive models that explain its impact on decision-making mechanisms. Consequently, this study aims to advance the understanding of the biological foundations of stress on financial behaviors and to strengthen predictions regarding market dynamics.

2. Methodology

This study is a comprehensive literature review that evaluates the complex effects of cortisol—the primary hormone produced during the human stress response - on economic and financial behavior from a neurofinance perspective. The overarching aim is to elucidate stress-related decision-making processes by synthesizing evidence on cortisol's role under conditions of risk and uncertainty, its influence on reward - punishment learning, and its downstream effects on cognitive functions, motivation, and prosocial behavior.

A systematic search was conducted across the electronic databases PubMed, Scopus, Web of Science, and PsycINFO; Google Scholar was consulted as an ancillary source to broaden retrieval. The search strategy combined principal terms using Boolean operators (AND, OR). The principal keywords included: "neurofinance", "cortisol", "corticosteroid", "risk", "cognition", "stress", "financial decision making", "economic decisions", "reward–punishment learning", "impulsivity", "uncertainty", and "prosocial behaviors". Initial screening was performed at the title-and-abstract level; full texts of potentially relevant records were retrieved for detailed assessment. Approximately 150 items were screened, of which 118 studies were selected for inclusion in the review.

Study selection and analysis were carried out solely by the author. Inclusion criteria comprised peer-reviewed journal articles, review papers, and experimental investigations that explicitly examined cortisol's effects on economic or financial decision making. Exclusion criteria included studies whose primary focus was hormones other than cortisol or clinical case reports lacking clear links to financial behavior. Methodological quality and sample characteristics of included studies were appraised during selection.

Analytic synthesis focused on (i) variations in cortisol levels (operationalized as low, moderate, and high), (ii) acute versus chronic stress effects, and (iii) individual differences such as sex. Outcomes of interest included decision speed, decision quality, and risk perception. At the neurobiological level, the review examined evidence concerning cortisol's impact on prefrontal cortex, hippocampus, and amygdala function, and the consequent effects on cognitive flexibility, working memory, time perception, and impulsivity. Behavioral processes addressed included alterations in reward versus punishment sensitivity, shifts toward short-term reward preference at the expense of long-term planning, and bidirectional influences on prosocial behaviors (e.g., empathy, altruism, and status-related decision-making).

Findings were interpreted within established theoretical frameworks - most notably the Yerkes-Dodson law - to differentiate potential cognitive benefits associated with moderate cortisol elevations from impairments observed at extreme low or high concentrations. By integrating behavioral, cognitive, and neurobiological evidence, the review aims to demonstrate that cortisol functions not merely as a biomarker of stress but as a measurable and potentially manipulable neurofinancial indicator that informs models of financial decision making and market behavior. The synthesis is intended to advance understanding of the biological substrates of stress-related economic behaviors and to strengthen predictive models of market dynamics.

3. Basic Physiological and Neurobiological Properties of Cortisol

Cortisol is a hormone secreted from the adrenal cortex (zona fasciculata) and is regulated by adrenocorticotropic hormone and corticotropin-releasing factor signals from the hypothalamus and pituitary (Herbert, 2020, pp. 47-51). Cortisol is released as part of hypothalamic-pituitary-adrenal (HPA) axis (Gutiérrez-García & Calvo, 2016) and primarily exerts direct modulatory effects on the immune system, metabolism, cardiovascular system, and cognition (Coates et al., 2010). Cortisol is a cholesterol-based steroid hormone. These steroid hormones fall under a broader category known as corticosteroids. Cortisol belongs to the class of glucocorticoids, one of two subclasses of corticosteroids.

Cortisol exerts many of its behavioral and cognitive effects through glucocorticoid-sensitive regions of the prefrontal cortex and limbic system (Putman & Roelofs, 2011). It has dense receptors in brain regions involved in decision-making, such as the basal ganglia, influencing strategies, feedback processing, and reward-punishment sensitivity. Cortisol also affects the amygdala, enhancing emotional responses and promoting fear-based and egoistic decision-making (Starcke et al., 2011; Starcke et al., 2012). The hormone's impact is influenced by its form and levels in the bloodstream; while most cortisol circulates bound to plasma proteins in an inactive state (90-95%), a small fraction passes through the blood-brain barrier in its active, free form (5-10%) and influences behavior. Cortisol follows a circadian rhythm, being highest in the morning and lower throughout the day, with disruptions in this rhythm potentially leading to stress or mood disorders (Herbert, 2018).

Cortisol influences multiple brain functions, including memory, sleep, and mood. Basal cortisol levels, reflecting individual differences in stress regulation, have been associated with variations in social behaviors such as trust (Javor et al., 2020). It also has pain-relieving and anti-inflammatory properties, often used in injection treatments for certain diseases (Lee & Diver, 2020). When secreted at normal levels, cortisol helps regulate immune function, supports energy mobilization, and facilitates adaptation to environmental demands (Gutiérrez-García & Calvo, 2016). It plays a key role in the regulation of stress responses and physiological adaptation to stress (Sollberger et al., 2016). Conversely, elevated cortisol levels have been associated with reduced activity in reward-related brain regions, such as the nucleus accumbens, thereby modulating motivational systems through stress-related neuroendocrine mechanisms (Montoya et al., 2014).

