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Santiago David Vásquez-Hidalgo, Lorrane Ribeiro de Souza, Bruno da Silva Santos, Rosa Maria Martins de Almeida

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Cognitive virtual games and cortisol: a prisma-based systematic review

Santiago David Vásquez-Hidalgo[1], Lorrane Ribeiro de Souza[1], Bruno da Silva Santos[2], Rosa Maria Martins de Almeida[3]

1.Neuroscience Program of the Instituto de Ciências Básicas da Saúde (ICBS), Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil.
2.Adult and Elderly Health Care at Hospital de Clínicas de Porto Alegre (HCPA), Porto Alegre, RS, Brazil.
3.Laboratório de Psicologia Experimental, Neurociências e Comportamento (LPNeC), Instituto de Psicologia, Serviço Social, Saúde e Comunicação Humana (IPSSCH), Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil.

Correspondence:
Rosa Maria Martins de Almeida,
rosa.almeida@ufrgs.br or rosa_almeida@yahoo.com.

Santiago David Vásquez Hidalgo
santyvh93@gmail.com.

Abstract

Objective: Over the last decades, gaming has become a popular way to spend time and connect with people worldwide, engaging millions of users. Literature has shown that games and competition in gaming are closely linked to physiological stress responses. The aim of this systematic review was to determine if cognitive virtual games are also linked with stress responses and to investigate this interplay.

Methods: Following the PRISMA protocol, five databases were used, including EMBASE, PubMed, PsycInfo, SCOPUS and Web of Science. The PICO strategy was employed to formulate the research question. The search was performed by three independent investigators using a predefined protocol registered on the PROSPERO database (CRD42022384921).

Findings: Following these procedures, 30 eligible empirical studies were considered for the review, which included 39 cognitive games, because some studies used more than one game in their research.

Fourteen of the selected studies showed significantly increased cortisol levels after playing virtual cognitive games, twelve studies reported a decrease in cortisol levels while the remaining four showed both, increase and decrease cortisol depending on variables such as gender differences, age or type of game. This highlights the complex relationship between virtual cognitive games and cortisol modulation.

Conclusion: Our results provided a comprehensive view of the intricate interplay between virtual cognitive games and cortisol dynamics, acknowledging both the potential stress-inducing and stress-alleviating effects of gaming. The implications of these findings go beyond entertainment, emphasizing the need for a nuanced understanding of the psychophysiological mechanisms involved.

Keywords: Hydrocortisone; Cortisol; Stress; Cognitive games

INTRODUCTION

Among the early stages of the COVID-19 pandemic, as people sought new ways to connect with others and refuge from the stressors of isolation, gaming transcended its role as a mere pastime: it experienced a remarkable surge in 2020, with video game sales reaching record numbers and the global number of gamers soaring into the billions[1]. Literature explored negative outcomes of gaming has progressively increased over the last decade and in 2013 the American Psychiatric Association (APA) recognized the Internet Gaming Disorder [IGD; 2]. Digital games, including cognitive games, have gained considerable attention in the field of neuroscience due to their potential impact on cognitive processes[3], frustration and stress [4]. Studies also indicate that video games helped many individuals to navigate through challenging life circumstances, with more intellectual and cognitively engaging games like chess offering considerable stimulation through their intricate patterns and calculations[5]. Gaming, however, is not without its drawbacks[6] and literature indicates that cognitively challenging tasks can intensify unpleasant feelings like fear and anxiety[7] and frustration, as individuals often confront obstacles and different types of complications[8].

Frustration, the irritable anguish triggered by unmet desires[9], is intricately linked to heightened stress responses both in humans and other primates[10], being closely intertwined with cortisol, a hormone produced by the adrenal gland as part of the Hypothalamic–pituitary–adrenal (HPA) axis response to stress-inducing stimuli, whether it's the physiological stress of blood loss or the emotional strain of facing a challenging test, for instance[11]. While cortisol plays a pivotal role in emotion regulation[12], helping to mobilize our energy reserves by regulating inflammatory responses and facilitating the metabolism of proteins and fats[13], high levels of cortisol can result in several negative consequences, including chronic stress, impaired immune function and increased blood pressure and risk of chronic diseases, such as cardiovascular conditions and diabetes[14–16]. Because of this, frustration can have a significant impact on our overall well-being, occupational functioning and even contribute to psychopathology development[17], being able to fuel open aggression[18] and one of the factors that can contribute to gaming addiction[19].

