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Revisión

Current Evidence on the Effects of Stress and Glucocorticoids on Decision-Making: A Systematic Review

Evidencia Actual sobre los Efectos del Estrés y los Glucocorticoides en la Toma de Decisiones: Una Revisión Sistemática

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Abstract
Stress is a psychophysiological response that helps the organism adapt to circumstances, with glucocorticoids playing a key role by influencing complex brain functions such as decision-making. This systematic review explores their impact by analyzing studies retrieved from PubMed, World Wide Science, PsycINFO, and Google Scholar using the strategies: (stress) AND (decision making), and "stress decision making," limited to 2019–2023. Of 2,097 articles, 26 met relevance and duplication criteria. Findings suggest stress and glucocorticoids can enhance rapid responses but increase risky choices in intricate evaluations. Glucocorticoid concentrations did not mediate these effects, which seem to arise from multifaceted biological and environmental interactions. Limitations include open-access-only sources.

Keywords: Stress; Glucocorticoids; Decision-making; Systematic review; Cognitive Neuroscience; Psychobiology; Psiconeuroendocrinology; Hypothalamic-pituitary-adrenal axis; Acute Stress; Chronic Stress; Executive Function; Brain Functioning.

Resumen
El estrés es una respuesta psicofisiológica que ayuda al organismo a adaptarse a las circunstancias, donde los glucocorticoides juegan un papel clave al influir en funciones cerebrales complejas como la toma de decisiones. Esta revisión sistemática explora su impacto analizando estudios recuperados de PubMed, World Wide Science, PsycINFO y Google Scholar, utilizando las estrategias: (stress) AND (decision making), y "stress decision making," limitadas al periodo 2019–2023. De 2,097 artículos, 26 cumplieron criterios de relevancia y duplicación. Los resultados sugieren que el estrés y los glucocorticoides pueden mejorar respuestas rápidas, pero aumentan las elecciones arriesgadas en evaluaciones intrincadas. No se observó que las concentraciones de glucocorticoides mediaran estos efectos, los cuales parecen surgir de interacciones biológicas y ambientales multifacéticas. Las limitaciones incluyen el uso exclusivo de fuentes de acceso abierto.

Palabras clave: Estrés; Glucocorticoides; Toma de Decisiones; Revisión Sistemática; Neurociencia Cognitiva; Psicobiología; Psiconeuroendocrinología; Eje Hipotálamo-Hipófisis-Adrenal; Estrés Agudo; Estrés Crónico; Función Ejecutiva; Funcionamiento Cerebral.

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INTRODUCTION

Stress is a psychophysiological response experienced by an organism when subjected to threatening or excessively demanding situations (Cameron & Schoenfeld, 2018; Hutmacher, 2021). This response involves the activation of the neuroendocrine system, secreting hormones that prepare the organism to react to these perceived threats (Sapolsky, 2021).

Among the main substances released in the stress response process are cortisol (CO), cortisone (CS), and corticosterone (CC). These hormones are known as glucocorticoids (Botía et al., 2023). Glucocorticoids are steroids produced by the activation of the hypothalamic-pituitary-adrenal (HPA) axis, and their fundamental functions include the regulation of metabolism, immune function, and the stress response (Chourpiliadis & Aeddula, 2023; Timmermans et al., 2019; Yang & Yu, 2021).

Prolonged exposure to the psychophysiological effects induced by stress and glucocorticoids can lead to adverse consequences, negatively impacting organ function and behavior (Bassil et al., 2022). These effects include biological aging, loss of neurons in the hippocampus, functional alterations in myelin and oligodendrocytes (Phillips-Wren & Adya, 2020; Aschbacher, 2013; Sapolsky, 1996; Antontseva et al., 2020), as well as deterioration of the prefrontal cortex (PFC), a region traditionally linked to conscious-voluntary activity (Derouesné, 2018; Domenech & Koechlin, 2015; Funahashi, 2017; Klein-Flügge et al., 2022).

However, short-term exposure to stress and glucocorticoids can be beneficial for immediate problem-solving, enhancing the speed of information gathering and analysis to make optimal decisions (Dhabhar et al., 2020; Guo, 2020; Kozioł-Nadolna & Beyer, 2021; Naseem et al., 2023). It is linked to cognitive benefits, fostering resilience, motivation, mobilization of resources to face immediate threats, optimal redistribution of oxygen and nutrients, and guiding adaptive behavior (Pernas et al., 2018; Oshri et al., 2022; Taborsky et al., 2022).

In critical situations, this rapid response can save lives, making these short-term psychophysiological responses advantageous (Dhabhar et al., 2020). However, Phillips-Wren & Adya (2020) warn that the acceleration in decision-making can reduce the processing time of the consequences, potentially increasing the risk of taking risks. Understanding both the favorable and unfavorable effects of stress and glucocorticoids in the short and long term is crucial for analyzing how these factors influence decision-making processes in stressful situations.

On the other hand, decision making (DM) is a complex interaction between multiple sociobiological processes that influence the evaluation of options and choice (Moutoussis et al., 2021; Christopoulos et al., 2018). Studying the psychophysiological effects of stress and glucocorticoids within this context could contribute to a deeper understanding of the factors involved in behavior under stressful conditions. The authors of the studies used for the review refer to different types of decision-making in their methods, namely: risky decisions (RKD); strategic decisions (SD); and routine decisions (RD).

Previous research in this field has yielded varied results, especially regarding the effects of stress and glucocorticoids on evaluation and choice processes. Despite the existence of evidence on glucocorticoids in DM, systematic reviews have not yet been conducted. Therefore, this systematic review aims to analyze existing studies on the impact of stress and glucocorticoids on DM, with particular attention to how these influences vary among different types of decisions. By addressing this issue, it is hoped to contribute to a deeper understanding of how sociobiological factors are involved in these complex interactions.

METHOD

For the present review, the recommendations and guidelines of the PRISMA method were followed (Moher et al., 2009).

For the sample collection of articles, the databases Pubmed, World Wide Science, PsycINFO, and Google Scholar were utilized with the keywords (stress) AND (decision making), stress "decision making" within a temporal window from 2019 to 2023. The chosen temporal window for the sample collection aligns with the objective of providing a current and up-to-date systematic review about this triple relationship.

The inclusion criteria for articles encompassed all experimental or clinical studies published in peer-reviewed scientific journals, studies presenting results on the effect of stress and glucocorticoids on DM, and research published in English. The exclusion criteria were studies without open access; only those available as conference abstracts were excluded from this review.

With the previously specified search criteria, a total of 2,097 articles were obtained. After applying the inclusion and exclusion criteria, a sample of 26 studies was obtained. 1,871 articles were discarded after reading the titles as they were not related to the objective of our review. 25 were excluded due to access restrictions, 80 due to duplication, and 72 for not meeting any of the inclusion criteria. After reading the abstracts, 23 studies were excluded for not aligning with the objectives of this review (Figure 1).

To assess the risk of bias in the included studies, the recommendation of the SING 50 guideline was followed, which suggests that the evaluation process be conducted by two independent reviewers to minimize the possibility of bias and ensure consistency in the results. The STROBE checklist for observational studies by Elm et al. (2007) was used as a tool for risk assessment. This checklist consists of 22 items that provide specific criteria for evaluating the quality and transparency of reports in observational studies, including aspects such as the title and abstract of the article, the introduction, the method design, the results, the discussion, and other relevant information.

The two reviewers independently analyzed each of the selected articles and assessed their compliance with each item on the STROBE checklist. They then compared their notes and, in cases of disagreement, discussed rationally whether the article met the corresponding item until they reached a consensus. Based on the results, Table 1 was created, detailing the items with the lowest compliance and the potential biases arising from this situation.

