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Stress and Anxiety: contemporary biopsychosocial perspectives

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Abstract. Stress and anxiety are key public health issues arising from the interaction of biological, psychological, and social factors. While stress is a normal adaptive response, chronic exposure can disrupt homeostasis and contribute to both physical and mental health disorders. The stress response involves complex regulation of the central nervous system, endocrine pathways, and immune function, and prolonged activation—particularly of the HPA axis—may lead to systemic inflammation, cognitive impairment, and increased disease vulnerability. Psychological factors such as maladaptive cognition, perceived lack of control, and emotional dysregulation further sustain anxiety states. Additionally, social determinants including socioeconomic status, occupational pressure, trauma, and environmental stressors significantly influence individual susceptibility. Overall, contemporary research highlights stress and anxiety as multidimensional phenomena requiring an integrated biopsychosocial approach to understanding their mechanisms and health impacts.

Keywords: stress, anxiety, stressors, disorders, learning disabilities, ADHD, ASD, ICTs

Introduction

Stress and anxiety constitute some of the most significant challenges to global public health, affecting millions of individuals across all age groups and socioeconomic backgrounds. Although stress represents a natural and adaptive physiological response that enables individuals to cope with environmental demands and threats, chronic or excessive exposure to stressors may have profound consequences for both physical and mental health. In recent decades, rapid social, economic, and technological changes have intensified exposure to persistent stressors, including occupational pressure, financial instability, social isolation, uncertainty, and environmental adversity, contributing to the increasing prevalence of anxiety-related disorders worldwide.

Contemporary research demonstrates that stress and anxiety are complex multidimensional phenomena influenced by the interaction of biological, psychological, and social factors. From a biological perspective, prolonged activation of the

stress-response system—particularly the hypothalamic–pituitary–adrenal (HPA) axis and the autonomic nervous system—has been associated with immune dysregulation, systemic inflammation, cognitive dysfunction, and increased vulnerability to chronic disease. Psychological processes such as maladaptive cognition, emotional dysregulation, and perceived lack of control further contribute to the persistence and severity of anxiety states. At the same time, social determinants including trauma, socioeconomic inequality, occupational demands, and reduced social support significantly shape individual susceptibility and resilience.

The biopsychosocial model has therefore emerged as a comprehensive framework for understanding the mechanisms and consequences of stress and anxiety. By integrating findings from neuroscience, psychology, psychiatry, and social sciences, this approach emphasizes that mental health cannot be examined independently from biological functioning and environmental context. Understanding the multidimensional nature of stress

and anxiety is essential for developing effective prevention strategies, therapeutic interventions, and public health policies aimed at improving psychological well-being and overall quality of life.

The stress system

The stress response system consists primarily of the autonomic nervous system (ANS) and the hypothalamic–pituitary–adrenal (HPA) axis, which interact closely with multiple regions of the CNS to coordinate adaptive responses to stressors (Tsigos et al., 2020). Under normal conditions, these systems maintain the body's internal balance, known as homeostasis. Chronic activation or dysregulation of the stress system can lead to a maladaptive state referred to as allostasis or cacosstasis, increasing vulnerability to disease (Chrousos, 2009). Key brain regions are essential for controlling stress response. The paraventricular nucleus (PVN) of the hypothalamus is significant because it produces corticotropin-releasing hormone (CRH) and arginine vasopressin (AVP). The locus coeruleus (LC) is another crucial part, releasing norepinephrine and working in tandem with other neurons as part of the LC/NE system. These components ensure the stress system is activated when needed (Chrousos, 1998; Nicolaidis et al., 2014). The HPA axis supports the body's adaptive response to stress. It includes the hypothalamic PVN, pituitary gland, and adrenal cortex (Chrousos, 2009). PVN produces CRH and AVP, stimulating the pituitary gland to release adrenocorticotropic hormone (ACTH). ACTH circulates in the blood, prompting the adrenal cortex to produce cortisol and aldosterone. The adrenal cortex plays a central role in producing these hormones, which influence various body functions. Cortisol binds to glucocorticoid receptors, moves into the cell nucleus, and binds to specific DNA sequences called glucocorticoid response elements (GREs), regulating gene activity (Stavreva et al., 2009). This process helps control the HPA axis and brings the stress response to end when appropriate. Cortisol is secreted in a 24-hour cycle, with levels peaking early in the morning, just before waking up. This morning's surge is driven by the body's internal clock and can be heightened by the stress of awakening. When acute stress occurs, the HPA (hypothalamic-pituitary-adrenal) axis is rapidly activated, leading to a quick spike in cortisol levels. Typically, this process is moderated by a feedback loop in which cortisol circulating in the bloodstream signals the pituitary gland and hypothalamus to decrease ACTH production, helping to control and balance cortisol release (Giannakakis et al., 2019).

The ANS is composed of the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS), which work together to maintain homeostasis. The SNS is activated during stressful situations, increasing heart rate, reducing digestive activity, and dilating pupils as part of the "fight or flight" response. This activation triggers the release of adrenaline and noradrenaline from the

adrenal medulla. On the other hand, the PNS helps the body rest and recover by slowing down the heart rate, enhancing digestion, and constricting pupils, relying on the neurotransmitter acetylcholine. Overall, cortisol, adrenaline, and noradrenaline are the primary stress hormones, crucial for mobilizing energy and preparing the body to handle challenges. The balance between the SNS and PNS ensures the body can effectively respond to and recover from stress. Dysregulation of this balance can lead to health issues, highlighting the importance of a well-functioning stress system (Agorastos et al., 2018).

The Hypothalamic–Pituitary–Adrenal (HPA) Axis

The HPA axis is one of the body's principal neuroendocrine systems involved in stress adaptation. It includes the hypothalamus, the pituitary gland, and the adrenal cortex. During stress, the PVN releases CRH and AVP, which stimulate the anterior pituitary gland to secrete adrenocorticotropic hormone (ACTH). ACTH then travels through the bloodstream to the adrenal cortex, where it promotes the production and release of glucocorticoids, primarily cortisol, as well as aldosterone (Nicolaidis et al., 2014).

Cortisol is the primary glucocorticoid hormone involved in the stress response. Once released into circulation, cortisol binds to glucocorticoid receptors (GRs) located in various tissues, including the brain. The cortisol–GR complex translocates into the cell nucleus and binds to specific DNA regions known as glucocorticoid response elements (GREs), regulating gene transcription and influencing numerous physiological processes (Pratt, 1990; Stavreva et al., 2009). Through these genomic effects, cortisol helps regulate metabolism, immune responses, cardiovascular function, and cognitive processes.

In addition to glucocorticoid receptors, mineralocorticoid receptors (MRs) are also involved in stress regulation within the CNS. Furthermore, two major CRH receptor subtypes, CRH-R1 and CRH-R2, contribute to stress system modulation. CRH-R1 is primarily associated with activation of the stress response, whereas CRH-R2 appears to participate in stress recovery and adaptive regulation (Agorastos et al., 2018).

A crucial characteristic of cortisol secretion is its circadian rhythm. Cortisol levels fluctuate over a 24-hour cycle, reaching their peak during the early morning hours shortly before awakening. This rise, often referred to as the cortisol awakening response, is regulated by the body's internal biological clock and may be intensified by the stress associated with waking. During acute stress, activation of the HPA axis causes a rapid increase in cortisol secretion. Under normal circumstances, cortisol exerts negative feedback on the hypothalamus and pituitary gland, reducing CRH and ACTH production and thereby helping terminate the stress response. Stress hormones play a central role in the body's response to threatening or demanding situations.

Among the most important stress-related hormones are cortisol, adrenaline, and noradrenaline, each of which influences physical health, emotional functioning, cognition, and behavior (Giannakakis et al., 2019).

Cortisol: The Hormone of Stress, Aggression, and Depression

Cortisol is a hormone produced by the adrenal cortex and is released in response to physical or psychological stress. During stressful situations, cortisol levels increase in order to provide the body with sufficient energy to cope with danger. Besides its role in stress response, cortisol regulates essential bodily functions such as blood pressure, blood glucose levels, and inflammation. It also contributes to memory formation by strengthening fear-related memories, helping individuals respond more effectively to future threatening situations.

However, prolonged exposure to stress may lead to excessive cortisol secretion and dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis. Although cortisol normally has anti-inflammatory properties, chronic dysregulation can trigger widespread inflammation, oxidative stress, immune dysfunction, degeneration, and premature aging. Elevated cortisol levels have also been associated with reduced hippocampal volume, particularly in brain regions related to neurogenesis and neuroplasticity. Research further indicates that cortisol increases amygdala activity during fear and anxiety while weakening communication between the amygdala and hippocampus.