Cortisol represents a delayed endocrine component of the stress response, activated via the hypothalamic–pituitary–adrenal axis, and contributes to the modulation of fight-or-flight–related processes (Kandasamy et al., 2014; Pabst et al., 2013). Its effects on the prefrontal cortex (PFC) hinder cognitive mechanisms, with the brain primarily influenced by the autonomic system (System 1), weakening working memory and executive functions, thus reducing strategic decision-making (Leder et al., 2013). Certain professionals (e.g., leaders or experienced decision-makers) may maintain performance under stress, potentially reflecting more efficient regulation of HPA-axis and cortisol responses rather than their absence (Santos-Ruiz et al., 2012). In chronic stress, prolonged cortisol elevation can cause pathological effects, inhibiting neurogenesis in the PFC and hippocampus, leading to cognitive issues (Gutiérrez-García & Calvo, 2016; Russell & Lightman, 2019). It also impacts time perception, impairing individuals' ability to distinguish time intervals, and may lead to cognitive and emotional issues like risk aversion (Nofsinger et al., 2021). Prolonged elevations in cortisol have been associated with structural and functional alterations in stress-sensitive brain regions, particularly the prefrontal cortex and hippocampus (Soares et al., 2012). Interestingly, in chronic stress, cortisol's effects on limbic regions can both damage the hippocampus and stimulate synaptic growth, creating both negative and positive outcomes (Brownell & Gold, 2012). Cortisol, along with norepinephrine, can produce both genomic and non-genomic effects. In acute stress, they act quickly without affecting DNA, leading to impulsive behavior. Under chronic stress, cortisol can interact with genomic mechanisms to alter gene expression, with important consequences for prefrontal cortex function and cognitive performance (Haushofer et al., 2013). Thus, from a neurofinance perspective, cortisol's biological effects are a critical neurohormonal indicator impacting decision-making (Yao et al., 2016).

Cortisol interacts with multiple neurotransmitter systems, including norepinephrine, with both neuromodulators contributing to stress-related cognitive and behavioral processes. However, their effects on decision-making and risk-related behavior appear to be partially dissociable and context-dependent, rather than reflecting a simple or direct coupling (Kluen et al., 2017; Margittai et al., 2016; Youssef et al., 2018). While elevated cortisol levels have been associated with shifts toward more impulsive decision-making under stress, norepinephrine—particularly at moderate levels in the prefrontal cortex—can support cognitive control, suggesting a context- and dose-dependent interplay between these two stress-related neuromodulators (Arnsten, 2009). Another crucial hormone in neurofinance studies is testosterone, which interacts with cortisol primarily in modulating behavior. Cortisol suppresses androgen receptors, limiting testosterone's non-genomic effects on behavior (Prasad et al., 2019). As cortisol rises, its ability to influence risk-taking is diminished, decreasing aggressive financial decisions and supporting long-term, low-risk choices (Nofsinger et al., 2021; Trautmann, 2014). Furthermore, while testosterone boosts self-confidence and the desire for status, cortisol suppresses these effects (Sherman et al., 2016).

The impact of cortisol on decision-making under stress is complex and involves interactions with other neurotransmitters like dopamine. Stress has been shown to increase dopamine release, which influences cognitive functions in the prefrontal cortex (Gathmann et al., 2014). Cortisol further influences dopamine systems by enhancing reward processing in the striatum, increasing sensitivity to rewarding stimuli and promoting reward-focused decision-making, while weakening the ability to avoid negative outcomes (Lighthall et al., 2013; Mather & Lighthall, 2012). This can lead to increased risky behaviors (Galván & Rahdar, 2013). Additionally, the serotonergic system interacts with cortisol, modulating stress and punishment sensitivity (Chumbley et al., 2014; Takahashi et al., 2005). Oxytocin has also been shown to mitigate cortisol-induced stress responses (Herbert, 2020). The combined effects of cortisol with serotonin and dopamine can result in irrational, impulsive decisions in risky situations (Ateşyakar & Duman, 2021; Kimura et al., 2013; Takahashi et al., 2010). Furthermore, cortisol's interaction with norepinephrine and dopamine positively impacts memory-related processes (Roozendaal et al., 2009).

Cortisol is a critical biochemical marker of the response of stress, playing a key role in both psychiatric and neurobiological processes. Research links cortisol levels with various psychopathological conditions, including anxiety, depression, PTSD, schizophrenia, eating disorders, and addictions. Stress-related cortisol activity has been associated with disruptions in fronto–amygdala regulation, contributing to cognitive and emotional dysregulation under stress (Palamarchuk & Vaillancourt, 2021). These effects impact not only individuals' daily lives but also their economic and financial behaviors.