Figure 1. PRISMA Flow Diagram in Four Stages

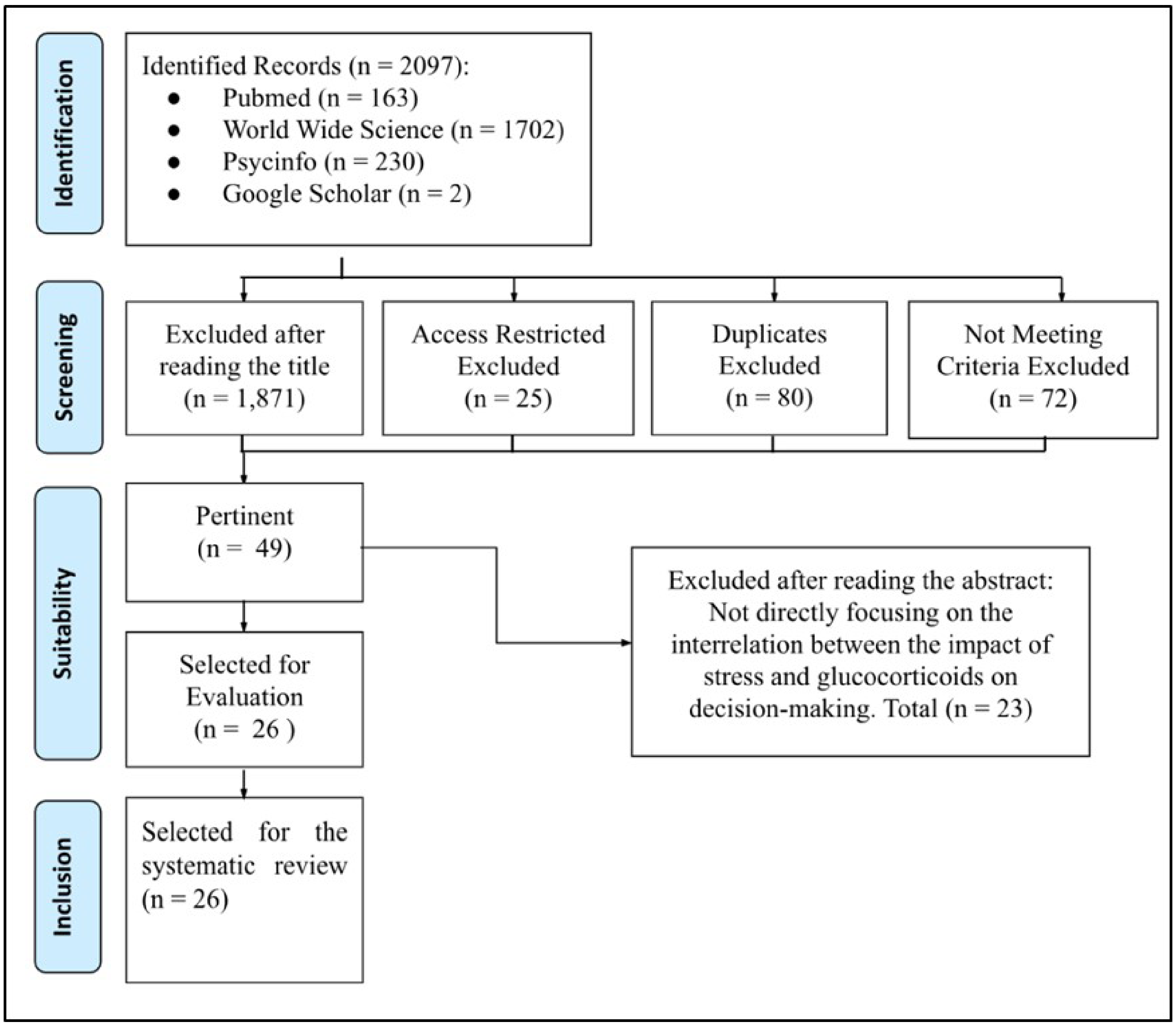


Table 1. Assessment of Bias Risk in Studies

STROBE CHECKLIST

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Blom, 2021	+	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+
Pighin et al., 2019	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Laino-Chiavegatti, 2023	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+
Fauquet-Alekhine, 2019	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+
Henriksen & Kruke, 2020	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	-
Raio et al., 2020	-	-	-	+	-	-	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+
Stamatis et al., 2020	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+
Doonan & Buchanan, 2023	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Fris et al., 2022	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
Hengen & Alpers, 2021	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+
Mazza et al., 2020	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	-
Rakshasa & Tong, 2020	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	-
Shi et al., 2023	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+
Byrne et al., 2019	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	+	-	+	+	+
Evans, 2022	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	-
Van-Timmeren et al., 2023	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+
Naumann & Schiller, 2021	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	+	-	+	-	-
Jang et al., 2019	+	+	-	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	-
Trapp & Vilares, 2020	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	-	+	+	-
Brunelin & Fecteau, 2021	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	-	+	+	+
Metz et al., 2020	+	+	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Warren et al., 2020	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
Ordoñes, 2021	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
Molins et al., 2021	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	-
Singer et al., 2021	+	+	-	+	-	+	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	+
Ziabari et al., 2020	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

The STROBE checklist consists of the following items (+= Met, -= Not Met): 1. Indicates the study design in the title or abstract and provides an informative and balanced summary; 2. Explains the reasons and scientific rationale; 3. Specifies objectives and hypotheses; 4. Presents key elements of the study design; 5. Describes the framework, locations, and relevant dates; 6. Provides eligibility criteria and the sources and methods for participant selection/follow-up; 7. Clearly defines all variables and, if applicable, the diagnostic criteria; 8. Indicates data sources and details of measurement methods; 9. Specifies measures taken to address potential sources of bias; 10. Explains how the sample size was determined; 11. Explains how quantitative variables were handled in the analysis; 12. Specifies all statistical methods and how missing data were treated; 13. Indicates the number of participants in each phase and the reasons for their loss; 14. Describes participant characteristics, information on exposures, and the number of missing data for each variable of interest; 15. Indicates the number of outcome events or provides summary measures; 16. Provides unadjusted estimates and, if applicable, adjusted for confounding factors; 17. Describes other analyses; 18. Summarizes main results in the discussion; 19. Discusses the limitations of the study, considering potential sources of bias; 20. Provides a cautious overall interpretation of the results; 21. Discusses the possibility of generalizing the results; 22. Specifies funding and the role of sponsors, and if applicable, of the prior study on which it is based.

RESULTS

Of the total sample of 26 studies, 20 involved human participants, gathering a total sample of 4,797 participants. Most of these studies examined stress in the context of acute stress (AS) (62%), with the remaining focusing on chronic stress (CHS). 69% of the analyzed studies found an unfavorable impact (UI) of stress on DM, 19% reported a favorable impact (FI), and 4% of the studies reported both favorable and unfavorable effects. The remaining 8% did not report the impact in terms of favorability for DM.

The evidence suggests that stress symptoms can have a FI on DM, both when the presence of symptoms is acute (Laino-Chiavegatti, 2023; Henriksen & Kruke, 2020; Byrne et al., 2019; Metz et al., 2020; Singer et al., 2021) and when it is chronic (Blom, 2021). Similarly, unfavorable effects are reported in the presence of such symptoms in both acute situations (Raio et al., 2020; Hengen & Alpers, 2021; Evans, 2022; Naumann & Schiller, 2021; Jang et al., 2019; Brunelin & Fecteau, 2021; Warren et al., 2020; Molins et al., 2021) and chronic conditions (Pighin et al., 2019; Fauquet-Alekhine, 2019; Stamatis et al., 2020; Doonan & Buchanan, 2023; Fris et al., 2022; Mazza et al., 2020; Rakshasa & Tong, 2020; Shi et al., 2023; Ordoñes, 2021).