This is of special note in competitive games, which can potentially exacerbate anxious and compulsive tendencies in players due to its stressful qualities and the intense pressure involved[20]. Furthermore, a strong need for achievement and difficulty tolerating discomfort or frustration has been associated with depression in people afflicted with IGD[21]. In this context, understanding the psychophysiological mechanisms underlying this interplay is crucial for the development of interventions with higher efficacy in reducing stress-related effects[22].

The purpose of this systematic review is, therefore, to investigate the interplay between these anxiolytic contexts and physiological stress-related responses, specifically to ascertain whether elevated cortisol levels will be observed in individuals engaging in cognitive and virtual games.

METHODS

1.Protocol and Registration

This systematic review followed the PRISMA 2020 guidelines. The review protocol was initially registered at PROSPERO (CRD42022384921), although the current scope of research evolved from its original registration.

2. Eligibility Criteria

All included studies investigated "Cognitive Virtual Games," defined as digital games specifically designed or primarily characterized by complex cognitive engagement, such as strategic reasoning, problem-solving, decision-making under uncertainty, working memory tasks, or logical thinking exercises. This includes strategy-based games (e.g., chess, shogi), simulation tasks, and experimental paradigms involving risk-taking, social decision-making, or cognitive load. Simple motor-based games or games requiring minimal cognitive processing were excluded.

Participants included healthy adolescents and adults aged 12 years or older. Exclusion criteria were participants under 12 years, those with diagnosed psychopathologies, substance abuse history, or studies lacking biological cortisol data.

Studies also were excluded from reviews and meta-analyses; books, thesis, dissertations, abstracts, and publications in congresses; non-human sample; The literature review includes articles that assessed cognitive virtual games and cortisol measures as a stress indicator; studies written in English, Spanish and Portuguese languages. The sample sizes ranged between 10 and 352 participants.

3. Information Sources and Search Strategy

Five databases were searched: PubMed, EMBASE, PsycNet, SCOPUS, and Web of Science between March and November 2023. Initially, some search strategies included the term "Young Adult*" (18–30 years), potentially narrowing results. This was corrected by re-running searches excluding age-restrictive filters, ensuring inclusion of participants aged 12 years and older.

Search terms included combinations of: (Anger OR Hostility OR Impulsiveness OR 'Impulsive Behavior' OR 'Impulsive Behaviors' OR Impulsivit* OR Frustration* OR Stress OR 'Psychological Stress*' OR 'Life Stress*' OR 'Psychologic Stress*' OR 'Psychological Stressor*') AND (Hydrocortisone OR Cortisol). Complete search strategies are presented in the Annex.

4. Study Selection and Data Extraction

The Rayyan software[54] was used for decision recording, article selection and analysis. With the material selection process, including applying of eligibility criteria, study selection, data extraction and checking being done by two independent reviewers (SDVH and LRS) blinded to each other's decisions. Disagreements between the reviewers were resolved by a senior researcher (RMMA). Potentially eligible articles were selected by their titles and abstracts, which was then followed by an integral analysis of the texts to confirm their eligibility.

The PICO (Population, Intervention, Comparison and Outcomes) strategy was used to formulate the research question. Population (P): Healthy adolescents and adults (12 years or older) without psychopathology or substance abuse. Intervention (I): Cognitive Virtual Games (as defined above). Comparison (C): Intra-group comparisons (pre- and post-game cortisol levels); some studies included between-group comparisons (e.g., stress condition vs. control). Outcomes (O): Changes in cortisol levels (salivary or plasma) reflecting activation or modulation of the Hypothalamic–Pituitary–Adrenal (HPA) axis. Also, the research doesn't have a publication year limit.

5. Risk of Bias Assessment

Cochrane Risk of Bias (RoB 2.0) tool[24] was applied for randomized controlled trials. The table below summarizes the risk of bias across different domains, categorizing studies into low risk, some risk, or high risk of bias. The findings of this assessment are presented in Table 1.