Moderate increases in cortisol may temporarily enhance executive functioning and self-regulation. In contrast, chronic cortisol dysregulation impairs cognitive and behavioral self-regulation and may contribute to aggressive behavior and emotional difficulties (Drigas & Mitsea, 2021).

Adrenaline: The Hormone of Stress and Alertness

Adrenaline, also known as epinephrine, is both a hormone and neurotransmitter released by the adrenal medulla in response to stress. It is responsible for initiating the body's immediate "fight-or-flight" response by producing physiological and behavioral changes that help individuals cope with stressful stimuli.

Repeated elevations in adrenaline increase blood circulation, cause vasoconstriction, and may lead to high blood pressure. Stress-related adrenaline secretion is also associated with immune dysregulation and inflammatory diseases. Furthermore, adrenaline interacts with several brain regions, including the prefrontal cortex, midbrain, and locus coeruleus, influencing dopaminergic, noradrenergic, and serotonergic activity.

Because adrenaline works closely with noradrenaline, it contributes significantly to learning and memory consolidation. However, chronic stress-induced adrenaline release may disrupt the

functioning of brain regions involved in memory and emotional regulation, such as the hippocampus, amygdala, and neocortex (Drigas & Mitsea, 2021).

Noradrenaline: The Chemical of Alertness

Noradrenaline, or norepinephrine, is a hormone and neurotransmitter primarily secreted by the locus coeruleus. It is closely associated with alertness, vigilance, attention, anxiety, and the fight-or-flight response. Chronic stress leads to sustained release of noradrenaline, resulting in sympathetic nervous system hyperactivity, disruption of bodily homeostasis, immune dysfunction, and gastrointestinal problems.

Research has connected noradrenaline dysregulation with several neurological and psychological disorders, including depression, dementia, Alzheimer's Disease, and Attention-Deficit/Hyperactivity Disorder (ADHD). Since norepinephrine is synthesized from dopamine, the two neurotransmitters share several functional characteristics. In the prefrontal cortex, noradrenaline helps regulate dopamine activity during stress (Drigas & Mitsea, 2021).

The Sympathetic and Parasympathetic Nervous Systems

When the amygdala perceives a stimulus as threatening, it activates the HPA axis, the sympathetic nervous system, and the catecholaminergic system. This triggers a cascade of hormonal responses:

- ✓ the hypothalamus releases corticotropin-releasing hormone (CRH),
- ✓ the pituitary gland releases adrenocorticotropic hormone (ACTH),
- ✓ and the adrenal glands release cortisol and adrenaline.

At the same time, the sympathetic nervous system prepares the body for action by:

- ✓ increasing heart rate,
- ✓ enhancing blood flow to muscles,
- ✓ dilating the lungs,
- ✓ increasing blood glucose levels,
- ✓ stimulating fat metabolism,
- ✓ activating sweat glands,
- ✓ and adjusting vision for distant focus.

Under normal conditions, once the perceived danger subsides, the parasympathetic nervous system restores balance and homeostasis. It promotes healing, relaxation, digestion, immune functioning, and energy conservation while reducing stress hormone levels.

The prefrontal cortex (PFC), responsible for higher cognitive functions such as attention, decision-making, emotional regulation, and self-control, is especially vulnerable to prolonged stress. Chronic stress alters the structure and functioning of the PFC, reduces brain-derived neurotrophic factor

levels, and weakens working memory, attention, and long-term memory processes.

At the same time, chronic stress strengthens the activity of the amygdala, the brain region associated with fear and emotional reactivity. Consequently, the brain becomes more sensitive to stress and less capable of logical thinking and emotional regulation. Individuals may experience reduced self-control and difficulty regulating thoughts, emotions, and behaviors (Drigas & Mitsea, 2021).

The Autonomic Nervous System

The autonomic nervous system plays a central role in maintaining physiological balance during stress. It is composed of two major branches: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS).

The SNS mediates the “fight-or-flight” response, which prepares the body to confront or escape perceived threats. Activation of the SNS increases heart rate and blood pressure, dilates pupils, inhibits digestive activity, and stimulates the adrenal medulla to release adrenaline and noradrenaline into circulation (Chrousos, 1998; Agorastos et al., 2018). These catecholamines rapidly mobilize energy reserves and enhance alertness and physical performance.

In contrast, the PNS promotes recovery and restoration following stress exposure. Often referred to as the “rest-and-digest” system, the PNS decreases heart rate, stimulates digestion, constricts pupils, and conserves energy. Acetylcholine serves as its primary neurotransmitter. The balance between sympathetic and parasympathetic activity is essential for maintaining homeostasis and ensuring efficient adaptation to changing environmental demands.

The Neurobiology of Stress and Anxiety

The stress response is primarily mediated by the hypothalamic–pituitary–adrenal (HPA) axis and the autonomic nervous system (ANS). During stressful experiences, the hypothalamus releases corticotropin-releasing hormone (CRH), stimulating the anterior pituitary gland to secrete adrenocorticotropic hormone (ACTH), which subsequently promotes cortisol production by the adrenal cortex. Simultaneously, activation of the sympathetic nervous system leads to the release of catecholamines, including adrenaline and noradrenaline, preparing the organism for the classical “fight-or-flight” response.

Acute stress responses are adaptive and evolutionarily essential because they enhance vigilance, energy mobilization, and survival. However, chronic activation of stress pathways can lead to prolonged cortisol exposure, autonomic dysregulation, and disruption of homeostasis. This cumulative physiological burden is commonly described as allostatic load, a concept referring to the long-term wear and tear on the body caused by

repeated adaptation to stressors. Recent neurobiological studies suggest that chronic stress significantly affects brain structures involved in emotional regulation and cognition, particularly the amygdala, hippocampus, and prefrontal cortex. Persistent stress exposure has been associated with impaired executive functioning, memory deficits, emotional dysregulation, and increased vulnerability to anxiety disorders and depression. Contemporary reviews further demonstrate that chronic stress may alter neural plasticity and contribute to structural and functional brain changes associated with psychiatric pathology (Girotti et al., 2024).

Anxiety itself is increasingly understood as a neurobiological and evolutionary response closely related to uncertainty and anticipation of threat. Recent neuroscientific literature emphasizes that uncertainty is one of the most powerful triggers of anxiety, activating defensive neural circuits and increasing hypervigilance, avoidance behaviors, and emotional sensitivity. Anxiety responses become maladaptive when threat anticipation persists in the absence of immediate danger, contributing to generalized anxiety, social anxiety, panic symptoms, and chronic psychological distress (Blanchard & Canteras, 2024).

Psychosocial Stressors and Social Determinants

Psychosocial stressors refer to stressful experiences that emerge from social interactions, environmental conditions, occupational demands, and sociocultural contexts. Unlike purely physical stressors, psychosocial stress depends heavily on subjective interpretation and cognitive appraisal.

Modern societies expose individuals to numerous psychosocial stressors, including financial insecurity, unemployment, academic pressure, occupational burnout, interpersonal conflict, social isolation, discrimination, trauma, and rapid social change. The digitalization of modern life has also contributed to increased psychological burden through continuous information exposure, social comparison, technological overload, and reduced work-life boundaries (Amodu et al., 2024).

Recent studies indicate that occupational stress remains one of the most significant psychosocial challenges globally. Chronic workplace stress has been associated with emotional exhaustion, reduced productivity, anxiety disorders, sleep disturbances, and depressive symptoms. Organizational environments characterized by poor psychosocial safety climates, excessive demands, low autonomy, and workplace mistreatment substantially increase psychological vulnerability (Albayrak et al., 2024).

Family and social relationships also play critical roles in stress regulation. Supportive interpersonal environments may buffer the effects of stress and enhance resilience, whereas dysfunctional family dynamics, loneliness, neglect, or social rejection may intensify emotional dysregulation and increase psychiatric risk. Research consistently demonstrates that social isolation constitutes a major psychosocial

determinant of anxiety and depression, particularly among adolescents, older adults, and vulnerable populations.

Moreover, socioeconomic inequalities significantly influence stress exposure and mental health outcomes. Individuals experiencing poverty, housing instability, food insecurity, or limited access to healthcare often exhibit higher allostatic load and increased prevalence of anxiety and stress-related disorders. Psychosocial stress therefore represents not only an individual psychological issue but also a broader societal and public health concern (Amodu et al., 2024).

The Biological and Psychological Basis of Stress

The stress response is primarily regulated by the hypothalamic–pituitary–adrenal (HPA) axis and the autonomic nervous system (ANS). During stressful situations, the hypothalamus activates the HPA axis by releasing corticotropin-releasing hormone (CRH), leading to the secretion of adrenocorticotropic hormone (ACTH) from the pituitary gland and cortisol from the adrenal cortex. Simultaneously, the sympathetic nervous system stimulates the release of adrenaline and noradrenaline, preparing the body for the “fight-or-flight” response (Tsigos et al., 2020).