Similarly, we observed that 58% of the reviewed studies investigated the relationship between glucocorticoids and DM. CO was the most studied glucocorticoid, present in the majority of the investigations (93%) (Doonan & Buchanan, 2023; Evans, 2022; Molins et al., 2021; Rakshasa & Tong, 2020; Naumann & Schiller, 2021; Ziabari et al., 2020; Stamatis et al., 2020; Van-Timmeren et al., 2023; Trapp & Vilares, 2020; Warren et al., 2020; Brunelin & Fecteau, 2021; Metz et al., 2020; Byrne et al., 2019; Singer et al., 2021). Regarding its impact on DM, 53% of the studies report an UI, 20% report an FI, 13% do not report favorability, and the remaining 13% observe both FI and UI.

Only one study (7%) was found that measured the effects of CC on DM. This study reported a FI of CC on the DM process (Laino-Chiavegatti, 2023). This review did not find any studies that related the levels or effects of CS to DM. Regarding the duration of exposure to glucocorticoids, 79% of the studies with CO samples examined its effects in the context of AS, while the remaining 21% did so in the context of CS. The study with measures of CC was conducted in the setting of exposure to acute stress.

Regarding study methods, we observed that the most frequently used technique was controlled experiments (44%), followed by subjective evaluation methods such as interviews, questionnaires and data analysis (15%), and experiments with animals (15%). Less common were neuroimaging studies (7%) and cross-sectional designs (7%). Pharmacological techniques, structural equation models, and causal-temporal network models were each used in 4% of the studies (Table 2).

RKD was the most used type of decision making in the methods of the reviewed studies, appearing in a total of 11 studies (Pighin et al., 2019; Doonan & Buchanan, 2023; Hengen & Alpers, 2021; Henriksen & Kruke, 2020; Rakshasa & Tong, 2020; Ordoñes, 2021; Raio et al., 2020; Shi et al., 2023; Stamatis et al., 2020; Warren et al., 2020; Metz et al., 2020). In the other hand are RD, which are reported in only 5 studies (Blom, 2021; Ziabari et al., 2020; Trapp & Vilares, 2020; Brunelin & Fecteau, 2021; Singer et al., 2021), and SD in 10 studies (Laino-Chiavegatti, 2023; Evans, 2022; Fauquet-Alekhine, 2019; Fris et al., 2022; Mazza et al., 2020; Molins et al., 2021; Naumann & Schiller, 2021; Van-Timmeren et al., 2023; Byrne et al., 2019; Jang et al., 2019).

Table 2. Characteristics of Reviewed Studies

Authors	n	Method	Duration	Impact of Stress	Sample	Effects of Stress on DM	Glucocorticoids	Impact of Glucocorticoids	ES
Blom, 2021	423	interviews	chronic	favorable	human	In the financial aspect, it has a limited impact on decision-making (DM)	NA	NA	0.28
Pighin et al., 2019	48	experimental	chronic	unfavorable	human	Mild hypoxia increases willingness to take risks.	NA	NA	0.3
Laino-Chiavegatti, 2023	32	experimental	acute	favorable	animal	Modulates risk-taking decisions and inhibitory control when rewards are linked to punishment.	CC	favorable	NA
Fauquet-Alekhine, 2019	93	review	chronic	unfavorable	database	In high-risk industries, it encourages impulsive decisions.	CO	unfavorable	NA

Henriksen & Kruke, 2020	24	review	acute	favorable	database	Generates intuitive responses based on training for armed confrontation situations.	NA	NA	NA
Raio et al., 2020	56	experimental	acute	unfavorable	human	Produces faster DM and increases responsiveness to rewards.	NA	NA	NA
Stamatis et al., 2020	90	experimental	chronic	unfavorable	human	Recurrent negative thinking increases DM with aversion.	CO	NA	0.30
Doonan & Buchanan, 2023	283	observational	chronic	unfavorable	human	Related to perception and aversion to risk.	CO	NA	NA
Fris et al., 2022	507	survey	chronic	unfavorable	human	Affects professional choices in medical students.	NA	NA	NA

Hengen & Alpers, 2021	87	experimental	acute	unfavorable	human	Social isolation has variable effects on decision-making depending on the level of social anxiety.	NA	NA	0.40
Mazza et al., 2020	1300	survey	chronic	unfavorable	human	Affects moral DM	NA	NA	NA
Rakshasa & Tong, 2020	30	experimental	chronic	unfavorable	animal	Social isolation increases high-risk decisions.	CO	unfavorable	0.89
Shi et al., 2023	16	experimental	chronic	unfavorable	animal	Influences risky decisions in mice.	NA	NA	NA
Byrne et al., 2019	100	experimental	acute	favorable	human	Improves DM to maximize rewards	CO	favorable	0.369
Evans, 2022	261	experimental	acute	unfavorable	human	Increases suboptimal and rewarding decisions in learning tasks.	CO	unfavorable	NA

Van-Timmeren et al., 2023	42	experimental	acute	NA	human	There are no significant differences in model-based DM.	CO	both	0.07
Naumann & Schiller, 2021	68	experimental	acute	unfavorable	human	It can have an impact on decision-making in situations of uncertainty.	CO	unfavorable	0.10
Jang et al., 2019	1023	structural equations	acute	unfavorable	human	In the early years of life, it may increase motivation for alcohol consumption in adulthood.	NA	NA	NA
Trapp & Vilares, 2020	60	experimental	acute	NA	human	It might not have a direct effect on sensorimotor decisions.	CO	NA	0.5
Brunelin & Fecteau, 2021	30	experimental	acute	unfavorable	human	Stimulation in DLPFC with tDCS prevents unfavorable effects of stress.	CO	unfavorable	NA

Metz et al., 2020	104	pharmaco-logical	acute	unfavorable	human	Hydrocortisone reduces rigorous DM.	CO	unfavorable	NA
Warren et al., 2020	45	experimental	acute	unfavorable	human	Increases DM in children and speed of choice.	CO	unfavorable	NA
Ordoñes, 2021	22	experimental	chronic	unfavorable	human	At early ages, it is linked to impulsive behavior.	NA	NA	NA
Molins et al., 2021	69	experimental	acute	unfavorable	human	It can increase the willingness to take risks.	CO	unfavorable	0.18
Singer et al., 2021	179	experimental	acute	favorable	human	Influences altruistic DM	CO	favorable	NA
Ziabari et al., 2020	4	causal temporal-network	acute	both	network model	Favorable or unfavorable response depending on the context	CO	both	NA

DM (Decision-Making); CO (Cortisol); CC (Corticosterone); NA (Not Available); DLPFC (Dorsolateral Prefrontal Cortex); tDCS (Transcranial Direct Current Stimulation); ES (Effect Size)

STRESS IN DECISION MAKING

This studies evidence implies that stress, whether acute or chronic, can have dual effects on the DM process (Figure 2). In AS contexts, Molins et al. (2021) and Raio et al. (2020) noted increased risk-taking propensity and decreased loss aversion in young adults. They propose that under AS, young individuals may exhibit heightened risk-taking, and in already impulsive participants, this DM process could be further expedited.

Similarly, Naumann & Schiller (2021) propose that AS can have an UI on DM in situations of uncertainty, especially when people face decisions based on previous experiences. The results of Singer et al. (2021) observed more altruistic DM after exposure to AS in young adults.

Van-Timmeren et al. (2023) results indicated no distinctions in goal-directed DM between a group with gambling addiction disorders and a control group, even post AS induction. Similarly, Trapp & Vilares (2020) propose that AS might not directly impact sensorimotor decisions, as physiological stress parameters did not alter participants average confidence in sensory information. Their experiment evaluated whether stress induced by the socially evaluated cold pressor task (SECPT) would modify low-level decisions, specifically the weight attribution to sensory information.