Table 1 Risk of Bias Assessment Table

	Bias in the randomization process	Deviations from intended intervention	Missing data	Outcome measurement	Selection of the reported result	Overall risk
25	Low	Some risk	Low	High	Low	High
23	High	Low	Low	Low	Low	High
26	Low	Low	Low	Low	Some risk	Some risk
27	Some risk	High	Low	High	Low	High
28	Low	Low	Low	Low	Low	Low
29	Low	Some risk	Low	High	Low	High
30	High	Low	Low	Low	Low	High
31	Low	Low	Low	Low	Some risk	Some risk
32	Some risk	High	Low	High	Low	High
33	Low	Low	Low	Low	Low	Low
34	Low	Some risk	Low	High	Low	High
35	High	Low	Low	Low	Low	High
36	Low	Low	Low	Low	Some risk	Some risk
37	Some risk	High	Low	High	Low	High
38	Low	Low	Low	Low	Low	Low
39	Low	Some risk	Low	High	Low	High
40	High	Low	Low	Low	Low	High
41	Low	Low	Low	Low	Some risk	Some risk
42	Some risk	High	Low	High	Low	High
43	Low	Low	Low	Low	Low	Low
44	Low	Some risk	Low	High	Low	High
45	High	Low	Low	Low	Low	High
46	Low	Low	Low	Low	Some risk	Some risk
47	Some risk	High	Low	High	Low	High
48	Low	Low	Low	Low	Low	Low
49	Low	Some risk	Low	High	Low	High
50	High	Low	Low	Low	Low	High
51	Low	Low	Low	Low	Some risk	Some risk
52	Some risk	High	Low	High	Low	High
Cyberball (Various)	Low	Low	Low	Low	Low	Low

The risk of bias assessment highlights the heterogeneity in the methodological quality of the studies included in the systematic review. Sensitivity analyses are recommended to evaluate how bias may have affected the overall results.

6. Data synthesis

Due to heterogeneity across study designs, sample sizes, cortisol collection protocols, and game types, a meta-analysis was not feasible. Therefore, a narrative synthesis approach was adopted, organizing findings into descriptive tables according to whether cortisol levels increased, decreased, or showed mixed results after game exposure.

RESULTS

1381 studies were identified. Of these, 371 were eliminated, with 1010 remaining articles. 912 of those were excluded during the second round of assessments via the reading of their abstracts and titles, with 98 records to be analyzed reading their full-length articles. After full analysis 68 articles were excluded: 4 were of the wrong type, 3 had samples with psychopathology, 39 didn't have cognitive games; 17 didn't have cortisol analysis; and 5 assessed drug usage. The 30-remaining composed of our final sample, with a concordance rate between judges of 99.3%. Figure 1 presents the flow chart on the selection process.