Acute stress responses are adaptive and help individuals cope with environmental demands. However, prolonged activation of stress systems may lead to physiological dysregulation, known as allostatic load, which has been associated with cardiovascular disease, immune dysfunction, metabolic disorders, anxiety disorders, depression, and cognitive impairment (Chrousos, 2009).

Modern neuroscience research further demonstrates that stress is closely linked to resilience, emotional regulation, and neuroplasticity. Recent studies suggest that resilience mechanisms involve interactions between neuroendocrine responses, cognitive processing, and environmental influences. Translational neuroscience models emphasize that individual responses to stress are shaped by both biological predisposition and psychosocial context.

Psychosocial Stressors and Social Environment

Psychosocial stressors are stressful experiences arising from interpersonal relationships, social roles, occupational demands, economic difficulties, discrimination, trauma, and major life events. Unlike purely physical stressors, psychosocial stress involves cognitive appraisal and emotional interpretation of situations.

Social environment plays a crucial role in determining stress vulnerability. Factors such as unemployment, financial insecurity, workplace pressure, academic demands, family conflict, and social isolation significantly influence psychological well-being. Contemporary research highlights that modern work environments increasingly expose individuals to psychosocial hazards, including

emotional exhaustion, workplace mistreatment, bullying, and job insecurity. Such conditions are strongly associated with anxiety, depression, burnout syndrome, and reduced mental health outcomes. The concept of psychosocial safety climate (PSC) has emerged as an important protective factor in occupational settings. PSC refers to organizational policies and practices that prioritize workers’ psychological health and emotional safety. Studies indicate that supportive workplace environments can reduce stress-related disorders and improve employee well-being and resilience (Amodu et al., 2024).

Anxiety, Perception, and Cognitive Appraisal

Anxiety is closely related to stress perception and cognitive appraisal processes. Although stress refers to the body’s response to demands or threats, anxiety reflects the emotional and psychological anticipation of danger. Chronic stress exposure can alter emotional regulation systems, increase hypervigilance, and contribute to persistent anxiety states.

Importantly, modern psychological models suggest that stressful events alone do not fully explain stress-related pathology. Individual interpretation, beliefs, coping mechanisms, and previous life experiences strongly influence stress perception. Recent theoretical frameworks emphasize the role of early developmental experiences and maladaptive core beliefs in shaping long-term stress vulnerability. Negative beliefs regarding self-worth, safety, and interpersonal trust may amplify perceived stress even in the absence of immediate external threats.

Additionally, exposure to psychosocial trauma during childhood or adulthood may significantly alter neuroendocrine and immune system functioning. Studies have shown that traumatic stress is associated with chronic inflammation, immune activation, and increased risk of neuropsychiatric disorders, including post-traumatic stress disorder (PTSD), depression, and dementia. Gender differences also appear to influence physiological and psychological responses to trauma and stress (Logue et al., 2024).

Stress, Society, and Mental Health

Stress is not only an individual experience but also a public health and societal issue. Contemporary societies are characterized by rapid technological change, social instability, economic uncertainty, and increased performance expectations, all of which contribute to heightened stress levels. The COVID-19 pandemic further intensified psychosocial stress worldwide by increasing fear, social isolation, occupational instability, and mental health problems.

Social determinants such as poverty, educational inequality, discrimination, migration, and lack of social support significantly influence mental health outcomes. Individuals living under chronic socioeconomic stress often experience higher

allostatic load and reduced access to protective resources, increasing vulnerability to anxiety disorders and chronic disease.

Recent integrative reviews also support the biopsychosocial model of health, emphasizing that biological, psychological, and social factors interact dynamically in the development of disease. Chronic psychosocial stress may contribute not only to psychiatric conditions but also to systemic inflammation, immune dysfunction, and chronic medical disorders (Hensel et al., 2024).

Stress, Sleep, and Resilience

An important psychosocial dimension of stress involves sleep quality and resilience. Sleep disturbances are both a consequence and a contributor to chronic stress. Dysregulation of the HPA axis and autonomic nervous system during chronic stress may lead to hyperarousal states, insomnia, emotional instability, and impaired cognitive functioning.

Recent literature demonstrates a strong relationship between sleep quality and psychological resilience. Improved sleep appears to enhance emotional regulation, reduce stress reactivity, and strengthen adaptive coping mechanisms. Cognitive-behavioral interventions targeting sleep disorders have been associated with reductions in stress levels, depressive symptoms, and anxiety severity.

Resilience refers to the ability to adapt positively to adversity and recover from stressful experiences. Protective factors promoting resilience include social support, emotional intelligence, coping flexibility, optimism, physical activity, and healthy interpersonal relationships. Neuroscientific research increasingly highlights resilience as a dynamic process involving neurobiological adaptation, psychological flexibility, and environmental support systems (Albayrak et al., 2024).

Chronic Stress, Inflammation, and Physical Health

Contemporary research increasingly supports the existence of strong bidirectional relationships between psychological stress and physical disease. Chronic activation of the HPA axis and sympathetic nervous system may dysregulate immune functioning, alter inflammatory pathways, and contribute to the development of systemic disease. Recent reviews suggest that prolonged psychosocial stress increases pro-inflammatory cytokine production and impairs immune regulation, contributing to cardiovascular disease, autoimmune disorders, metabolic dysfunction, gastrointestinal disorders, and dermatological conditions (Soares et al., 2024).

The relationship between stress and inflammatory diseases is particularly evident in psychodermatology. Chronic inflammatory skin disorders such as psoriasis, eczema, and chronic pruritus are strongly associated with anxiety, emotional distress, and diminished quality of life. Psychological stress can exacerbate inflammatory

skin responses, while visible dermatological conditions may themselves increase psychosocial distress and social withdrawal, creating a vicious cycle between mental and physical illness.

Emerging evidence also highlights interactions between psychosocial stress and the gut microbiome. Chronic stress may alter intestinal permeability, immune signaling, and gut microbial composition, contributing to inflammatory states associated with gastrointestinal and psychiatric disorders. Recent integrative findings suggest that dysregulation of the gut-brain axis may partially explain the strong association between chronic stress, depression, anxiety, and inflammatory disease processes (Soares et al., 2024).

Anxiety Disorders and Cognitive Processes

Anxiety disorders represent one of the most prevalent categories of psychiatric illness worldwide. They include generalized anxiety disorder (GAD), panic disorder, social anxiety disorder, illness anxiety disorder, and specific phobias. These disorders are characterized by excessive fear, persistent worry, hyperarousal, and maladaptive cognitive patterns.

Contemporary models of anxiety emphasize the role of cognitive appraisal, emotional regulation, attentional bias, and threat perception. Individuals with anxiety disorders often display increased sensitivity to uncertainty, catastrophizing tendencies, and heightened attentional focus on potential threats.

Recent literature on illness anxiety disorder demonstrates how maladaptive interpretations of bodily sensations may generate persistent health-related anxiety and compulsive reassurance-seeking behaviors. The digital era has intensified these patterns through increased access to online medical information, potentially reinforcing catastrophic thinking and health anxiety symptoms (Kikas et al., 2024).

Stress-related cognitive impairment has also become an important research focus. Chronic stress exposure may impair attention, working memory, learning capacity, and executive functioning. Neurocognitive dysfunction associated with stress may negatively affect occupational performance, academic achievement, and interpersonal functioning, further increasing psychosocial burden (Girotti et al., 2024).

Technology, Digital Mental Health, and Emerging Interventions

Recent years have witnessed increasing interest in digital approaches to stress and anxiety assessment and treatment. Advances in wearable technologies, artificial intelligence, and digital phenotyping have enabled researchers to monitor physiological and behavioral indicators associated with stress responses. Digital phenotyping refers to the collection of behavioral and physiological data through smartphones and wearable devices to assess emotional states and mental health patterns.

Recent systematic reviews suggest that physiological indicators such as heart rate variability, electrodermal activity, sleep patterns, and smartphone usage behaviors may provide valuable insights into stress and anxiety detection (Choi et al., 2024).

Virtual reality (VR)-based therapies also represent a promising area in contemporary anxiety treatment research. Studies indicate that VR interventions may reduce symptoms of social anxiety, stress, and phobias by providing controlled exposure environments and immersive therapeutic experiences. Although further evidence is required, VR-assisted therapies appear increasingly effective as complementary psychological interventions (Saeed et al., 2024).

Digital mental health technologies gained particular importance following the COVID-19 pandemic, during which social isolation and healthcare limitations increased demand for remote psychological support. However, concerns remain regarding accessibility, ethical implications, overreliance on technology, and the potential psychological effects of excessive digital exposure.