Conversely, during public health emergencies, Mazza et al. (2020) noted that CHS can influence moral DM in healthcare professionals. Those experiencing higher stress and emotional involvement may exhibit increased empathetic concern and excitement when making decisions involving moral judgment.

Stamatis et al. (2020) found that constant negative thoughts (CNT) resulting from a natural disaster could heighten the inclination to make aversive decisions in economic tasks with mixed trials. Variations in individual CNT were linked to stress-induced changes in DM. Those exposed to exceptionally stressful factors with higher CNT displayed increased loss aversion and more erratic response patterns.

Likewise, Doonan & Buchanan (2023) propose that CHS in young adults can result in an elevated perception of risk and reduced risk aversion. Fris et al. (2022) noted that CHS induced by time pressure, competitiveness, and academic workload may contribute to an UI on the professional decisions of medical students.

However, in the financial realm, Blom (2021) suggests that CHS resulting from income fluctuations minimally affects the quality of short-term DM in low-income market vendors and anticipates long-term search behavior. These findings indicate that even small and common income fluctuations in this context do not significantly influence daily DM. Likewise, CHS in conditions of low oxygen levels and within high-risk industries may elevate impulsive DM and the inclination to take risks (Pighin et al., 2019; Fauquet-Alekhine, 2019).

In clinical techniques, Brunelin & Fecteau (2021) found that transcranial direct current stimulation (tDCS) applied to the dorsolateral prefrontal cortex (DLPFC) can mitigate the negative biological and behavioral impacts of stress. Similarly, Metz et al. (2020) noted that hydrocortisone (cortisol) decreased risk aversion in trials featuring only gains, potentially attributed to a reduction in reward processing.

Hengen & Alpers (2021) propose that AS induced by social isolation may impact DM in individuals with social anxiety. This influence can affect risk/benefit assessment and information processing, resulting in prolonged response time. Similarly, Rakshasa & Tong (2020) obtained parallel results in an animal model, noting that CHS increases risk aversion in mice exposed to social isolation.

Likewise, in an animal model, Shi et al. (2023) state that extended exposure to CHS can impact risk aversion in both male and female mice. Conversely, Evans (2022) observed that AS enhances suboptimal and rewarding decisions in learning tasks, potentially heightening the preference for immediate rewards.

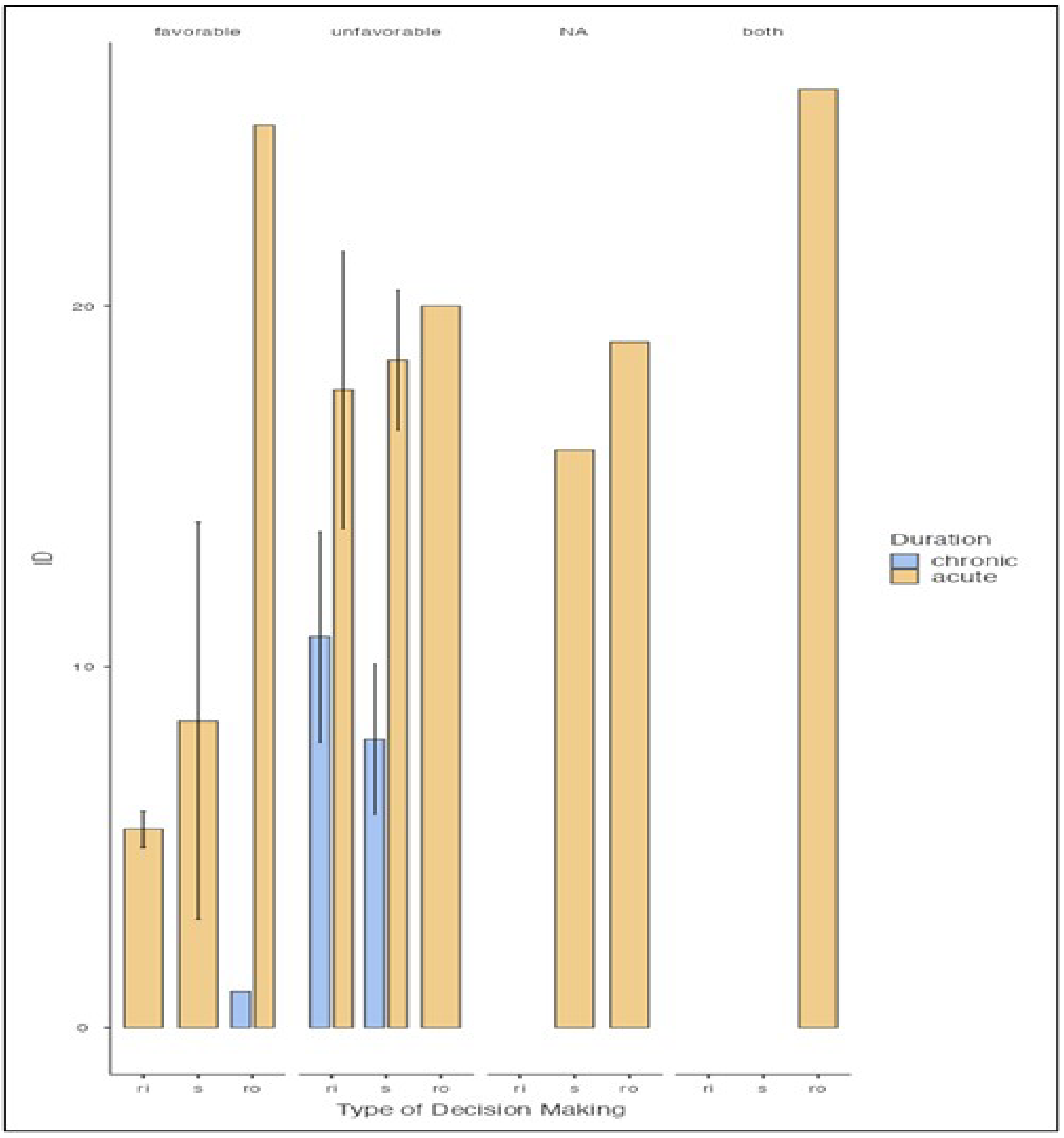
Consistent with this, Byrne et al. (2019) and Henriksen & Kruke (2020) highlight that AS improves DM to optimize long-term rewards in uncertain conditions. This proves advantageous in experience-dependent learning environments, where AS can enhance learning by prioritizing long-term rewards over immediate gains. Moreover, in armed confrontation scenarios, AS generates an intuitive response based on training, favorably impacting the survival of law enforcement personnel.

Laino-Chiavegatti (2023) proposes that AS in Long-Evans rats modifies RD and enhances inhibitory control when rewards are associated with punishment. The effects exhibit selective changes in reward-seeking behavior, diminishing risk-taking, and influencing impulse control differently between males and females.

Conversely, Warren et al. (2020) noted accelerated DM speed in infants during AS, correlating with heightened brain activity from the amygdala to the DLPFC. Similarly, Jang et al. (2019) propose that stress-induced memories in childhood and insecure attachment might serve as internal signals triggering alcohol consumption. In a parallel vein, Ordoñes (2021) suggests that stress stemming from early-life adversity is associated with substance use, attention deficit, and impulsive behavior.

Ultimately, Ziabari et al. (2020) propose that AS elicits an emotional response that amplifies vigilance, perception, and attention to threat-related stimuli. They suggest that the effects of AS are context-dependent and influenced by individual differences.