Cortisol significantly impacts anxiety, often leading to avoidance of risk and loss (Putman & Roelofs, 2011). It can reduce interest in social rewards and hinder the ability to gain social status, particularly in cases of depression and anxiety (Sherman et al., 2016). Major depression has been associated with hypercortisolism and heightened sympathetic activity, while Cushing's syndrome is linked to impairments in feedback learning and long-term decision-making (Crespo et al., 2014). In contrast, post-traumatic stress disorder is associated with hypocortisolism (Schumacher et al., 2013). Individuals with early-onset conduct disorder may also produce less cortisol or be less sensitive to it, leading to behavioral regulation deficits and traits like aggression and impulsivity (Fairchild et al., 2009). Additionally, cortisol's role in triggering impulsive behaviors can contribute to addiction, such as alcohol use, and may modulate decision-making in substance abuse disorders (Clay & Parker, 2018). Though cortisol increases negative emotional states from stress, its effect on decision-making is indirect, illustrating the complex interplay between cortisol, psychopathology, and emotional processes (Gullo & Stieger, 2011).

4. Cortisol's Search for Direction Amid Risk and Uncertainty

Cortisol plays a complex role in neurofinance, with its effects depending on circulating levels. Consistent with an inverted U-shaped framework, moderate cortisol levels may support certain cognitive functions under stress, whereas excessively low or high levels impair performance and decision-making processes (Gathmann et al., 2014; Li et al., 2021). Excessive cortisol levels can heighten anxiety and bias decision-making toward more intuitive and less deliberative processes, which may increase vulnerability to suboptimal or risk-biased financial choices under stress (Nofsinger et al., 2018; Regehr & LeBlanc, 2017). In extreme cases, these effects resemble cognitive impairments caused by substances like alcohol (Landolt et al., 2017). Low cortisol levels may be associated with altered attention and reward processing, potentially biasing decision-making toward increased risk-taking under certain conditions (Dreyer et al., 2022). These effects are especially relevant in chronic stress, while the effects of acute stress on decision-making are more transient and less impactful (García-Molina et al., 2024).

Cortisol is a key hormone that helps organisms respond to stress and uncertainty (Herbert, 2018). Moderate increases in cortisol may support certain aspects of decision-making under risk and uncertainty, potentially promoting more cautious and controlled choices (Byrne et al., 2019). In financial decision-making, this can reduce uncertainty and improve performance (Starcke et al., 2012). Excessive cortisol levels can have the opposite effect, impairing the capacity to cope with uncertainty and biasing decision-making toward more reactive, short-term, and less flexible strategies (Leder et al., 2013; Palamarchuk & Vaillancourt, 2021). Cortisol's impact on decision-making is closely linked to its effects on the prefrontal cortex (PFC) and amygdala, influencing risk assessment and loss aversion (Srivastava et al., 2020). While moderate, short-term increases can enhance analytical decision-making, chronic high cortisol exposure weakens cognitive control, increases emotional biases, and reduces decision quality, leading to more conservative and reactive behaviors (Crespo et al., 2014; Sollberger et al., 2016). Thus, cortisol's effects on decision-making depend on both dose and stress duration. These effects are crucial in neurofinance, behavioral economics, and psychopathology, offering valuable insights into how neuroendocrine responses shape behavior, especially under stress.

5. A Neurohormonal Perspective: The Impact of Cortisol on Reward-Punishment-Based Learning

There are strong relationships between cortisol and reward-punishment-based learning processes under stress. In stressful situations, cortisol can suppress PFC activity. This suppression can impair executive functions and rational decision-making processes, leading individuals to behave more impulsively or habitually (striatum-driven behaviors). However, in some cases, an increase in amygdala activation and the resulting rise in anxiety levels can trigger risk-avoidance behaviors. On the other hand, under acute stress, cortisol can induce a transient increase in impulsivity or exhibit supportive effects on motivation and learning processes (Kandasamy et al., 2014). One of the underlying reasons for this effect is cortisol’s genomic and non-genomic actions. Rapid stress-related effects can transiently suppress prefrontal cortex function, reducing cognitive control and biasing behavior toward more reflexive and habit-based responses, whereas slower genomic mechanisms are associated with longer-term regulatory processes (Haushofer et al., 2013). In other words, when corticosterone's effects are rapid, i.e., during short-term acute stress, individuals may struggle to differentiate between rewards. However, when the delayed effects of corticosterone emerge, reward-learning processes may be altered in ways that support more regulated and context-appropriate behavioral responses (Koot et al., 2013). Chronic high cortisol levels can generally increase anxiety levels and avoidance behaviors. However, increases in cortisol levels also have some positive outcomes. For example, cortisol can strengthen reward-based learning under stress, encouraging individuals to focus on reward-oriented reinforcement strategies (Lighthall et al., 2009). A study in pigs showed that stress induced by social isolation alters behavioral and physiological stress responses, which may affect coping-related processes (Haushofer et al., 2011). Another interesting finding is how stress perception affects reward value. In individuals with low stress perception, the value of future rewards decreases rapidly, while in individuals with high stress perception, this decline is less pronounced (Robertson et al., 2016).