Information and Communication Technologies (ICT) are increasingly linked with creativity, as modern technological developments offer innovative digital tools and platforms that allow individuals to communicate and develop ideas in creative and original ways (Galitskaya & Drigas, 2019). Within the educational field, and especially in elementary geometry education, ICT has reshaped traditional instructional practices by introducing interactive applications and personalized learning experiences that address different student needs and learning preferences (Arvanitaki & Zaranis, 2020).

The incorporation of Artificial Intelligence (AI) into educational systems has further strengthened these opportunities. Contemporary adaptive learning environments can monitor students' performance in real time and automatically modify the difficulty of activities according to each learner's progress, ensuring that students are both adequately supported and appropriately challenged throughout the learning process (Alier et al., 2024). These technological innovations have been shown to increase student motivation and participation while also improving comprehension of geometric principles and spatial concepts (Drigas et al., 2022). Through the use of virtual and interactive learning environments, students are able to manipulate and visualize geometric figures, which helps transform abstract mathematical concepts into more understandable and accessible forms (Meryansumayeka et al., 2022).

At the same time, the use of ICT and AI in education encourages collaboration among learners and supports the development of communication and teamwork skills that are increasingly necessary in modern society (Mitsea et al., 2022). These technological approaches also contribute to the

creation of inclusive educational environments by offering equal learning opportunities to students with varying abilities, experiences, and educational backgrounds (Drigas & Sideraki, 2021; Moral-Sánchez & Siller, 2022). By emphasizing creativity, flexibility, and inclusiveness, ICT-enhanced educational practices help prepare students for future academic demands and the evolving challenges of the contemporary world (Chaidi & Drigas, 2022).

Nevertheless, despite the increasing integration of AI technologies in education, several research gaps remain regarding their application in elementary geometry teaching. Additional studies are required to examine how AI-based educational tools can be adapted to suit individual learning styles, cognitive characteristics, and different learning rates, thus enabling more personalized educational pathways for students. Moreover, further longitudinal research is necessary to evaluate whether AI interventions maintain their effectiveness over time, particularly in supporting the acquisition of core mathematical and geometric skills (Alier et al., 2024). Addressing these gaps is essential to ensure that AI integration in elementary education remains both effective and accessible for all students (Polydoros et al., 2025).

Modern society is increasingly shaped by the Information Age, where digital services and technological tools have become integrated into everyday life as well as into educational policies and practices across all levels of education. As a result, teachers, trainers, and learners have numerous opportunities to utilize digital technologies in ways that support the understanding, recognition, and regulation of emotions. Through these processes, individuals may also improve their ability to manage stress and regulate stress-related hormones.

Digital technologies are available in multiple forms, including information and communication technologies (ICTs), web and mobile applications, artificial intelligence (AI), STEM-based tools, serious games, e-learning platforms, and tele-education services. These technologies can be implemented in both general and special education settings as tools for assessment, intervention, emotional support, and stress management.

ICTs, in particular, can contribute to emotional regulation and the reduction of stress by supporting educational and therapeutic interventions. Similarly, mobile applications and mobile technologies represent promising tools for large-scale interventions aimed at enhancing emotional regulation among students and the general population.

Artificial intelligence and STEM technologies are also considered powerful educational tools because they can improve learning processes while supporting the assessment and development of emotional intelligence, emotional regulation, and related emotional competencies.

In addition, serious games have emerged as an innovative educational approach for teaching digital skills, scientific knowledge, personal development, and emotional regulation. These interactive environments can help learners strengthen emotional awareness and self-management abilities in engaging and motivating ways.

E-learning and tele-education services can further support both general and special education by providing opportunities for training in emotional recognition, emotional regulation, and emotional intelligence. These digital learning environments offer flexible and accessible methods for developing socio-emotional skills.

Overall, digital technologies can enhance educational processes from an emotional and psychological perspective. When combined with emotional intelligence techniques, metacognitive strategies, mindfulness practices, and executive function training, digital tools can increase individuals' awareness of emotions, stress responses, and self-regulation strategies.

In conclusion, various forms of digital technologies — including ICTs, mobile and web applications, AI and STEM tools, virtual reality technologies, serious games, e-learning systems, and tele-education services — play an important role in strengthening stress-management abilities and promoting emotional intelligence, emotional awareness, and self-regulation skills (Bravou et al., 2022).

Stress, anxiety, AI technologies and students with Learning Disabilities

Mathematics anxiety constitutes a significant obstacle to students' academic achievement and overall engagement with mathematics. Learners who experience difficulties and consistently low performance in mathematical subjects often encounter substantial challenges in understanding and applying mathematical concepts. These challenges are frequently intensified by strong feelings of fear, stress, and emotional tension during mathematical activities, a phenomenon commonly described as “mathematics anxiety”. Traditional mathematics instruction frequently fails to address the individualized learning needs of these students, contributing to a repetitive cycle of frustration, reduced confidence, and avoidance behaviors that further reinforce academic underachievement. Consequently, the reduction of mathematics anxiety has become a major concern for both educators and researchers. Recent developments in Artificial Intelligence (AI) offer promising opportunities to address these ongoing educational challenges. AI technologies have the capacity to develop adaptive and personalized learning environments tailored to the specific needs of individual learners. Previous research has examined the relationship between mathematics anxiety and cognitive as well as executive functions, including working memory and calculation fluency, highlighting the importance of specialized interventions for improving educational

outcomes among struggling learners. Furthermore, the integration of AI into educational practices has demonstrated significant potential for promoting academic resilience and minimizing inequalities in mathematics education. AI-supported educational systems are capable of adjusting instructional content according to each student's learning pace while simultaneously providing immediate and individualized feedback. Such features may help alleviate the pressure and emotional distress commonly associated with mathematical tasks. Personalized AI-based interventions often incorporate gamification techniques, adaptive exercises, and real-time error correction, all of which have shown encouraging results in reducing mathematics anxiety and encouraging the development of a growth mindset among students. By establishing supportive and low-stress learning environments, AI technologies may assist students not only in managing anxiety but also in strengthening their resilience when facing academic difficulties. Given that a considerable proportion of classroom instruction is still devoted to repetitive tasks that could potentially be automated, the future growth and educational influence of Artificial Intelligence in Education (AIED) appears particularly significant (Lampou, 2023; Zaugg, 2024). AI has already demonstrated substantial benefits across multiple educational domains, including personalized learning, adaptive assessment systems, intelligent tutoring platforms, automated grading, virtual and augmented reality applications, predictive learning analytics, language learning support, and the promotion of accessibility and inclusion in education.

Despite these advancements, an important gap remains in the literature regarding the role of AI in reducing mathematics anxiety among students. Although numerous studies have investigated the effects of AI on academic achievement and student engagement, relatively limited research has focused specifically on its potential to address mathematics anxiety, particularly among students with special educational needs or persistent learning difficulties (Hwang & Chien, 2022).

Moreover, although AI technologies have shown considerable effectiveness in improving academic performance and participation, additional research is necessary to determine how these tools can foster motivation, engagement, emotional regulation, and resilience within diverse educational environments that present unique learning barriers and challenges (Owan et al., 2023). While AI applications appear promising in supporting academic success, their contribution to students' emotional management and psychological resilience, especially among learners experiencing mathematics-related anxiety, remains insufficiently explored and requires further scientific investigation.

The present study aims to examine the extent to which AI-based technologies can contribute to reducing mathematics anxiety and enhancing academic resilience among seventh-

grade students with consistently low mathematical performance. More specifically, this research seeks to investigate how AI-driven personalized learning environments and targeted emotional support mechanisms may address the existing gap in the literature concerning the relationship between Artificial Intelligence, mathematics anxiety, and learning difficulties among low-performing students. Through this investigation, the study aims to provide further insight into how AI technologies may contribute to the development of more inclusive, supportive, and effective educational environments for students experiencing persistent mathematical underachievement, particularly in relation to first-degree educational inequalities.

The incorporation of Artificial Intelligence (AI) into mathematics education has significantly transformed instructional approaches aimed at supporting students with mathematical learning difficulties. AI-based educational platforms improve the learning process by delivering personalized and adaptive instruction that is tailored to each student's individual abilities and educational needs, thereby enhancing mathematical performance and understanding. Intelligent tutoring systems, for example, are capable of providing immediate feedback and individualized guidance, enabling learners to address conceptual misunderstandings and gradually strengthen their confidence in mathematics (Hwang & Chien, 2022).

Furthermore, AI systems can process and analyze large amounts of educational data in order to generate individualized learning pathways that maintain appropriate levels of challenge and engagement for students (Bhutoria, 2022). Through these adaptive mechanisms, AI technologies contribute to reducing learning gaps while promoting deeper conceptual understanding and improved problem-solving abilities. As a result, AI-based educational interventions appear to play an important role in enhancing academic achievement and supporting more effective mathematics instruction (Hillmayr et al., 2020).