Figure 2. Types of Decision Making, Impact and Duration of Stress



ri (Risky. Decision); s (Strategic Decision); ro (Routinary Decision)

GLUCOCORTICOIDS IN DECISION MAKING

There are physiological aspects involved in the stress response, such as the release of glucocorticoids that occur because of exposure to stressful stimuli, and which also plays a role in the effects of stress on DM (Sapolsky, 2021).

Concentrations of various glucocorticoids have been observed to differ based on the chronicity of exposure to the stressful situation and the type of decision demanded by it (Aschbacher, 2013; Antontseva et al., 2020; Pernas et al., 2018; Oshri et al., 2022; Taborsky et al., 2022; Sapolsky, 1996).

Similarly, the main glucocorticoids involved in the stress response are CO, CS, and CC (Botía et al., 2023). However, in our sample, we observed that out of a total of 14 studies investigating the glucocorticoid-DM relationship, 13 measured CO concentrations, while 1 utilized measurements of CC (Figure 3).

We observed that the most used technique for measuring glucocorticoids was salivary concentration (41.6%), followed by measurement through urine, adaptive causal network modeling, observation (16.6% of studies each), and hair samples (8.3%).

In the reviewed literature, in the context of CHS, Doonan & Buchanan (2023) did not observe evidence suggesting a direct effect of CO, measured in hair samples, on DM among university students and non-student peers.

Rakshasa & Tong (2020), after analyzing urinary CO, report an impact on DM, promoting a preference for immediate rewards and biasing DM towards riskier options. On the other hand, Stamatis et al. (2020) observed that CO, generated from repetitive negative thinking (RNT), may have an impact, altering the menstrual cycle, sleep quality, reinforcing smoking habits, and medication consumption.

On the other hand, in the context of AS, the reviewed literature suggests that CO can induce an impact on DM in situations of uncertainty and the maximization of long-term rewards (Byrne et al., 2019), as well as moral and pro-social DM, contributing to altruistic DM (Singer et al., 2021).

However, Evans (2022) observes that the release of CO could lead to a reduction in the PFC activity, weakening the ability to pay attention to relevant stimuli and negatively impacting working memory performance. These authors noted that individuals with a high-stress response exhibited a significant increase in suboptimal but immediately rewarding decisions in a social DM task (Social Decision Tree Task).

In this same context, high levels of salivary CO have been associated with a stress response that influences loss aversion. Molins et al. (2021) suggest that stress reduces loss aversion, meaning that individuals under stress are less likely to be reactive to losses and may be more willing to take risks. On the other hand, Naumann & Schiller (2021) observe a decrease in the willingness to take risks and a lower occurrence of suboptimal DM. However, the relationship between CO and DM is complex and may vary depending on the context.

Metz et al. (2020), after CO induction, suggests that it could aid in DM in gain-only trials, as it amplifies loss aversion by reallocating resources to the central executive network, promoting fear, and consequently enhancing the analysis of losses.

In contrast, Brunelin & Fecteau (2021) observed that CO can reduce stress reactivity. Following stress exposure, the group treated with transcranial direct current electrical stimulation (TDCE) showed significantly higher levels of salivary CO compared to the control group.

Trapp & Vilares (2020), after stress induction using the SECPT, obtained subjective stress ratings as well as physiological parameters. They propose that stress did not affect the participant's sensitivity to changes in prior and sensory uncertainty. Both groups were able to detect and modulate their behavior, accordingly, as predicted by Bayesian statistics. The study suggests that, contrary to predictions, stress may not directly impact sensorimotor decisions.

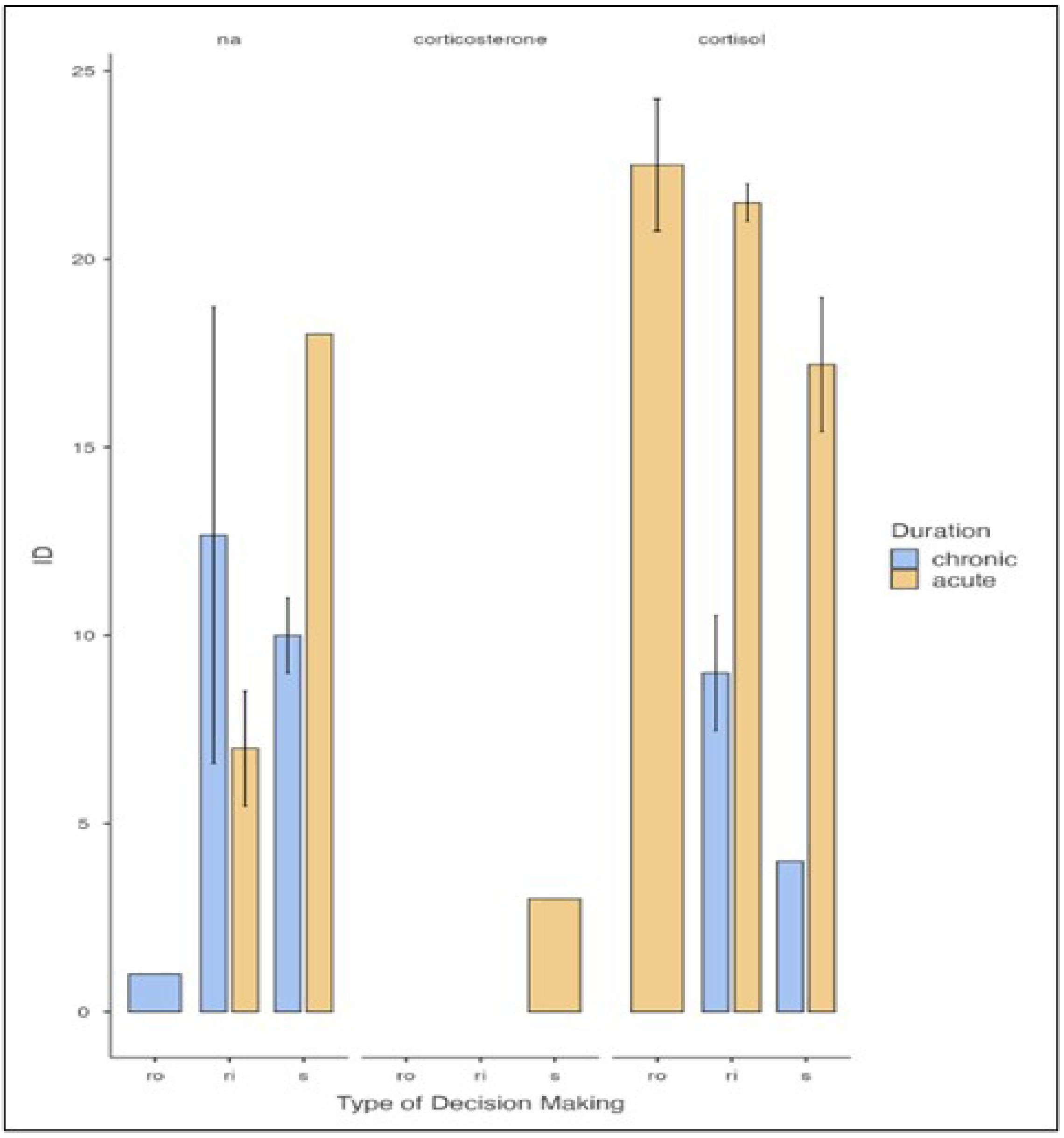
Ziabari et al. (2020), through an adaptive temporal-causal network model, indicate that CO has an impact on learning new decisions in response to stress, allowing individuals to respond more appropriately to specific types of threats and maintain homeostasis. However, they also analyze the impact of DM and suggest that it could lead to depression, anxiety, or schizophrenia. Furthermore, this study highlights that functional connectivity between the amygdala and the ventromedial prefrontal cortex during economic DM is influenced by CO, with different connectivity patterns observed in individuals who respond and do not respond to CO. These authors propose that CO has both an impact and an impairment on individuals responses to stress and their cognitive and affective processes.