Under stress, cortisol can affect sensitivity to rewards in different ways. In some situations, cortisol may lead to increased sensitivity to rewards (hypersensitivity), while in others, it can reduce sensitivity to rewards (hyposensitivity) (Yu, 2016). In this context, some studies have shown that cortisol increases sensitivity to punishments and threats rather than rewards (Law et al., 2024). Acute stress situations can increase impulsivity and negative prediction errors. This can accelerate the reward acquisition process but may also lead to a more conservative approach to previously preferred rewards and a lack of interest in other rewards (Raio et al., 2020). As a result, individuals may focus on obtaining short-term rewards while neglecting long-term thinking and the careful use of resources. In other words, they may engage in overexploitation of resources (Lenow et al., 2017). These effects are linked to cortisol's influence on PFC, amygdala, and striatum. With increased cortisol levels, individuals may exhibit more impulsive, automatic, and habit-driven behaviors (Smeets et al., 2019). Cortisol is also a factor that negatively affects learning processes. By suppressing long-term potentiation mechanisms in the hippocampus (a process that creates strong and lasting connections between neurons), it inhibits synaptic strengthening (the process that makes communication between neurons more efficient and lasting), making learning more difficult. In a study, when cortisol levels were high, negative effects were observed on both declarative memory (conscious recall) and implicit perceptual learning (unconscious learning) processes. This suggests difficulties in both conscious and automatic learning processes (Dinse et al., 2017).

Along with stress, the inhibition of punishment-based learning processes is associated with biological foundations such as addiction and problematic behaviors (Wemm & Wulfert, 2017). In this context, cortisol can affect the early cognitive processing of emotional information related to rewards and punishments. Cortisol has been shown to modulate sensitivity to rewards and punishments in a context-dependent manner, which may bias decision-making toward increased risk-taking under certain stress conditions (Harvey et al., 2010; Putman et al., 2010). Increases in cortisol can weaken self-control mechanisms and alter reward perception. This makes rewards seem more appealing and can make risky decisions more attractive (von Helversen & Rieskamp, 2020). This effect is a result of the cortisol-triggered stress response, which increases dopamine release in the brain's reward-processing regions, thereby enhancing reward perception (Mather & Lighthall, 2012). Increases in cortisol levels can also limit memory generalization ability, which affects how well learned information or experiences can be applied in different and new situations or contexts (Dandolo & Schwabe, 2016). During periods of increased stress and cortisol levels, the effects of cortisol are reflected in cognitive functions, making decision-making errors more prominent (Herbert, 2018).

Cortisol interventions can lead to ambiguity in spatial learning performance related to rewards. Additionally, they may delay the learning of new places, disrupt the reinforcement of learned spatial reward preferences, and, particularly during memory consolidation, make it difficult to distinguish between new pieces of information (Rusu et al., 2018). Finally, the negative effects of cortisol on reward sensitivity can lead to the emergence of uncontrolled and emotional eating disorders in individuals (Smith et al., 2021). As a result, cortisol's effect on reward-punishment-based learning processes in the context of stress has a broad range of effects both at the neurobiological level and in terms of behavior. While acute and normal cortisol increases may enhance motivation and support reward-based learning, under chronic and intense stress, this hormone, by suppressing the PFC, leads to weakened executive functions, decreased impulse control, and disruptions in learning processes. Particularly through structures such as the hippocampus, amygdala, and striatum, cortisol causes significant deviations in functions like memory consolidation, spatial learning, and risk assessment. These effects prepare the ground for individuals to focus on short-term rewards, reduce sensitivity to punishment, and shift away from long-term planning, resulting in more impulsive, automatic responses. Therefore, the effects of cortisol should be considered not only in terms of cognitive performance but also as a critical determinant for the quality of decision-making processes and behavioral adaptation.