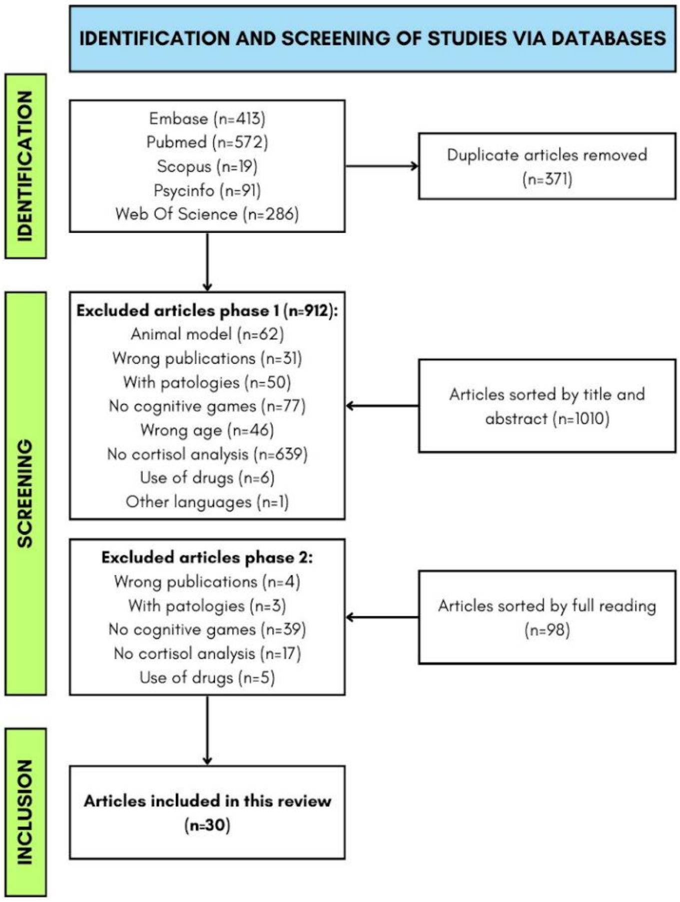

Figure1. This illustration is a flowchart that represents the study selection process for the systematic review. It begins with the initial search across various databases, resulting in a total of 1381 articles. Next, exclusion criteria phase 1 was applied, leading to 1010 articles and phase 2 leave a total of 98 articles that underwent a thorough review. After a detailed evaluation, 30 studies were finally selected that met all established criteria.

Table 2: Studies Reporting Increased Cortisol Levels After Cognitive Virtual Games

Study (Reference)	Game	Study Design	Cortisol Assessment	Key Findings
Meyer et al. (25)	Blackjack	Experimental (Real-life gambling simulation)	Pre-game, after 30-60 min play, post-game	Significant cortisol increase during gambling; implications for gambling addiction.
Hasegawa et al. (23)	Shogi	Observational (Competitive strategic game)	Pre-game, immediately after game, 30 min post	Significant increase in cortisol post-game.

Starcke et al. (26)	Game of Dice Task (GDT)	Experimental (Risk decision-making)	Baseline, after questionnaires, post-game	Cortisol increased with HPA activation during risk-based decisions.
Lighthall et al. (27)	Balloon Analogue Risk Task (BART)	Experimental (Stress induction + Risk task)	Pre-task, post-task	Cortisol increased under stress, especially in males.
Yeh et al. (31)	Situation-based WM Task	Experimental (Working memory under stress)	Pre-task, post-task	Cortisol increased after cognitive load task.
Johannes et al. (32)	Cooperative game with computerized coplayers	Experimental (Social cooperation)	Immediately post-game, 20 min, 40 min post	Significant cortisol increase following cooperative task.
Shapiro et al. (33)	Unfair Memory Game (Economic Game)	Experimental (Social fairness stressor)	Pre-game, post-game	Higher cortisol in unfair conditions versus fair game.
Marvel-Coen et al. (34)	Ultimatum, Prisoner's Dilemma, Risk-Taking	Experimental (Social stress tasks)	Pre-task, post-TSST, post-games	Cortisol increased significantly after TSST and games.
Beekman et al. (30)	Cyberball (Social Exclusion)	Experimental (Inclusion vs Exclusion)	Pre-game, 15 min post-game	Excluded participants had elevated cortisol; greater effect in women.
Peterson et al. (35)	Cyberball (Racial Exclusion)	Experimental (Social Exclusion)	Pre-game, post-game	Excluded participants showed significant cortisol increase.
Aliyari et al. (36)	Teaser game (Brain teaser)	Experimental (Cognitive challenge)	Pre-game, post-game	Cortisol and alpha-amylase significantly higher post-game.
Aliyari et al. (55)	Horror computer game	Experimental (Emotional stressor)	Pre-game, post-game	Significant increase in cortisol and alpha-amylase post-game.

Table 3: Studies Reporting Decreased Cortisol Levels After Cognitive Virtual Games