Laino-Chiavegatti (2023), suggests that CC under economic DM conditions can have an impact by increasing dopamine levels, especially when there is a possibility of punishment, as observed in an animal model. Therefore, it is proposed that CS may play a modulating role in response speed to DM.

Finally, we did not find any articles focusing on the study of CS. Among the remaining authors, some investigated the effects of stress on DM but without including glucocorticoids (Blom, 2021, Pighin et al., 2019, Fris et al., 2022, Henriksen & Kruke, 2020, Mazza et al., 2020, Ordoñes, 2021, Jang et al., 2019, Raio et al., 2020, Shi et al., 2023; Fauquet-Alekhine, 2019; Warren et al., 2020).

Despite the evidence reviewed so far, Van-Timmeren et al. (2023) propose that CO levels can affect DM, both in AS and CHS. However, the specific effects may vary depending on the studied population and the specific DM process examined.

Figure 3. Type of Glucocorticoids, Duration, and Impact



ri (Risky. Decision); s (Strategic Decision); ro (Routinary Decision)

RISK OF BIAS

Out of the 26 studies evaluated, an average score of 18 and a mode of 20 were found across a maximum of 22 items on the STROBE checklist for observational studies by Elm et al. (2007), suggesting a moderate variability in compliance with quality standards. The most omitted items were those related to the specification of measures to address potential sources of bias and the discussion of the study's limitations considering possible sources of bias. This indicates a tendency to overlook critical aspects of transparency and self-criticism in the methodology, affecting the reliability and interpretation of the results. To assess interrater agreement, each of the 22 items was independently applied to the 26 studies by two reviewers, resulting in 572 individual assessments. The agreement rate was calculated using the formula:

$$\text{Agreement}\left(\%\right) = \left(\frac{n_{\text{agreement}}}{n_{\text{total}}}\right) \times 100$$

where n agreement = 526 and n total = 572, yielding a 92% agreement. This reflects a high level of consistency between reviewers in the application of quality criteria.

DISCUSION

The study aimed to explore the impact of stress and glucocorticoids on DM. To elucidate this complex relationship, we conducted a systematic review covering evidence from 2019 to 2023. After reviewing relevant articles, 26 investigations were included, with 20 involving human participants, comprising a total sample of 4,797 individuals. Following data collection and analysis, our results indicated that the effects of stress and glucocorticoids on DM are contingent on diverse contexts and individual variations.

Despite the relevance of these results, only 4% of the studies stand out for including information on the different effects of stress and glucocorticoids on DM (Van-Timmeren et al., 2023; Ziabari et al., 2020). Van-Timmeren et al. (2023) suggest that stress has both effects on DM, emphasizing that CO can affect both AS and CHS conditions. However, specific effects may vary depending on the studied population and the specific DM processes examined. Therefore, discrepancies in the results of the found studies are to be expected, as they are conducted in a variety of contexts.

Upon observing the studies included in the review, it becomes apparent that the referenced studies are focused on durations of both AS and CHS. These studies cover a variety of specific contexts, such as financial stress (Blom, 2021), oxygen reduction (Pighin et al., 2019), punishments (Laino-Chiavegatti, 2023), high-risk industries (Fauquet-Alekhine, 2019), armed confrontation situations (Henriksen & Kruke, 2020), unusual emotional states (Raio et al., 2020), natural disasters (Stamatis et al., 2020), risk perception (Doonan & Buchanan, 2023), career choices (Fris et al., 2022), social isolation (Hengen & Alpers, 2021; Rakshasa & Tong, 2020), emotional stress (disgust) (Molins et al., 2021), moral decisions (Mazza et al., 2020), risky decisions (Shi et al., 2023), social stress (Singer et al., 2021), low thermal conditions (Byrne et al., 2019), learning tasks (Evans, 2022), achievement-oriented situations (Van-Timmeren et al., 2023), uncertainty (Naumann & Schiller, 2021), early life (Jang et al., 2019; Ordoñes, 2021), and clinical and pharmacological conditions (Trapp & Vilares, 2020; Brunelin & Fecteau, 2021; Metz et al., 2020; Warren et al., 2020).

This diversity of contexts can uniquely shape DM with a wide range of responses. For instance, situations involving financial stress (Blom, 2021) may trigger different DM compared to scenarios involving social or disgust stress (Singer et al., 2021; Molins et al., 2021). Additionally, differences in results may also be related to the duration of stress, as events in AS (Molins et al., 2021; Raio et al., 2020; Naumann & Schiller, 2021; Singer et al., 2021; Van-Timmeren et al., 2023; Trapp & Vilares, 2020; Hengen & Alpers, 2021; Brunelin & Fecteau, 2021; Metz et al., 2020; Evans, 2022; Byrne et al., 2019; Henriksen & Kruke, 2020; Laino-Chiavegatti, 2023; Warren et al., 2020; Jang et al., 2019; Ordoñes, 2021; Ziabari et al., 2020) may have different effects compared to prolonged CHS situations (Mazza et al., 2020; Stamatis et al., 2020; Doonan & Buchanan, 2023; Fris et al., 2022; Blom, 2021; Pighin et al., 2019; Fauquet-Alekhine, 2019, Rakshasa & Tong, 2020; Shi et al., 2023). Similarly, Ziabari et al. (2020) indicate that stress can trigger both an impact and an impairment of DM.

Initially, stress elicits an emotional response that enhances vigilance, perception, and attention to stimuli related to the threat. This may be considered disruptive, but its main purpose is to improve coping with challenging situations. Although it may be unpleasant at times, this mechanism is positive as it provides the possibility of helping to overcome obstacles.

However, whether these difficulties are overcome or not, or whether the type of decision-making that takes place involves routine, risky, or strategic decisions could depend on the intricate interaction between multiple neurobiological factors (Evans, 2022), endocrine factors (Rakshasa & Tong, 2020; Stamatis et al., 2020; Molins et al., 2021; Naumann & Schiller, 2021; Byrne et al., 2019; Singer et al., 2021), prenatal and postnatal factors (Ordoñes, 2021), genetic-epigenetic factors (Trapp & Vilares, 2020; Byrne et al., 2019), individual development (Warren et al., 2020; Jang et al., 2019; Naumann & Schiller, 2021), environmental triggers (Pighin et al., 2019; Fauquet-Alekhine, 2019; Henriksen & Kruke, 2020), population-species attributes, and natural selection to respond in a certain way to the stressful stimulus (Sapolsky, 2017).

As a result, this could lead to a diversity of responses, as the influence of the aforementioned factors on the perception and reaction to stress could determine how DM is affected under different contexts, stress durations, gender differences, the studied population, and glucocorticoids administration (Mazza et al., 2020; Fris et al., 2022; Laino-Chiavegatti, 2023; Shi et al., 2023; Metz et al., 2020; Brunelin & Fecteau, 2021). This adds a level of complexity to this dynamic interaction, as the specific characteristics and demands of each of these elements can lead to divergent responses.

CONCLUSIONS

Based on the evidence presented in our study, stress, and glucocorticoids exert an influence on DM that may be relevant under specific conditions. These effects are diverse and often reliant on the context and individual characteristics of the studied population. Broadly speaking, the reviewed evidence suggests potential benefits from stress and glucocorticoids effects in situations requiring quick decisions, where a highly deliberative approach could be life-threatening.

However, unfavorable consequences arise in decisions requiring a detailed assessment, leading to an increased propensity for risky behaviors and impaired evaluation of risks and consequences in certain stressful situations.

Cortisol concentrations do not appear to mediate the effects of stress on decision-making. The observed impacts stem from the complex interplay of neurobiological, endocrine, pre-postnatal, genetic-epigenetic, individual development, environmental triggers, population-species attributes, natural selection, stress duration, gender differences, and the characteristics of the studied population.