The Impact of AI-Based Interventions on Mathematics Anxiety

Mathematics anxiety, which is characterized by intense fear and emotional distress associated with mathematical tasks, has been widely recognized as a factor that negatively affects both students' academic performance and psychological well-being. AI-based interventions offer promising opportunities for addressing this issue by establishing supportive and low-pressure educational environments that help reduce stress and promote self-confidence among learners (Johnston-Wilder & Lee, 2024).

Many AI-supported educational systems incorporate gamification elements, including rewards, achievement tracking, and interactive activities, which encourage positive student engagement and help reframe mistakes as valuable

learning opportunities rather than indicators of failure (Johnston-Wilder & Lee, 2024). In addition, personalized feedback provided through AI tutoring systems assists students in managing negative emotions related to mathematics while simultaneously fostering the development of a growth mindset and reducing fear of failure (Soler-Dominguez et al., 2024). The adaptive characteristics of AI learning environments ensure that instruction corresponds to students' individual learning levels, thereby minimizing frustration, stress, and feelings of inadequacy during mathematical activities (Hamari et al., 2016).

The Influence of AI-Based Interventions on Academic Resilience

Academic resilience refers to students' ability to recover from setbacks, adapt to difficulties, and persist despite academic challenges. This characteristic is considered particularly important for students experiencing mathematics anxiety and learning difficulties (Johnston-Wilder & Lee, 2024). AI-supported educational applications contribute to the development of academic resilience by creating engaging, supportive, and individualized learning environments that encourage persistence and self-confidence.

Interactive AI platforms motivate students to perceive challenges as opportunities for learning and personal growth rather than as obstacles to success (Ng et al., 2024). Moreover, adaptive pacing and real-time feedback help maintain students' motivation and confidence, even when they encounter demanding mathematical tasks or repeated mistakes (Jaiswal & Arun, 2021). Through continuous guidance and personalized support, AI technologies may strengthen students' perseverance and willingness to engage with difficult academic content.

Relationships Between Cognitive Strategies, Mathematics Anxiety, and Academic Resilience

Existing research suggests that students who effectively utilize metacognitive and cognitive learning strategies are generally better equipped to regulate anxiety, maintain resilience, and achieve improved academic outcomes.

AI systems provide valuable opportunities for integrating cognitive, emotional, and motivational support within educational settings by teaching students how to regulate emotions, modify learning strategies, and persist during challenging learning experiences (Akavova et al., 2023; Akintayo et al., 2024). Studies have shown that students who use AI-supported educational tools often report lower levels of mathematics anxiety and higher levels of academic resilience due to the personalized feedback, emotional support, and adaptive learning environments these technologies provide. Consequently, the holistic integration of cognitive, emotional, and motivational support through AI-

based interventions may contribute significantly to overcoming learning difficulties and promoting long-term academic success (Polydoros et al., 2025).

Learning Disabilities, Psychosocial Disorders, Executive Functions, and Self-Regulation

Children with learning disabilities and psychosocial disorders require specialized support and targeted interventions in order to achieve positive academic, emotional, and social outcomes. Understanding the multidimensional difficulties experienced by these children is essential for promoting their overall development and well-being. Educators and mental health professionals must recognize the significant impact that psychosocial disorders may have on the academic achievement and social functioning of students with learning disabilities. By identifying the complex interactions between learning difficulties and psychosocial challenges, professionals can implement appropriate intervention strategies that support both academic progress and emotional adjustment. This is particularly important because psychosocial disorders may substantially interfere with children's cognitive, emotional, and social development. Research indicates that children with learning disabilities frequently experience difficulties extending beyond academic underachievement, including challenges related to psychological well-being and social adaptation. These difficulties often manifest through emotional, behavioral, and social problems. Studies have shown that students with specific learning disabilities are more likely to experience internalized difficulties such as anxiety, depression, and low self-esteem, while simultaneously facing external challenges associated with social interaction and behavioral regulation (Williams et al., 2006). Such difficulties may negatively affect their psychosocial development and limit opportunities for healthy social participation. Furthermore, children with learning disabilities often experience challenges in establishing and maintaining positive interpersonal relationships with both peers and adults (Sofologi et al., 2022).

Internalized Problems

Anxiety disorders are among the most prevalent mental health conditions observed during childhood and adolescence, with the average age of onset occurring around eleven years old. Research demonstrates that anxiety symptoms are particularly common among students with learning disabilities, with studies reporting that approximately seven out of ten students experiencing anxiety symptoms also present learning difficulties. Several studies have additionally indicated higher prevalence rates among boys compared to girls (Shamionov et al., 2022). Evidence from twin studies conducted by Willcutt and Pennington (2000) confirmed that children with learning disabilities demonstrate significantly higher levels of anxiety compared to children without such

difficulties. Similarly, large-scale investigations involving children with speech, language, and learning disorders revealed persistent emotional disturbances and increased rates of anxiety disorders over time, emphasizing the importance of continuous psychological support and intervention.

The relationship between learning disabilities and psychosocial disorders appears particularly complex, as students with learning disabilities are more vulnerable to anxiety, depression, social isolation, and somatic complaints (Polychroni et al., 2024). Anxiety disorders frequently coexist with depressive symptoms in this population, intensifying psychosocial difficulties and negatively affecting self-esteem. Additionally, research suggests that children with learning disabilities are more likely to experience bullying and peer rejection, factors that further contribute to emotional distress and reduced well-being. Students with learning disabilities who experience anxiety and depressive symptoms frequently demonstrate additional cognitive and emotional difficulties, including attention deficits, concentration problems, low activity levels, reduced self-confidence, sadness, emotional confusion, and impaired emotional regulation. Furthermore, physical complaints such as fatigue and somatic symptoms are highly prevalent among children with learning disabilities, negatively influencing both academic performance and overall quality of life (Sajan & Sunitha, 2018).

Externalized Problems

Behavioral difficulties represent another significant challenge among students with learning disabilities. These problems frequently involve attention deficits, impulsivity, aggressive behavior, and difficulties in socialization. Processing difficulties may impair children's ability to interpret social cues accurately, leading to maladaptive social responses and behavioral dysregulation. Anger and frustration are also commonly observed among students with learning disabilities. Social scientists suggest that these emotional reactions often arise from repeated experiences of academic failure and social rejection. Interestingly, students may express anger more openly within emotionally secure environments, particularly toward close family members such as mothers. Research conducted in Sweden demonstrated that individuals with dyslexia exhibit higher levels of aggressive behavior compared to individuals without dyslexia (Selenius et al., 2011). Repeated negative academic experiences and persistent reading difficulties may contribute to psychological distress and emotional dysregulation, potentially increasing aggressive responses and long-term psychosocial risks (Douglas & Skeem, 2005).

Self-Regulation and Self-Esteem

Self-regulation constitutes a crucial developmental process involving emotional, cognitive, and behavioral control. It encompasses

self-monitoring, goal-setting, planning, reflection, and behavioral evaluation, making it essential for academic success and psychosocial adjustment (Strauman & Hariri, 2023). Strong self-regulation skills have been associated with positive social, emotional, academic, and health outcomes. Students with learning disabilities often exhibit weaker self-regulation abilities, relying more frequently on avoidance-oriented strategies and superficial learning approaches (Kampylafka et al., 2023). Reduced self-regulation is also associated with lower academic resilience, impaired persistence, and increased vulnerability to academic failure. Digital distractions and mind wandering may further impair self-regulated learning and contribute to lower academic performance. Various interventions have been developed to strengthen self-regulation skills in special education populations. Programs focusing on academic and behavioral learning strategies, video self-monitoring techniques, biofeedback interventions, and social-cognitive approaches have demonstrated significant improvements in cognitive skills and behavioral regulation among students with learning difficulties. Self-esteem also plays a central role in the psychosocial adjustment of students with learning disabilities. High self-esteem contributes to optimism, resilience, and emotional stability, whereas low self-esteem is associated with anxiety, depression, aggression, and feelings of inferiority. Research consistently demonstrates that students with learning disabilities tend to exhibit lower self-esteem compared to their peers. Family communication patterns, parenting styles, and overall family functioning significantly influence the self-esteem and self-concept of children with learning disabilities (Homayoon & Almasi, 2021). Therefore, promoting positive self-esteem through supportive family and educational environments is essential for improving both academic outcomes and emotional well-being.

Finally, self-image, which encompasses perceptions of intelligence, personality, and physical appearance, is influenced by multiple factors including family relationships, academic performance, social experiences, and cultural expectations. Students with learning difficulties often experience discrepancies in self-image and self-esteem compared to their peers, largely due to repeated experiences of success and failure within academic environments. Understanding these multidimensional influences is essential for fostering healthy psychological development and supporting positive educational experiences among students with learning disabilities (Galitskaya et al., 2024).