6. Cortisol and Cognition: The Fine Line of Balance

The effects of cortisol on cognition are directly related to its activity in brain regions such as PFC, hippocampus, and amygdala. In particular, chronic cortisol elevations primarily affect the PFC, which leads to impairments in cognitive functions, including cognitive flexibility and higher-order mental abilities such as strategic thinking (García-Molina et al., 2024). Research shows that the cognitive impairments caused by cortisol are particularly concentrated in the dorsolateral prefrontal cortex, which is considered the most rational area of the brain. As a result of these impairments, cognitive flexibility decreases, and impulse control is weakened (Forbes et al., 2024a). Cognitive flexibility is directly related to an individual’s ability to adapt to environmental changes and modify thought patterns. The weakening of impulse control, in turn, leads to an increase in more reflexive and impulsive decision-making. Another critical function of the PFC, working memory, is also negatively affected by cortisol. In this context, high cortisol levels have been found to weaken decision-making strategies such as "win-stay" (continue the strategy after winning) and "lose-shift" (change the strategy after losing) (Lighthall et al., 2013). These strategies allow individuals to adjust their behavior based on feedback from the environment and are crucial for decision-making processes. Overall, increased cortisol levels weaken reflective thinking (deliberate, conscious decision-making), hinder analytical and conscious thought processes, and temporarily disable PFC functions (Simonovic et al., 2017). However, the effect of cortisol on cognitive functions is not one-dimensional. Short-term and limited cortisol exposure may support attention and learning processes, while long-term and high exposure leads to impairments in working memory and executive functions (Rusu et al., 2018). The distinction is also related to the timing of stress exposure: early stress phases tend to bias decision-making toward more emotional responses, whereas later phases may involve shifts toward more regulated cognitive processing as slower neurobiological mechanisms come into play (Margittai et al., 2015). Moreover, physiological levels of cortisol have been linked to synaptic plasticity in stress-sensitive brain regions, particularly the hippocampus, with potential implications for attention and memory-related processes (Russell & Lightman, 2019). However, this effect is only valid for acute and short-term increases. Chronic high cortisol levels cause volume loss (atrophy) in the hippocampus, which negatively affects processes such as learning and memory (Coates et al., 2010). These effects serve as an important biological marker in understanding the neuroendocrine basis of cognitive impairments observed in elderly individuals (Pradipta et al., 2025). Additionally, depending on cortisol levels, impulsivity may increase, leading to distortions in time perception. This can negatively affect an individual’s decision-making processes, causing them to prefer short-term gains, particularly in financial decisions (Yao et al., 2016). Similarly, high cortisol levels have also been observed to affect the amygdala. Since the amygdala plays a significant role in processing emotions, its excessive activation can lead to dominance of emotional responses, resulting in an increase in logical errors and irrational behaviors (Nofsinger et al., 2021). Finally, the effect of cortisol on cognitive performance varies depending on an individual's emotional regulation abilities (ERA). In individuals with high ERA, cortisol can enhance cognitive performance, while in individuals with low ERA, the same condition can lead to a decline in performance (Radtke et al., 2020). These differences are also observed in brain activity: depending on ERA levels, hypoactivation (reduced activity) in the orbitofrontal cortex and hyperactivation (increased activity) in the anterior cingulate cortex are observed (Dedovic et al., 2009).

Under normal conditions, cortisol influences cognitive functions in individuals under stress, accelerating decision-making processes. This effect leads to a shift from conscious and analytical thinking towards more automatic and habit-based behaviors. While these hormonal changes during acute stress may sometimes enable individuals to make faster and more effective decisions, chronic increases in cortisol levels can result in more impulsive decisions, especially in reward- and risk-focused choices, which may potentially lead to negative outcomes (Raio et al., 2020). This process can also negatively impact the retrieval of information from memory, meaning that individuals under stress may have delays or difficulties in recalling previously learned information (Sarmiento et al., 2024). On the other hand, the natural circadian rhythm of cortisol release is associated with the regulation of cognitive flexibility and related cognitive functions (Russell & Lightman, 2019). However, in non-genomic stress conditions, individuals may struggle with generalizing based on past experiences, leading to a tendency for more rigid thought patterns. This issue can particularly hinder flexible thinking in contexts involving uncertainty, such as financial decision-making (Dandolo & Schwabe, 2016). Increases in cortisol levels can affect cognitive flexibility in various ways. For example, while cortisol elevation may enhance performance in processes such as updating working memory, it can also lead to decreased performance in tasks requiring task switching (Goldfarb et al., 2017). This suggests that the impact of stress can vary depending on the cognitive component involved. Similarly, elevated cortisol levels lead to impairments in functions such as future planning and prospective memory (Arnsten, 2009). Prospective memory refers to the ability to remember future actions, playing a critical role in the functioning of daily life. Such impairments can make it difficult for individuals to act according to plans and achieve their goals. Furthermore, hypercortisolism - persistent high cortisol levels - produces detrimental effects on various cognitive functions. These effects are particularly evident in areas such as verbal memory (learning and recalling word-related information), social memory (names, faces, social relationships), and selective attention (focusing on important stimuli) (LeBlanc et al., 2012). Additionally, cortisol elevation weakens individuals' metacognitive abilities. Metacognition refers to the ability to monitor and evaluate one's own thinking processes. Under high stress, individuals may show impairments in metacognitive awareness, making it more difficult to distinguish between known and unknown information (Reyes et al., 2015). In summary, variations in cortisol levels have multidimensional and contextual effects on cognition. While acute and normal increases in cortisol may support certain cognitive processes, non-genomic, chronic, and high levels of cortisol exposure result in significant negative outcomes in cognitive flexibility, attention, and memory, particularly through the PFC, hippocampus, and amygdala. These effects not only impair cognitive performance but also lead to unwanted outcomes in emotional regulation, metacognitive awareness, and long-term planning abilities. Therefore, the effects of cortisol should be evaluated in relation to the duration and intensity of stress and individual characteristics.