Despite our efforts to conduct a rigorous study, it is essential to acknowledge limitations that could be pertinent and should be considered in future research. The choice to exclusively utilize open-access sources may have excluded relevant research hosted in databases with limited or restricted access, as well as publications with lower visibility. Similarly, the decision to rely solely on open-access articles might have constrained the range of consulted sources and the representativeness of the analyzed sample.

Future research should aim to ensure broader access to literature, encompassing restricted access databases and publications. This approach allows for the inclusion of a more extensive range of evidence, minimizing biases in the presentation of available research.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

AUTHOR CONTRIBUTIONS

ER-A contributed substantially to the conception of the work, analysis, and interpretation of the data, and drafted the manuscript. PL-S contributed substantially to the conception of the work and revised the manuscript critically for important intellectual content. HM-S contributed substantially to the conception of the work and analyzed and interpreted the data and revised the manuscript critically for important intellectual content. All authors provided approval for publication of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the research are appropriately investigated and resolved.

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REFERENCE

Antontseva, E., Bondar, N., Reshetnikov, V., & Merkulova, T. (2020). The Effects of Chronic Stress on Brain Myelination in Humans and in Various Rodent Models. *Neuroscience*, 441, 226–238. https://doi.org/10.1016/j.neuroscience.2020.06.013

Aschbacher, K., O'Donovan, A., Wolkowitz, O. M., Dhabhar, F. S., Su, Y., & Epel, E. (2013). Good stress, bad stress and oxidative stress: insights from anticipatory cortisol reactivity. *Psychoneuroendocrinology, 38*(9), 1698–1708. https://doi.org/10.1016/j.psyneuen.2013.02.004

Bassil, K., De Nijs, L., Rutten, B. P. F., Van Den Hove, D. L. A., & Kenis, G. (2022). In vitro modeling of glucocorticoid mechanisms in stress-related mental disorders: Current challenges and future perspectives. *Frontiers in cell and developmental biology*, 10, 1046357. https://doi.org/10.3389/fcell.2022.1046357

Botía, M., Escribano, D., Martínez-Subiela, S., Tvarijonaviciute, A., Tecles, F., López-Arjona, M., & Cerón, J. J. (2023). Different Types of Glucocorticoids to Evaluate Stress and Welfare in Animals and Humans: General Concepts and Examples of Combined Use. *Metabolites, 13*(1), 106. https://doi.org/10.3390/metabo13010106

Blom, S. A. (2021). Financial stress and decision-making: Evidence from market vendors in Addis Ababa. *AgEcon Search*. https://doi.org/10.22004/ag.econ.313928

Brunelin, J., & Fecteau, S. (2021). Impact of bifrontal transcranial Direct Current Stimulation on decision-making and stress reactivity. A pilot study. *Journal of psychiatric research*, 135, 15–19. https://doi.org/10.1016/j.jpsychires.2020.12.068

Byrne, K. A., Cornwall, A. C., & Worthy, D. A. (2019). Acute stress improves long-term reward maximization in decision-making under uncertainty. *Brain and cognition*, 133, 84–93. https://doi.org/10.1016/j.bandc.2019.02.005

Cameron, H. A., & Schoenfeld, T. J. (2018). Behavioral and structural adaptations to stress. *Frontiers in neuroendocrinology*, 49, 106–113. https://doi.org/10.1016/j.yfrne.2018.02.002

Chourpiliadis, C., & Aeddula, N. R. (2023, 17 julio). Physiology, glucocorticoids. StatPearls - NCBI Bookshelf. https://www.ncbi.nlm.nih.gov/books/NBK560897/

Christopoulos, V. N., Andersen, K. N., & Andersen, R. A. (2018). Extinction as a deficit of the decision-making circuitry in the posterior parietal cortex. *Handbook Of Clinical Neurology*, 163-182. https://doi.org/10.1016/b978-0-444-63622-5.00008-5

Derouesné, C. (2018). AR Luria and the role of frontal lobes in the regulation of higher mental activities and behavior. *Revue Neurologique*. https://doi.org/10.1016/j.neurol.2018.09.007

Dhabhar, F. S., Meaney, M. J., Sapolsky, R. M., & Spencer, R. G. M. (2020). Reflections on Bruce S. McEwen's contributions to stress neurobiology and so much more. *Stress, 23*(5), 499–508. https://doi.org/10.1080/10253890.2020.1806228

Domenech, P., & Koechlin, E. (2015). Executive control and decision-making in the prefrontal cortex. *Current Opinion in Behavioral Sciences*, 1, 101–106. https://doi.org/10.1016/j.cobeha.2014.10.007

Doonan, A., & Buchanan, T. W. (2023). Chronic stress, hair cortisol, and risky Decision-Making processes in young adults. *Psychoneuroendocrinology*, 153, 106171. https://doi.org/10.1016/j.psyneuen.2023.106171

Elm, E. von, Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., & Vandenbroucke, J. P. (2007). Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ, 335*(7624), 806–808. https://doi.org/10.1136/bmj.39335.541782.AD

Evans, H. (2022, April 20). Acute stress influences Decision-Making by diminishing the consideration of Long-Term reward. Carolina Digital Repository. https://cdr.lib.unc.edu/concern/honors_theses/br86bc72r

Fauquet-Alekhine, P. (2019). Statistical approach to identify stress and biases Impairing Decision-Making in High-Risk industry. *Zenodo*. https://doi.org/10.5281/zenodo.3593208

Fris, D. a. H., Van Vianen, A., Koen, J., De Hoog, M., & De Pagter, A. P. J. (2022). Medical students' career decision-making stress during clinical clerkships. *Perspectives on Medical Education, 11*(6), 350–358. https://doi.org/10.1007/s40037-022-00734-8

Funahashi, S. (2017). Prefrontal Contribution to Decision-Making under Free-Choice Conditions. *Frontiers in Neuroscience*, 11. https://doi.org/10.3389/fnins.2017.00431

Guo K. L. (2020). DECIDE A Decision-Making Model for More Effective Decision Making by Health Care Managers. *The health care manager, 39*(3), 133–141. https://doi.org/10.1097/HCM.0000000000000299

Henriksen, S. V., & Kruke, B. I. (2020). Norwegian Police Use of Firearms: Critical Decision-Making in Dynamic and Stressful Situations. *Nordic Journal Of Studies In Policing, 7*(2), 99-120. https://doi.org/10.18261/issn.2703-7045-2020-02-03

Hengen, K. M., & Alpers, G. W. (2021). Stress Makes the Difference: Social Stress and Social Anxiety in Decision-Making Under Uncertainty. *Frontiers in Psychology*, 12, 578293. https://doi.org/10.3389/fpsyg.2021.578293

Hutmacher F. (2021). Putting Stress in Historical Context: Why It Is Important That Being Stressed Out Was Not a Way to Be a Person 2,000 Years Ago. *Frontiers in Psychology*, 12, 539799. https://doi.org/10.3389/fpsyg.2021.539799

Jang, O., Park, S. C., Kim, S. G., Lee, J. S., & Kim, J. H. (2019). How early life stress and insecure attachment affect decision-making style and motivation to use alcohol: a structural equation model. *Psychiatry and Clinical Psychopharmacology, 29*(2), 178–181. https://doi.org/10.1080/24750573.2019.1611019

Klein-Flügge, M. C., Bongioanni, A., & Rushworth, M. F. S. (2022). Medial and orbital frontal cortex in decision-making and flexible behavior. *Neuron, 110*(17), 2743–2770. https://doi.org/10.1016/j.neuron.2022.05.022