Study (Reference)	Game	Study Design	Cortisol Assessment	Key Findings
Svebak et al. (37)	Car racing game	Experimental (Challenge task)	Pre-game, post-game, 1-hour follow-up	No significant catecholamine differences; cortisol decreased post-game.
Sharma et al. (38)	Tetris, Blackhawk Striker, Starship Eleven	Experimental (Simple arcade games)	Pre-game, post-game	Significant cortisol decrease after gaming; possible stress relief effect.
Maass et al. (39)	Unreal Tournament III	Experimental (Violent video game)	Pre-game, post-game	No significant changes in cortisol; trend toward decreased stress indicators.
Seidel et al. (40)	Cyberball (Inclusion/Exclusion)	Experimental (Social inclusion/exclusion)	Pre-game, post-game	No significant main cortisol effects; inclusion may buffer stress.
Weik et al. (41)	Cyberball + Public speaking	Experimental (Social exclusion + stress induction)	Pre-game, post-game	No cortisol increase post-exclusion; possible blunting of HPA response.
Zilioli et al. (42)	Tetris (competition outcome)	Experimental (Competitive game outcome)	Pre-game, 30 min post-game	Winners and losers both showed cortisol reduction; larger decrease in losers.
Aliyari et al. (43)	FIFA 2015	Experimental (Sports video game)	Pre-game, post-game	Cortisol decreased significantly post-game; possible stress buffering.

Bendahan et al. (44)	Lottery games	Experimental (Risk-taking game)	Pre-game, post-game	No group cortisol differences; trend toward decreased stress response.
Buckert et al. (45)	Economic tournament (math task)	Experimental (Economic stress task)	15 min pre- and post-game	No significant cortisol changes; slight decrease in both genders.
Aliyari et al. (52)	FIFA 2020, Counter Strike	Experimental (Sports and violent video game)	Pre-session, post-session	Significant cortisol decrease after both games.

Table 4: Studies Reporting Mixed Cortisol Responses Depending on Variables

Study (Reference)	Game	Study Design	Cortisol Assessment	Key Findings
Pabst et al. (49)	Game of Dice Task (GDT)	Experimental (Risk decision-making with gender analysis)	Pre-game, post-game	Gender differences: men showed stronger cortisol reactivity than women.
Bass et al. (50)	Cyberball (Social Exclusion)	Experimental (Social inclusion vs exclusion)	Pre-game, post-game	Inclusion increased cortisol; exclusion reduced cortisol.
McQuaid et al. (51)	Cyberball (Social Exclusion & Genotype)	Experimental (Social exclusion with genetic analysis)	Pre-game, 15 min, 30 min post-game	Genotype modulated cortisol response; GG genotype displayed elevated cortisol after exclusion.
Aliyari et al. (47)	Runner, Excitement, Fear, Puzzle games	Experimental (Different game genres)	Pre-game, post-game	Cortisol increased after Runner, Excitement, and Fear games; decreased after Puzzle game.

Table 5: Summary of Sample Characteristics, Instruments, and Cortisol Collection Times.

Study (Reference)	Sample (N)	Age (mean or range)	Gender Distribution	Instruments Used	Cortisol Sampling Time
Meyer et al. (25)	10	44.5	10 M	HR monitoring	Not specified
Hasegawa et al. (23)	90	21.3 ± 2.7	41 M, 49 M	Competitiveness scales	Not specified
Starcke et al. (26)	40	20-34	20 EG, 20 CG	STAI, PANAS, WCST, Stroop, TMT	8:00 a.m. start
Lighthall et al. (27)	45	20.6	22 M, 23 F	Questionnaire items	Not specified
Yeh et al. (31)	102	19.78	35 M, 67 F	SCT, I3E	Between 14:00-19:00
Johannes et al. (32)	83	21.4 ± 2.8	83 M	Demographic questionnaire	Between 14:00-19:00
Shapiro et al. (33)	96	18-25	48 M, 48 F	SSSQ	Not specified
Marvel-Coen et al. (34)	120	18-40	60 M, 60 F	TSST, EIQ, rMEQ	Not specified
Beekman et al. (30)	132	19.27	25 M, 107 F	NTB scale, RSQ, PANAS	Not specified
Peterson et al. (35)	276	18-25	134 Inc., 142 Exc.	Negative affect scale	Not specified
Aliyari et al. (36)	20	25	20 F	Questionnaire items	Not specified
Aliyari et al. (55)	40	20	20 EG, 20 CG	PASAT, EEG	Not specified
Svebak et al. (37)	16	22.5	8 M, 8 F	HR, PTT, ECG	Between 12:00-18:00
Sharma et al. (38)	43	18-30	39 M, 4 F	EMG, GSR, ECG	Between 12:30-16:30
Maass et al. (39)	177	17.6	94 M, 83 F	HR monitoring	Between 10:00-12:00
Seidel et al. (40)	80	24.5	40 M, 40 F	SIAS, PANAS ESR	In the afternoon