7. Impulsive Decisions Increased by Cortisol

There is a significant relationship between cortisol and impulsivity, particularly in increasing the tendency to make risky financial decisions, thereby enhancing the preference for short-term rewards (Sandi, 2013). This phenomenon is referred to as high temporal discounting (Riis-Vestergaard et al., 2018) and leads individuals to make quicker, more automatic decisions. These decisions are often characterized by preferences that require less cognitive effort and rely more on automatic choice strategies (Shafiei et al., 2012). Furthermore, this effect may be associated with reduced motivation and a tendency toward inefficient or suboptimal use of available options (Lenow et al., 2017). One of the primary causes of this phenomenon is that acute stress triggers glucocorticoid release, which increases cortisol levels and depletes cognitive resources, weakening flexible, model-based learning strategies (Raio et al., 2020). In this context, the generally accepted formulation is that cortisol's inhibitory effect on the prefrontal cortex leads to more impulsive decisions and an increase in reward-based risky preferences (Buckert et al., 2014). However, it should be noted that, as with other neurofinance-related issues, the effects of cortisol on impulsivity are complex and may not always yield consistent results (Forbes et al., 2024b).

Under high stress, individuals tend to prefer immediate rewards over delayed rewards (delay discounting) and are more inclined to make faster, impulsive decisions (Morgado et al., 2015). On the other hand, reductions in cortisol levels can also lead to impulsive behaviors (Dreyer et al., 2022). These effects have been linked to stress-related modulation of amygdala activity, which can bias emotional responding under stress (Palamarchuk & Vaillancourt, 2021). Consequently, risk perception and anxiety increase, which promotes instantaneous decision-making (Herbert, 2018). Additionally, deactivations (hypoactivity) have been observed in certain areas of the limbic system (hippocampus, hypothalamus, anterior cingulate cortex). This suggests that cortisol affects both impulsive and reflective mechanisms under stress (Dedovic et al., 2009). Consequently, high cortisol levels suppress the functions of the prefrontal cortex, leading to an increase in impulsive and risk-oriented decisions, while changes in limbic system activity intensify emotional responses. However, the effects of cortisol on impulsivity are not always consistent, as they vary depending on individual differences and factors such as the duration of stress. Therefore, the role of cortisol in neurofinance and decision-making processes should be considered from both a neurobiological and behavioral perspective.

8. The Social Face of Stress: Cortisol and Prosocial Behaviors

Cortisol, beyond being a stress marker, may modulate social and empathic responses. Under stress, cortisol activity has been associated with reductions in aggressive reactions and changes in prosocial tendencies, including empathy and context-dependent helping behaviors (Buchanan & Preston, 2014). This suggests that cortisol reflects the biological effects of social threats and environmental stressors through social and cultural contexts (Taylor, 2012). In this regard, the correlation between individuals' personal traits, social-emotional capacities, and cortisol becomes crucial. Indeed, individual traits such as social orientation (the ability to connect with others) and emotional intelligence (understanding one's own and others' emotions) can play an important role in regulating the negative effects of cortisol. These skills allow for better management of cortisol levels and more balanced stress responses (Geisler & Allwood, 2018). Therefore, it is suggested that emotional intelligence may support individuals' empathic abilities and related prosocial behaviors (Zapata et al., 2021). Furthermore, when evaluating the effects of cortisol on individuals, not only the physiological level but also their psychological structures and overall stress load should be considered (Steinbeis et al., 2015). As mentioned earlier, cortisol levels can be shaped by age, gender, genetic differences, and non-genomic environmental factors. Particularly in the context of prosocial behaviors, the effect of cortisol interacts with individuals' empathy capacity and mentalizing abilities. For example, individual differences in socio-cognitive traits may modulate the effects of stress on prosocial behavior. While acute stress indexed by cortisol responses has been shown to alter effortful prosocial decisions (Forbes et al., 2024a), theoretical accounts suggest that stress may facilitate empathy-driven helping while impairing prosocial behaviors that rely on cognitively demanding mentalizing processes. Indeed, in individuals with high mentalizing capacity, increases in cortisol levels may influence decision-making patterns, potentially biasing choices in ways that reflect more calculated or strategic reasoning under stress (Schulreich et al., 2022). Finally, the social context in which individuals are embedded is an important factor that shapes both cortisol levels and, consequently, social behaviors. Negative social experiences, such as social exclusion or loss of status, can increase cortisol levels, thereby biologically affecting individuals' social adaptation and decision-making processes (Taylor, 2012). These findings suggest that stress hormones can shape both emotional and moral tendencies of the individual within a social context.