Furthermore, children with Learning Disabilities (LD) are more likely to experience teasing and bullying from their peers. Peer rejection is often linked to increased anxiety and constant concern about being mocked or victimized, which can negatively affect students' concentration in the

classroom as well as their ability to acquire and retain information (Antoniou & Kirkcaldy, 2013).

Research findings concerning performance-approach goals remain inconsistent and often contradictory. Some studies indicate that these goals are not associated with deep learning strategies, especially among primary school students, while others connect them to negative outcomes such as anxiety, negative emotions, and surface-level learning strategies. Nevertheless, evidence also suggests that in demanding academic tasks, performance-approach goals may predict academic achievement, self-regulation, engagement, effort, and persistence even more strongly than mastery-approach goals, particularly among individuals with a strong need for achievement.

Based on these findings, many researchers acknowledged that performance-approach goals may also have beneficial effects and proposed revisions to achievement goal theory through the multiple-goals perspective. According to this approach, students can benefit simultaneously from both mastery and performance goals because these orientations are not necessarily incompatible, and each may contribute differently to learning and achievement. Furthermore, the contradictory findings may stem from differences in how performance-approach goals are defined. In some cases, the emphasis is placed on demonstrating competence, whereas in others it focuses more on outperforming peers and gaining favorable judgments. The aspect of normative comparison appears to stimulate greater engagement, interest, and effort among students.

In contrast, performance-avoidance goals are generally considered maladaptive because they are associated with a wide range of negative cognitive and emotional outcomes. These include self-handicapping behaviors, learned helplessness, withdrawal from learning activities, procrastination, high anxiety, surface-processing strategies, and poor academic achievement. Additionally, performance-avoidance goals are negatively related to effective self-regulation strategies and overall school performance.

Similar patterns have been observed regarding students' perceptions of classroom goal structures. Learning environments that emphasize mastery and personal improvement are associated with positive educational behaviors such as deep learning strategies, increased effort, intrinsic motivation, help-seeking behaviors, autonomy support, and positive emotions. Mastery-oriented classroom structures also predict critical thinking, metacognitive skills, school engagement, and persistence. On the other hand, classrooms focused primarily on performance and competition are linked to less adaptive behaviors, including anxiety, shame, self-handicapping, and surface-level learning, while also reducing intrinsic motivation and effective management of demanding tasks.

Students who are at risk for academic failure or who demonstrate low academic achievement often display challenging motivational and behavioral profiles. However, relatively few studies have examined personal goals and classroom goal structures among students with learning disabilities (LD) or reading comprehension difficulties (RCD). Students with LD frequently report low motivation and engagement in learning tasks, task avoidance, learned helplessness, procrastination, negative emotions, low academic self-efficacy, and limited help-seeking behaviors. Moreover, they tend to adopt higher levels of performance-avoidance goals and lower levels of mastery goals, while perceiving their classroom environments as more performance-oriented. These students also use fewer self-regulation strategies, rely more on surface approaches to learning, demonstrate reduced persistence, make less use of deep cognitive processing strategies, show deficits in metacognitive skills, and experience elevated anxiety.

A similar motivational profile is observed among struggling readers, who often demonstrate lower motivation, more negative attitudes toward reading, weaker self-regulation skills, and reduced use of deep learning strategies compared to skilled readers. Students with poor reading comprehension, in particular, tend to show deficits in motivation and working memory, limited monitoring abilities, lower use of evaluation and integration strategies, reduced school enjoyment, and higher levels of school burnout. In addition, students with reading difficulties appear to adopt performance-avoidance goals more frequently than typically achieving students.

Although the effects of performance-approach goals are still not entirely clear, some researchers argue that these goals may function more adaptively for high-risk students or for students with low perceived competence, as they are positively related to effort and academic performance. Finally, some findings emphasize the importance of mastery-oriented classroom structures for reading comprehension, whereas performance-oriented structures appear to be associated with lower engagement and less positive emotional experiences (Kampylafka et al., 2023).

Teaching is considered one of the most stressful professions due to factors such as excessive workload, difficult classroom conditions, problematic interactions with students, constant curriculum reforms, administrative difficulties, low student motivation, and insufficient governmental support. Research conducted across different countries has consistently shown that occupational stress is associated with reduced job satisfaction among teachers. Specific stressors that contribute to lower job satisfaction include heavy workload, relationships with students and colleagues, students' academic progress, and lack of social support. High levels of stress may negatively affect the quality of teaching and create feelings of professional and social insecurity, while the inability to cope

effectively with stress and dissatisfaction may eventually lead teachers to leave the profession.

In the Greek educational context, teachers have experienced particularly high stress levels due to the prolonged economic crisis. Studies indicate that Greek teachers have had to deal with stressors related to sudden organizational reforms, salary reductions, evaluation procedures, and job insecurity. At the same time, Greece has experienced significant immigration waves during the last two decades, increasing the number of non-Greek-speaking students who require individualized or small-group language support. Meeting these educational needs may further increase teachers' stress and burnout levels. Additionally, teachers often report inadequate training and insufficient educational materials for supporting students with disabilities. Intercultural classrooms are also frequently perceived as especially demanding by teachers and school leaders, although research directly examining these factors remains limited.

Within the field of special education, teachers are expected to manage challenging student behaviors, low academic performance, and high family expectations. Research findings regarding stress and job satisfaction among special education teachers remain inconclusive. Although the percentage of students with special educational needs continues to increase, state support and educational provisions remain insufficient. Furthermore, special education teachers in Greece face additional challenges due to the unclear definition of their professional roles and the ambiguity surrounding inclusive education practices. These difficulties may negatively influence their professional identity and attitudes toward inclusion, particularly regarding students with severe disabilities. Earlier studies also questioned the way students with special educational needs are grouped in Greek schools, as some disabilities are viewed as more suitable for mainstream education than others, potentially reinforcing school segregation.

Based on these organizational and educational challenges, the study aimed to investigate the main sources of occupational stress and job satisfaction among both mainstream and special education teachers. More specifically, the research sought to identify the stressors and self-efficacy factors that predict teachers' job satisfaction and to examine whether self-efficacy mediates the relationship between occupational stress and job satisfaction. Job satisfaction refers to the sense of fulfillment individuals derive from their professional activities and is generally defined as positive attitudes toward one's job role. In the case of teachers, job satisfaction reflects their emotional responses to teaching tasks and the profession itself. Sources of teacher job satisfaction can be divided into three categories: intrinsic factors, such as teaching itself and interaction with students; extrinsic factors, including educational reforms, negative media exposure, and the low social status

of teachers; and school-related factors, such as relationships with principals, colleagues, students, and parents.

Research findings on mainstream teachers' job satisfaction are mixed. Some studies suggest that teachers are generally satisfied with intrinsic aspects of their profession, including instruction, interaction with students, and opportunities for professional development, while dissatisfaction is often associated with salary, evaluations, and poor working conditions. Other studies indicate that organizational factors, such as positive school climate, supportive leadership, and harmonious relationships with colleagues, are also strong predictors of job satisfaction. Studies conducted in Greece have shown that primary school teachers are generally satisfied with school administration, relationships with colleagues, and the teaching profession itself.

Findings regarding special education teachers are also contradictory. Some studies in Greece report moderate to high levels of job satisfaction related to the teaching profession, school administration, and work engagement, as well as lower levels of stress and anxiety. In some cases, special education teachers report high professional quality of life despite inadequate training and pressure from families. However, other studies indicate that special education teachers may experience heavier workloads, underestimate the challenges of the teaching process, and feel more dissatisfied than mainstream teachers, especially when working with students who display severe emotional and behavioral difficulties (Kampylafka et al., 2023).

Overall, the literature suggests that special education teachers often report higher job satisfaction than mainstream teachers, mainly because of the nature of their profession. Nevertheless, organizational factors such as school administration and working conditions may still contribute to dissatisfaction in special education settings, highlighting the need for further research into these discrepancies. Occupational stress has consistently been linked to low job satisfaction, professional burnout, and teacher attrition. Some studies identify occupational stressors as the strongest predictors of job dissatisfaction among teachers. At the same time, positive relationships with colleagues and supportive school environments appear to reduce stress and increase commitment and satisfaction. Although Greek mainstream teachers report lower stress levels compared to some European counterparts, they also express feelings of inadequacy regarding the education of students with special needs due to insufficient training. Stress among special education teachers is often associated with students' individual difficulties, inclusive education challenges, poor working conditions, and excessive workload. Nevertheless, some studies suggest that mainstream teachers actually report higher stress levels and stronger self-

efficacy beliefs compared to special education teachers, possibly because they face more demanding classroom diversity, behavioral issues, time pressure, paperwork, and bureaucratic responsibilities.