Kozioł-Nadolna, K., & Beyer, K. (2021). Determinants of the decision-making process in organizations. *Procedia Computer Science*, 192, 2375–2384. https://doi.org/10.1016/j.procs.2021.09.006

Laino-Chiavegatti G. (2023). Acute stress modulation of risk/reward decision-making (T). University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0432712

Mazza, M., Attanasio, M., Pino, M. C., Masedu, F., Tiberti, S., Sarlo, M., & Valenti, M. (2020). Moral Decision-Making, Stress, and Social Cognition in Frontline Workers vs. Population Groups During the COVID-19 Pandemic: An Explorative Study. *Frontiers in Psychology*, 11, 588159. https://doi.org/10.3389/fpsyg.2020.588159

Metz, S., Waiblinger-Grigull, T., Schulreich, S., Chae, W. R., Otte, C., Heekeren, H. R., & Wingenfeld, K. (2020). Effects of hydrocortisone and yohimbine on decision-making under risk. *Psychoneuroendocrinology*, 114, 104589. https://doi.org/10.1016/j.psyneuen.2020.104589

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: the

PRISMA statement. *Annals of Internal Medicine, 151*(4), 264–269. http://doi.org/10.7326/0003-4819-151-4-200908180-00135

Molins, F., Ayuso, C., & Rosa, M. a. S. (2021). Emotional stress & decision-making: an emotional stressor significantly reduces loss aversion. *Stress, 24*(6), 780–786. https://doi.org/10.1080/10253890.2021.1919617

Moutoussis, M., Garzón, B., Neufeld, S., Bach, D. R., Rigoli, F., Goodyer, I., Bullmore, E., NSPN Consortium, Guitart-Masip, M., & Dolan, R. J. (2021). Decision-making ability, psychopathology, and brain connectivity. *Neuron, 109*(12), 2025–2040.e7. https://doi.org/10.1016/j.neuron.2021.04.019

Naseem, A., Akram, M., Ullah, K., & Ali, Z. (2023). Aczel-Alsina Aggregation Operators Based on Complex Single-valued Neutrosophic Information and Their Application in Decision-Making Problems. *Decision Making Advances, 1*(1), 86–114. https://doi.org/10.31181/dma11202312

Naumann & Schiller (2021). Stress and decision making: a neuroeconomic approach. Thesis. Universität Jena https://www.db-thueringen.de/servlets/MCRFileNodeServlet/dbt_derivate_00055338/Diss_PeterNaumann.pdf

Ordoñes, E. (2021). The Effects of Early Life Stress on Impulsive and Risky Decision-Making Behaviors. Thesis. Temple University Graduate Board https://scholarshare.temple.edu/bitstream/handle/20.500.12613/7199/OrdoxF1esSanchez_temple_0225E_14709.pdf

Oshri, A., Cui, Z., Carvalho, C., & Liu, S. (2022). Is perceived stress linked to enhanced cognitive functioning and reduced risk for psychopathology? Testing the hormesis hypothesis. Psychiatry research, 314, 114644. https://doi.org/10.1016/j.psychres.2022.114644

Pernas,I., Espinosa, A., Gonzalez, R. (2018). Theoretical methodological and practical considerations about the stress. *Scielo*, (18) 1-3. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1727-81202018000300697#c1

Phillips-Wren, G., & Adya, M. (2020). Decision making under stress: the role of information overload, time pressure, complexity, and uncertainty. *Journal of Decision Systems, 29*(1), 213–225. https://doi.org/10.1080/12460125.2020.1768680

Pighin, S., Bonini, N., Hadjichristidis, C., Schena, F., & Savadori, L. (2019). Decision making under stress: mild hypoxia leads to increased risk-taking. *Stress, 23*(3), 290-297. https://doi.org/10.1080/10253890.2019.1680634

Raio, C. M., Konova, A. B., & Otto, A. R. (2020). Trait impulsivity and acute stress interact to influence choice and decision speed during multi-stage decision-making. *Scientific Reports, 10*(1). https://doi.org/10.1038/s41598-020-64540-0

Rakshasa, A. M., & Tong, M. S. (2020). Making “Good” Choices: Social Isolation in Mice Exacerbates the Effects of Chronic Stress on Decision Making. *Frontiers in Behavioral Neuroscience*, 14, 81. https://doi.org/10.3389/fnbeh.2020.00081

Sapolsky R. M. (1996). Why stress is bad for your brain. *Science* (New York, N.Y.), 273(5276), 749–750. https://doi.org/10.1126/science.273.5276.749

Sapolsky, R. M. (2017). Behave the biology of humans at our best and worst. New York, New York, Penguin Press.

Sapolsky, R. M. (2021). Glucocorticoids, the evolution of the stress-response, and the primate predicament. *Neurobiology of Stress*, 14, 100320. https://doi.org/10.1016/j.ynstr.2021.100320

Shi, T., Feng, S., Zhong-Lin, Z., Li, F., Fu, Y., & Zhou, W. (2023). Stress-altering anterior insular cortex activity affects risk decision-making behavior in mice of different sexes. *Frontiers in Cellular Neuroscience*, 17. https://doi.org/10.3389/fncel.2023.1094808

Singer, N., Sommer, M., Wüst, S., & Kudielka, B. M. (2021). Effects of gender and personality on everyday moral decision-making after acute stress exposure. *Psychoneuroendocrinology*, 124, 105084. https://doi.org/10.1016/j.psyneuen.2020.105084

Stamatis, C. A., Puccetti, N. A., Charpentier, C. J., Heller, A. S., & Timpano, K. R. (2020). Repetitive negative thinking following exposure to a natural stressor prospectively predicts altered stress responding and decision-making in the laboratory. *Behavior research and therapy*, 129, 103609. https://doi.org/10.1016/j.brat.2020.103609

Taborsky, T., Kuijper,B., Fawcett, T., English,S., Leimar,O., McNamara, J., Ruuskanen, S. (2022). An evolutionary perspective on stress responses, damage and repair. *Hormones and Behavior*, (142) 1-12. https://doi.org/10.1016/j.yhbeh.2022.105180.

Timmermans, S., Souffriau, J., & Libert, C. (2019). A General Introduction to Glucocorticoid Biology. *Frontiers in immunology*, 10, 1545. https://doi.org/10.3389/fimmu.2019.01545

Trapp, S., & Vilares, I. (2020). Bayesian decision-making under stress-preserved weighting of prior and likelihood information. *Scientific Reports, 10*(1). https://doi.org/10.1038/s41598-020-76493-5

Van-Timmeren, T., Piray, P., Goudriaan, A. E., & Van Holst, R. J. (2023). Goal-directed and habitual decision making under stress in gambling disorder: An fMRI study. *Addictive Behaviors*, 140, 107628. https://doi.org/10.1016/j.addbeh.2023.107628

Warren, S. L., Zhang, Y., Duberg, K., Mistry, P., Cai, W., Qin, S., Bostan, S. N., Padmanabhan, A., Carrion, V. G., & Menon, V. (2020). Anxiety and Stress

Alter Decision-Making Dynamics and Causal Amygdala-Dorsolateral Prefrontal Cortex Circuits During Emotion Regulation in Children. *Biological psychiatry, 88*(7), 576–586. https://doi.org/10.1016/j.biopsych.2020.02.011

Yang, R., & Yu, Y. (2021). Glucocorticoids are double-edged sword in the treatment of COVID-19 and cancers. *International journal of biological sciences, 17*(6), 1530–1537. https://doi.org/10.7150/ijbs.58695

Ziabari, S. S. M., & Treur, J. (2020). Decision Making Under Acute Stress Modeled by an Adaptive Temporal–Causal Network Model. *Vietnam Journal Of Computer Science, 07*(04), 433-452. https://doi.org/10.1142/s2196888820500244