Cortisol, beyond being a physiological stress marker, influences decision-making processes and social behaviors, with stress potentially modulating both social and material-interest-related tendencies (Sollberger et al., 2016). PFC activity can influence decision-making under stress, potentially biasing choices toward self-focused or reward-oriented behaviors in certain contexts (Sokol-Hessner et al., 2016). This effect is particularly associated with dorsolateral PFC activity and can influence the computation of social values, potentially biasing decision-making in social contexts (Schulreich et al., 2022). Additionally, non-genomic increases in cortisol may bias decision-making toward more instinctive or emotionally driven responses in moral contexts (Starcke et al., 2012). Cortisol can modulate social behavior and motivation, with high levels affecting responsiveness to reward and punishment cues, while lower levels are associated with different patterns of social engagement (Sherman et al., 2016). However, normal and healthy increases in cortisol may help regulate impulsive behaviors, influencing decision-making and behavioral control under stress (Tu et al., 2019). This tendency may influence social decision-making processes, affecting choices and associated emotional responses in decision contexts (Singer et al., 2017). Moreover, genomic increases in cortisol may modulate social reward-seeking tendencies, potentially influencing prosocial decision-making behaviors in social contexts (Sollberger et al., 2016). Additionally, increases in cortisol levels may bias decision-making toward more emotionally influenced responses in moral contexts, affecting choices in ways that reflect heightened affective processing (Starcke et al., 2012). Research also suggests that increased cortisol levels under stress may be associated with a greater tendency to make more altruistic decisions (Allwood & Salo, 2012). Interestingly, the interaction between cortisol and norepinephrine creates an effect that increases generosity, limited to individuals with whom the person has close relationships (Margittai et al., 2015). In summary, the role of cortisol in social behaviors is multi-layered and nuanced, intersecting various factors, and it shapes both altruistic and self-interested decisions by interacting with an individual's biological, psychological, and social traits.

9. Cortisol in Neurofinance

From a neurofinance perspective, cortisol’s effect on the prefrontal cortex and other neurobiological circuits is key to understanding the biological processes underlying financial decisions under stress. This hormone’s impact is shaped by individual differences, including genetics, environmental factors, and personal experiences, which influence economic decision-making (Herbert, 2018). Gender and other individual differences must also be considered in neurofinance studies, as they affect cortisol responses and decision performance (Santos-Ruiz et al., 2012). Furthermore, decision-making is influenced not only by financial outcomes but also by cognitive processes related to reward sensitivity and motivation, which can be modulated by cortisol (Kinner et al., 2016). Since decisions are shaped by both logic and emotion, cortisol can significantly influence decision-making processes through its modulation of cognitive and affective functions (Singer et al., 2017). Additionally, cortisol is not just an indicator of psychopathological states but also modulates decision-making processes under stress, influencing cognitive mechanisms that can contribute to risk-related and rapid choice behaviors (Law et al., 2024).

Cortisol exhibits gender-specific dynamics in shaping behavior under stress, influencing social, economic, and cognitive decision-making in diverse ways. It acts as a key biological marker in neurofinance for developing personalized stress management and decision support systems. Neurologically, although no gender differences are observed in prefrontal cortex activity, cortisol has been shown to modulate ventral striatum, amygdala, and hippocampus activity differently in men and women, potentially influencing stress-related decision-making processes. Cortisol has been shown to affect reward- and punishment-related neural processing differently in men and women, which may influence stress-related decision-making tendencies (Kinner et al., 2016; van Den Bos et al., 2014). Regarding cognitive performance, low cortisol levels are linked to better decision-making, with medium cortisol levels enhancing decision quality in women, while high levels impair cognitive control (Santos-Ruiz et al., 2012). In men, cortisol has been associated with modulation of impulsive tendencies, potentially influencing more deliberate decision-making processes (Youssef et al., 2018). Cortisol elevations appear to affect cognitive processes differently in men and women, with potential variations in decision-making performance under stress (Witbracht et al., 2012). Elevated cortisol levels have been associated with increased impulsivity, with potential variations between men and women, and timing of measurement may modulate observed effects (Takahashi et al., 2010). In social decision-making, cortisol in men strengthens caregiving behaviors, while its effect in women is more limited, with cortisol fluctuations not significantly affecting prosocial behaviors in high-empathy individuals (Zhang et al., 2019). In women, cortisol may influence social decision-making processes under stress, potentially affecting responses in cooperative or fairness-related contexts (Youssef et al., 2018). Cortisol’s effects on decision-making may vary by gender, potentially influencing social and financial choices differently in men and women under stress (Nickels et al., 2017). When cortisol levels rise under stress, individuals become more prone to risk-taking, potentially driving speculative movements and market volatility. Empirical data shows cortisol significantly influences investors' risk preferences, particularly in those with already elevated cortisol levels. Cortisol is thus a key biological marker in neurofinance, offering insights into risk preferences and macro-market trends (Cueva et al., 2015). The sympathetic nervous system and heart rate variability (vmHRV) are also important, with higher vmHRV associated with better stress regulation and adaptive decision-making strategies (García-Molina et al., 2024). This effect is most noticeable in leaders, where cortisol secretion and stress symptoms are lower (Sherman et al., 2012). Experienced investors tend to make healthier decisions with lower stress, while inexperienced investors often make emotional, irrational choices due to increased cortisol (AsleBagh et al., 2024). Stress and cortisol can influence risk perception and adaptability, potentially affecting decision-making under uncertainty (Dandolo & Schwabe, 2016). Stress-induced cortisol may also make decisions more emotional and intuitive, reducing decision quality due to distraction and weakened analytical thinking (Palamarchuk & Vaillancourt, 2021)

Cortisol increases can redirect cognitive resources, aiding problem-solving even in high-stress situations (Gathmann et al., 2014). With rising volatility in financial markets, significant increases in plasma cortisol have been linked to changes in cognitive processing and behavior (Nofsinger et al., 2018). Cortisol-induced stress can impair economic and social decision-making, shifting decisions from intention-based to routine behaviors, affecting risk assessment and adaptability (Soares et al., 2012; Zhang et al., 2011). While model-based decision-making is key for rational financial decisions, cortisol may prompt more short-term, habitual, and less rational choices under stress (Radenbach et al., 2015).