Teacher self-efficacy has been positively associated with job satisfaction. Teachers who perceive themselves as capable and effective tend to be more enthusiastic, more committed to their profession, and more willing to apply innovative teaching strategies. Self-efficacy also appears to reduce professional burnout and strengthen job satisfaction. Furthermore, research suggests that self-efficacy may mediate the relationship between occupational stress and job satisfaction, meaning that stronger self-efficacy beliefs can lessen the negative impact of stress on teachers' professional well-being. However, according to the authors, there is still limited evidence regarding this mediating role specifically among special education teachers. (Polychroni et al., 2025).

Metacognition, Mindfulness, and Self-Regulation

Metacognition refers to higher-order self-regulatory abilities that allow individuals to monitor, regulate, and adapt their thoughts, emotions, and behaviors. It involves recognizing functional and dysfunctional mental states and developing effective coping strategies. Executive functions located in the prefrontal cortex play a crucial role in metacognitive functioning.

Training metacognitive skills strengthens the prefrontal cortex and improves the ability to regulate stress responses and emotional reactions. According to some researchers, metacognition closely resembles mindfulness because both emphasize self-awareness and conscious self-regulation. Mindfulness practices and meditation have been shown to reduce stress hormones such as cortisol and adrenaline while increasing relaxation-related neurochemicals including serotonin, melatonin, endorphins, and gamma-aminobutyric acid (GABA). Moreover, mindfulness enhances connectivity among important brain regions such as the thalamus, hypothalamus, hippocampus, prefrontal cortex, and amygdala. These neural improvements support emotional balance, cognitive flexibility, self-regulation, and conscious control over the autonomic nervous system (Drigas & Mitsea, 2021).

Clinical research has demonstrated that mindfulness can positively influence both mental and physical health in adults and children, including healthy individuals and patients with various medical conditions. Studies indicate that higher levels of trait mindfulness, which can be strengthened through mindfulness-based interventions, are associated with improved psychological well-being. Mindfulness techniques appear to provide therapeutic benefits for individuals with psychiatric disorders, including moderate improvements in people experiencing psychosis. Such interventions may also increase

mindfulness skills, reduce excessive worry, and function as a preventive strategy against the development of mental health difficulties.

A variety of exercises have been designed to cultivate mindfulness, often supported through guided meditation. These techniques promote self-awareness and body awareness and are generally beneficial for individuals with limited awareness of their emotions or physical state. However, for highly self-focused individuals, they may occasionally trigger anxiety, emotional distress, flashbacks, pain, or even substance misuse (Britton & Willoughby, 2019). One common mindfulness practice involves sitting upright on a chair or cushion with closed eyes while focusing attention on the natural rhythm of breathing, either near the nostrils or in the abdomen. The goal is not to control the breath but simply to observe it naturally (Kabat-Zinn, 2013). When distracting thoughts arise, practitioners are encouraged to notice them without judgment and gently redirect attention back to the breath.

Another technique is body scan meditation, in which attention is systematically directed to different parts of the body while observing present-moment sensations. Mindfulness can also involve awareness of sounds, thoughts, emotions, and behaviors occurring in the present. Kabat-Zinn's well-known mindful eating exercise, which involves slowly and consciously tasting a raisin, is intended to reconnect individuals with internal sensations of hunger and fullness, thereby encouraging healthier eating habits (Kabat-Zinn, 2013).

Additional mindfulness approaches include yoga practices performed with conscious awareness of bodily sensations and walking meditation (Kabat-Zinn, 2013).

Although the effects of mindfulness interventions have been extensively studied, the mechanisms that make individuals more or less mindful remain less understood. Meta-analyses show that mindfulness practice increases mindfulness levels compared with active control groups, although the difficulty of accurately measuring mindfulness may partly explain the findings. Evidence also suggests that mindfulness may depend more on current and continuous practice than on the total years of experience. Bergomi et al. (2015) found that self-reported mindfulness was strongly associated with ongoing meditation practice rather than accumulated experience over time.

Some studies have explored additional mechanisms. One investigation viewed mindfulness as a process involving competition for attention. Findings showed that mindfulness was associated with intentional efforts to remain mindful, positive emotional states, and lower feelings of being rushed or overwhelmed. Research also suggests a reciprocal relationship between positive mood and mindfulness: feeling good can increase mindfulness, while mindfulness itself can improve mood (Gotink et al., 2016).

In recent years, mindfulness-based approaches have become increasingly integrated into these treatments due to their positive effects on the difficulties experienced by adults with ADHD and depression. The effectiveness of these interventions depends heavily on the expertise of trained psychologists and psychotherapists, particularly those experienced in treating adults with ADHD and leading mindfulness- or dialectical behavior therapy-based groups.

One major mechanism linking ADHD and depression is emotional regulation, which involves the internal and external processes responsible for initiating, inhibiting, maintaining, and managing emotional reactions and attention-related responses (Durbin & Shafir, 2008; Feng et al., 2009). Difficulties in emotional regulation are closely associated with the development of depression and are commonly observed in individuals with ADHD. Research has shown that these difficulties may appear before depression develops, highlighting the importance of early identification and intervention (Moraiti et al., 2023).

Self-management includes several key components, such as setting goals, monitoring and recording one's own behavior, and providing self-reinforcement. These strategies encourage greater independence in the classroom by transferring the responsibility for behavior management from the teacher to the student. Research has shown that self-management can significantly enhance independent functioning, even allowing some students to function successfully without the constant support of an assistant and with reduced reliance on the teacher. As students become less dependent on adults, they gain more opportunities to interact with classmates and participate actively in classroom activities. Additional studies have reported similar positive outcomes, including improvements in social skills, peer interactions, and independent work abilities among students with Autism through the use of self-management techniques (Moraiti et al., 2023).

Neurophysiological Stress, Anxiety and ASD

In modern society, stress is considered one of the major contributors to physical and mental health problems. Although moderate stress can sometimes enhance adaptation and performance, prolonged stress may significantly impair an individual's overall functioning and well-being. Stress emerges when a person perceives a real or potential threat that requires rapid behavioral adjustment. The nervous system plays a crucial role in identifying danger and regulating the body's physiological and behavioral responses to stressful situations.

The brain demonstrates substantial neuroplasticity in response to stress and experience, especially during development. Processes such as synaptic pruning, dendritic remodeling, and neuronal replacement are influenced by stressful experiences. Chronic stress can disrupt brain circuits involved in

mood regulation, anxiety, cognition, and judgment, leading to emotional and behavioral difficulties. In addition, stress affects the body through immunological, metabolic, autonomic, and neuroendocrine mechanisms.

The body's stress response involves several interconnected systems, particularly the autonomic nervous system (ANS) and the hypothalamic-pituitary-adrenal (HPA) axis. During stressful situations, catecholamines such as norepinephrine and epinephrine are rapidly released, while the HPA axis regulates glucocorticoids such as cortisol. The stress response begins when the hypothalamus secretes corticotropin-releasing hormone (CRH), which stimulates the pituitary gland to release adrenocorticotropic hormone (ACTH). ACTH then triggers cortisol secretion from the adrenal glands. Cortisol contributes to the stress response by influencing both physiological and behavioral adaptation.

Recent research highlights the important role of the gut microbiome in communication with the brain. The gut-brain axis represents a bidirectional communication system involving neural pathways, hormones, cytokines, and neuropeptides. Through this system, the gut microbiota influences digestion, emotional regulation, motivation, and higher cognitive functioning.

The microbiome is also essential for normal brain development and adult brain functioning. It contributes to neuroplasticity, neurogenesis, and microglial activation. Furthermore, the microbiome affects the structure and functioning of the amygdala, a brain region strongly associated with fear, anxiety, emotional learning, and stress responses. Disruptions in amygdala functioning have been linked to several neuropsychiatric conditions, including Autism Spectrum Disorder (ASD).

Additionally, gut bacteria contribute to the production and regulation of neurotransmitters such as serotonin, dopamine, GABA, histamine, and acetylcholine. These processes occur through the coordinated action of the autonomic, enteric, neuroendocrine, and HPA systems.

Stress and Early Brain Development

Psychosocial stress experienced early in life is strongly associated with the development of anxiety and depressive disorders, as well as cognitive and behavioral difficulties. Children exposed to chronic stress frequently demonstrate impairments in language, attention, memory, executive functioning, and cognitive flexibility. They are also more likely to interpret social cues negatively, experience academic difficulties, and display behavioral problems (Pergantis et al., 2025).

Research suggests that early stress may alter brain structure, particularly in the hippocampus and prefrontal cortex. Reduced hippocampal volume has been associated with abnormal cortisol secretion and dysregulation of the HPA axis.