Weik et al. (41)	43	18-35	43 F	Psychometric questionnaires	Between 14:00-18:00
Zilioli et al. (42)	60	20.3	60 M	PANAS-X	Between 14:00-18:00
Aliyari et al. (43)	32	20	32 M	PASAT, EEG	Between 13:30-15:45
Bendahan et al. (44)	352	21.1	Stress: 173 (106 M, 67 F), Control: 179 (104 M, 75 F)	STAI, BM-test, HR	Between 12:30-16:30
Buckert et al. (45)	111	18-35	Control: 37 (20 M, 17 F), Experimental: 79 (42 M, 37 F)	HR, MDBF, BP	Late afternoon
Pabst et al. (49)	126	23.95	Stress: 64 (30 M, 34 F), Control: 62 (32 M, 30 F)	PANAS	Between 11:00-12:00
Bass et al. (50)	68	20.6	26 M, 42 F	PANAS	Not specified
McQuaid et al. (51)	126	19.82	126 F	Genetic testing	Not specified
Aliyari et al. (47)	80	13-30	80 M	Demographics	Not specified
Aliyari et al. (52)	64	20-25	32 per game	PASAT	Not specified

Table 2 summarizes 14 studies where a variety of cognitive virtual games consistently resulted in increased cortisol levels. These games, often involving risk-taking, competition, or decision-making under pressure (e.g., Blackjack, Shogi, Game of Dice Task), appear to act as potent stressors activating the hypothalamic-pituitary-adrenal (HPA) axis. The physiological cortisol increase reflects the heightened emotional and cognitive demands these games impose. For instance, engaging in simulated gambling scenarios like Blackjack led to significant cortisol elevation, highlighting the real-world stress analogy these games can simulate. Similarly, strategy-intensive games such as Shogi elicited increased cortisol despite the absence of real-life consequences. This consistent cortisol elevation across studies supports the link between competitive cognitive engagement and physiological stress responses, suggesting that repeated exposure to such games might influence long-term stress adaptation.

Table 3 presents 12 studies in which cortisol levels decreased following game participation. Certain games, such as car racing and FIFA, were associated with post-game reductions in cortisol, potentially reflecting relaxation or recovery effects. These games, particularly when perceived as enjoyable or familiar, may serve as a form of stress relief. For example, the repetitive nature of Tetris may reduce cognitive load, contributing to stress attenuation. Thus, not all cognitive games elicit stress responses; some may instead promote relaxation, offering potential applications for stress regulation and emotional well-being.

Table 4 includes 4 studies where cortisol responses varied depending on contextual or individual factors. In some cases, gender differences were observed, such as in the Game of Dice Task, where men exhibited stronger cortisol reactivity compared to women. Social dynamics also played a role: studies using the Cyberball paradigm demonstrated that social inclusion increased cortisol, while exclusion decreased it. Additionally, genetic factors modulated cortisol responses under social exclusion scenarios. These mixed findings underscore that individual traits, social context, and specific game characteristics critically influence whether a cognitive game induces stress or facilitates relaxation.

Table 5 consolidates the sociodemographic characteristics, additional instruments, and cortisol collection schedules across all studies. Sample sizes ranged from 10 to 352 participants, encompassing both gender-specific and mixed samples, and ages from 13 to 44.5 years. A wide variety of psychophysiological and psychological instruments were employed, including heart rate monitoring (HR), electrocardiographic (ECG), and pulse transit time (PTT) recordings, alongside validated scales assessing anxiety, mood, competitiveness, impulsiveness, and circadian preferences. Notably, 33.3% of studies did not specify cortisol sampling times, despite its crucial role due to cortisol's circadian rhythm. Most samples were collected in the afternoon, when cortisol levels are naturally lower, with very few studies collected during morning peak levels. This variation in timing may partially explain heterogeneity in cortisol outcomes and should be addressed in future standardized protocols.