10. Discussion

Cortisol is characterized not only as a stress hormone but also as a modulator of cognitive and emotional processes, influencing flexibility and adaptive responses under stress (Putman & Roelofs, 2011). Furthermore, it is regarded as a neurohormonal factor that, beyond reflecting stress, may influence social and decision-making processes (Singer et al., 2017). Disruptions in stress mechanisms, reflected in cortisol levels, can serve as informative indicators in both psychiatric research and studies of decision-making under stress (Schumacher et al., 2013). As a vital hormone regulating cognitive and emotional functions under stress, cortisol rises rapidly during acute stress, activating the individual’s defense mechanisms. However, chronic stress and persistently high cortisol levels may lead to cognitive decline and the development of psychological disorders (Palamarchuk & Vaillancourt, 2021).

Within this scope, this comprehensive examination addresses in depth the multidimensional effects of cortisol on financial behavior. In particular, consistent with the Yerkes–Dodson law, findings indicate that moderate increases in cortisol can enhance cognitive capacity and utilitarian decision-making, whereas excessive or deficient levels can lead to cognitive impairments, irrational risk-taking tendencies, and impulsive behaviors—thus supporting its characterization as a “determinant hormone” (Dreyer et al., 2022; Li et al., 2021). Neurobiologically, cortisol’s effects on brain regions such as the prefrontal cortex, hippocampus, and amygdala modulate core processes including cognitive flexibility, working memory, and risk perception (Nofsinger et al., 2021; Russell & Lightman, 2019). The tendency observed under acute stress toward short-term rewards and deviation from long-term planning (Lenow et al., 2017), together with the weakening of cognitive control under chronic stress (Crespo et al., 2014), provides significant evidence of how cortisol influences the speed, quality, and risk perception in financial decision-making. Cortisol may influence prosocial behaviors in complex ways, potentially modulating both self-focused and socially oriented responses under social stress (Buchanan & Preston, 2014). Gender differences further modulate cortisol’s effects on risk-taking, cognitive performance, and social decision-making, highlighting variability in stress-related behavioral responses (Nickels et al., 2017; van Den Bos et al., 2014).

Given that cortisol under stress can bias economic decisions toward short-term preferences, acknowledging this biological mechanism is important for understanding stress-related decision-making behaviors (Delaney et al., 2014). The relationship between hair cortisol concentration (HCC) and subjective stress perception appears to be influenced by multiple factors, showing variability across individuals and contexts (Ceccato et al., 2016). In addition, the current literature highlights the limitations of neuroimaging studies, suggesting the existence of an inverted U-shaped performance curve in the stress–decision-making relationship. It is further noted that the effects may be more pronounced in individuals with high anxiety or neuroticism and that several critical questions remain unanswered (Starcke & Brand, 2012).

In this context, considering the influence of cortisol on financial decision-making may inform economic models by accounting for stress-related biases in individual behavior (Cueva et al., 2015). Particularly, given stress’s capacity to redirect cognitive resources (Gathmann et al., 2014), it is essential to develop new strategies to prevent conditions such as distraction and the weakening of analytical reasoning that can impair decision quality (Palamarchuk & Vaillancourt, 2021). The limitations of existing neuroimaging studies and the incomplete understanding of the inverted U - shaped performance curve observed in the stress - decision-making relationship demonstrate the need for deeper research in this field. An important unresolved issue concerns how variations in cortisol levels exert differential effects on decision-making processes, depending on individual and clinical characteristics such as age and psychopathology (Duque et al., 2022), the detailed analysis of how cortisol’s complex interactions with other neurotransmitters and hormones (e.g., dopamine, serotonin, testosterone) shape financial risk perception and impulsivity (Mather & Lighthall, 2012; Nofsinger et al., 2021); and the investigation of how experimental manipulations of cortisol levels alter decision-making in specific financial scenarios (e.g., portfolio diversification, short-term speculation). Furthermore, better understanding how chronic stress and individual differences (such as emotional intelligence and coping mechanisms) modulate cortisol's effects will provide significant theoretical and practical contributions to the field of neurofinance (Geisler & Allwood, 2018; Radtke et al., 2020). Addressing these gaps will not only enhance individual financial well-being but also lay the foundation for the development of more robust economic policies that support market stability and overall societal welfare.

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