Chronic stress and childhood maltreatment may therefore negatively influence both brain development and emotional regulation.

Studies using structural and functional MRI have demonstrated that cumulative stress is associated with reduced prefrontal cortex volume and poorer working memory performance. Other findings indicate that parental stress may influence adolescents' brain activation patterns, particularly within the medial prefrontal cortex, which is involved in emotional regulation and stress processing. Furthermore, traumatic experiences during childhood and adolescence have been associated with alterations in brain structures such as the hippocampus, amygdala, and prefrontal cortex. Adolescents with Post-Traumatic Stress Disorder (PTSD) often show abnormal development of prefrontal brain regions and altered connectivity between the prefrontal cortex, hippocampus, and amygdala.

ASD, Sensory Modulation Disorder, and Stress

Sensory Modulation Disorder (SMD) is widely recognized as one of the major sensory-processing difficulties affecting individuals with ASD. Research comparing children with ASD, children with SMD, and typically developing children has revealed substantial differences in sensory processing and stress reactivity.

Children with ASD often display atypical sensory behaviors, including sensory under-responsiveness, sensory-seeking behaviors, and hypersensitivity to sensory stimuli such as sounds, touch, taste, and smell. Hearing and touch appear to be particularly affected. These sensory-processing difficulties are closely related to emotional dysregulation, social difficulties, and reduced adaptive functioning.

Studies also show that children with ASD frequently experience increased anxiety and physiological stress responses during everyday situations such as social interactions, medical procedures, or dental visits. Sensory-processing difficulties are strongly associated with behavioral distress, social participation difficulties, and repetitive behaviors.

Research further indicates that sensory symptoms in ASD vary depending on cognitive functioning levels. Children with ASD generally score higher on measures of sensory-processing dysfunction than typically developing children, although sensory profiles may differ between high-functioning and low-functioning individuals. Psychological stress can be measured through self-report questionnaires, behavioral observations, and physiological assessments. Common types of stress examined in research include traumatic events, chronic stress, major life events, and early-life stress exposure.

Three major approaches to stress assessment have been identified:

- ✓ the epidemiological approach, which focuses on stressful life experiences,
- ✓ the psychological approach, which examines individuals' perceptions of stress,
- ✓ and the biological approach, which investigates physiological dysregulation caused by stress.

Technological advancements have improved real-time stress monitoring through mobile devices and wearable technologies. These systems often combine physiological sensors with machine learning algorithms to assess stress responses continuously.

Common neurophysiological stress measurements include:

- galvanic skin response (GSR),
- ✓ electromyography (EMG),
- ✓ skin temperature,
- ✓ heart rate,
- ✓ heart rate variability (HRV),
- ✓ electrocardiography (ECG),
- ✓ salivary cortisol levels,
- ✓ electrodermal activity (EDA),
- ✓ and respiratory sinus arrhythmia (RSA).

Measuring Stress in Individuals with ASD

Individuals with ASD generally demonstrate higher levels of neurophysiological stress and anxiety compared to neurotypical individuals. Stress assessment in ASD typically includes:

- ✓ physiological measurements,
- ✓ self-report questionnaires,
- ✓ parent or caregiver reports,
- ✓ or combinations of these approaches.

Several studies have measured cortisol levels, heart rate variability, electrodermal activity, skin temperature, and autonomic nervous system functioning in individuals with ASD during stressful situations. Findings suggest that children with ASD often display distinct neuroendocrine responses to stress, particularly in social situations.

For example, some studies found reduced cortisol responses following social stress tasks among high-functioning children with ASD, despite similar sympathetic and parasympathetic activation compared to neurotypical children. Other studies demonstrated that children with ASD show greater behavioral and physiological distress during dental procedures and other stressful environments, particularly when sensory-processing difficulties are present (Pergantis et al., 2025).

Researchers have also used various questionnaires to evaluate stress and anxiety in ASD populations, including the Perceived Stress Scale, Stress in Children Questionnaire, Adjusted Stress Survey Schedule, and other ASD-specific stress assessment tools. Finally, heart rate variability and emotional dysregulation measures have increasingly been used to examine stress regulation among adolescents with ASD, helping

researchers better understand the relationship between autonomic functioning, sensory processing, emotional regulation, and anxiety in this population. (Pergantis et al., 2025).

Students with learning disabilities (LD) often face difficulties in processing information, which increases their vulnerability to emotional dysregulation and anxiety. Research indicates that many of the academic and social challenges experienced by students with LD and ADHD are connected to weaknesses in self-regulation and executive functioning processes. In addition, students with LD and emotional or behavioral disorders are more likely to develop internalizing problems such as anxiety and depression. Anxiety has a significant negative impact on learning because it disrupts attention and overloads working memory, leading to less efficient information processing. Worry, especially during examinations, reduces working memory capacity and contributes to poorer academic performance. Students with anxiety frequently demonstrate lower achievement, weaker self-efficacy, and a poorer self-concept. Studies also show that students with LD often rely on avoidance coping strategies when dealing with academic stress. Compared to students without LD, they are less likely to seek social support from peers and more likely to use cognitive avoidance. Adolescents and adults generally adopt such avoidance strategies when they feel unable to cope effectively with stress. Test anxiety is particularly common among adolescents with LD, who often report higher trait anxiety, more psychosomatic complaints, and lower self-esteem. Several interventions have been found effective in reducing anxiety and improving executive functioning skills. Cognitive-behavioral programs that combine progressive muscle relaxation, guided imagery, self-instruction training, and study skills training have been shown to reduce test anxiety successfully.

Mindfulness-based interventions, such as Mindfulness Martial Arts (MMA), help students increase self-awareness, emotional tolerance, calmness, and acceptance of distress. Similarly, Self-Regulated Strategy Development (SRSD) has been associated with improvements in planning, organization, brainstorming, self-monitoring, revising strategies, and other executive functioning skills. Research further supports a strong neuropsychological connection between emotional maladjustment and learning disabilities. High anxiety during reading tasks interferes with the phonological loop and increases demands on working memory. Likewise, math anxiety negatively affects mathematical achievement through its impact on verbal working memory. Children with mathematical learning disabilities often display anxiety specifically related to mathematics learning and assessment (Zografou & Drigas, 2022).

Additional studies reveal that students with LD experience more cognitive interference and inattention during examinations. Anxiety and

depression are also associated with increased worry, which disrupts complex working memory processes and lowers academic performance.

Students with LD tend to use different learning strategies compared to their nondisabled peers. They often prefer oral or visual explanations instead of written methods and frequently feel more stress, uncertainty, frustration, and helplessness during exams. Finally, research on children with dyslexia suggests that deficits in phonological working memory contribute to difficulties in learning exceptional words. Positive emotional states, however, may improve cognitive organization and help students process and integrate information more effectively (Zografou & Drigas, 2022).

Importantly, resilience may mitigate the physiological consequences of stress by moderating HPA axis activation and reducing chronic inflammatory responses. Preventive mental health approaches increasingly focus on strengthening resilience through psychological interventions, mindfulness practices, stress management programs, and community-based support systems (Albayrak et al., 2024).

Conclusion

The psychosocial dimensions of stress and anxiety reflect the intricate interaction between biological systems, cognitive processes, emotional regulation, social environments, and cultural influences. Contemporary scientific evidence clearly demonstrates that stress is not merely a physiological reaction but a multidimensional phenomenon deeply embedded within interpersonal, occupational, environmental, and societal contexts.

Chronic psychosocial stress contributes significantly to the development of anxiety disorders, cognitive dysfunction, immune dysregulation, inflammatory disease, and reduced quality of life. Advances in neuroscience and psychosocial research increasingly support integrative biopsychosocial models that recognize the interconnectedness of mental and physical health.

At the same time, modern research highlights the importance of resilience, social support, and early intervention in reducing stress-related morbidity. Emerging technologies, including digital phenotyping and virtual reality therapies, may offer innovative approaches for future mental health care. Nevertheless, addressing the psychosocial burden of stress also requires broader societal strategies aimed at reducing inequality, promoting supportive environments, improving occupational conditions, and strengthening public mental health systems.

Understanding the psychosocial dimensions of stress and anxiety is therefore essential not only for clinical practice and scientific research but also for developing more comprehensive and humane approaches to mental health promotion in contemporary society.

The stress system is a highly integrated neuroendocrine network designed to maintain homeostasis and promote survival during challenging situations. Through the coordinated actions of the HPA axis and the autonomic nervous system, the body adapts to both acute and chronic stressors by regulating hormonal, metabolic, cardiovascular, and behavioral responses. Although stress responses are essential for adaptation and survival, chronic activation of these systems may lead to significant physiological dysregulation and increased susceptibility to disease. Understanding the mechanisms underlying stress physiology is therefore crucial for improving the prevention and treatment of stress-related disorders.

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