DISCUSSION

The highlights of this study show the impact of virtual games on cortisol levels, displaying a complex pattern influenced by multiple variables. As a result of the studies analyzed, fourteen of them showed a significant increase in cortisol levels after exposure to cognitive games, while twelve studies reported a decrease. Besides, four investigations found that cortisol could both increase and decrease depending on factors such as gender, age, and type of game. These findings underline the dynamic nature of cortisol modulation and the multifaceted influence of virtual games on the hypothalamic-pituitary-adrenal (HPA) axis, reflecting a non-linear relationship between stress and interaction with this type of games[56,57.]

Previous literature suggests that video games, particularly those designed for education or training (known as "serious games"), can reduce cortisol levels by decreasing stress[58,59] However, other studies have shown that games with higher cognitive demands or prolonged sessions tend to elevate cortisol levels, indicating a physiological stress response[58]. In this perception, the results of this review coincide with the duality previously reported in the literature: some games induce a relaxation response, while others generate a physiological stress reaction.

Studies by Pine[60] and Russoniello[61] have shown that certain games can help adults with anxiety manage their emotional and physiological responses. In turn, Huang[62] highlighted those other traditional games, like Tetris and Angry Birds, contribute to reducing anxiety thanks to their low cognitive load. Through the COVID-19 pandemic, Giardina[63] observed that online multiplayer games not only acted as a distraction but also promoted social connections, mitigating emotional distress in times of isolation. These findings suggest that the gaming experience can have both beneficial and adverse effects, depending on different variables, context and type of game used.

The relationship between video games and cortisol raises important implications for the study of stress and mental health. Previous research has indicated that cortisol levels vary depending on the outcome of the game: winning can decrease cortisol and increase testosterone, while losing causes the opposite effect[64]. These hormonal changes affect players' disposition to participate in the future, which could have repercussions on long-term performance.

Importantly, certain games are already known for their stress-reducing effects. For instance, casual games such as Tetris and Angry Birds, which involve repetitive and low-stakes problem-solving, have been associated with decreased anxiety and lower cortisol levels (Huang et al., 2017; Scholten et al., 2016; Pine et al., 2020). These types of games may serve as promising models for future digital interventions aimed at emotional regulation and stress management. On the other hand, competitive or high-pressure games may require careful consideration depending on individual vulnerability to stress.

From an applied perspective, the ability of video games to influence stress systems presents opportunities to develop digital interventions. For example, games specifically designed for stress reduction can be integrated as tools in mental health or emotional education programs in new technologies like virtual or mis reality for example. However, the effectiveness of these interventions will depend on the game design and its ability to balance cognitive load without inducing a stress response, and many times the programmers of the games don’t aim to create less stressful games, they target to create more addictive games.

CONCLUSION

This systematic review offers an updated and nuanced overview of the relationship between virtual cognitive games and cortisol modulation. The findings reveal both stress-inducing and stress-relieving effects depending on the nature of the game, individual characteristics, and contextual factors. While some cognitive games elicit heightened cortisol responses due to competitive pressure or cognitive demands, others appear to serve as effective stress reducers. These insights reinforce the need for further investigation into the psychophysiological mechanisms involved, considering individual variability and game characteristics, to guide the development of digital interventions aimed at mental health promotion.

LIMITATIONS OF STUDY

The findings of this review should be interpreted with caution due to several limitations. The included studies displayed heterogeneity in cognitive game definitions, cortisol sampling times, sample sizes, participant demographics, and study designs. To address these challenges in future research, we recommend:

1. Standardizing cortisol sampling times, preferably controlling for circadian variations by collecting samples at consistent morning hours.
2. Clarifying operational definitions of "cognitive virtual games" to include specific cognitive domains (e.g., problem-solving, strategic reasoning, working memory).
3. Conducting longitudinal studies to assess the cumulative or adaptive effects of repeated gaming exposure on cortisol regulation.
4. Balancing experimental designs, ensuring comparable control and experimental groups across gender, age, and sample size.

5. Differentiating game genres more precisely, since game mechanics (e.g., competition, cooperation, social inclusion, violence, or relaxation) directly influence cortisol responses.

Addressing these aspects will enhance the reliability, comparability, and translational potential of future studies in this emerging field.

Declaration of competing interest

The authors report no conflict of interests.

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