THE COGNITIVE DECLINE OF GENERATION Z: TECHNOLOGICAL DEPENDENCE, DIGITAL OVEREXPOSURE AND THE HISTORIC COLLAPSE OF PISA PERFORMANCE

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ABSTRACT

The 2022 Programme for International Student Assessment (PISA) revealed the most substantial global decline in student academic performance since its creation, with unprecedented reductions across mathematics, reading, and science competencies among OECD countries. Although the COVID-19 pandemic exacerbated disruptions to learning, the OECD notes that downward trends were already evident before 2018, signaling structural drivers rather than transient effects. This article argues that the cognitive decline observed among Generation Z is intrinsically linked to the unprecedented digital environment surrounding their development - marked by chronic exposure to smartphones, algorithmic social media platforms, search engines, streaming services, and, more recently, generative artificial intelligence. These technologies simultaneously ***extend*** *human capacities while* ***eroding*** *foundational cognitive functions such as attention, deep reading, working memory, executive control, and metacognitive reasoning. Integrating McLuhan's theory of technological extension and obsolescence, Desmurget's neurodevelopmental critique of screen overexposure, Haidt's sociopsychological model of the "great rewiring of childhood," and empirical findings of PISA 2022, the article presents a comprehensive framework explaining the mechanisms linking digital immersion to academic decline. The analysis demonstrates that the digital ecology of Generation Z fundamentally reshapes cognitive and motivational systems, producing the widespread learning deficits documented internationally. The article concludes with recommendations for anticipatory governance, educational policy reform, and multi-level interventions aimed at safeguarding cognitive development in an era of deep technological saturation.*

KEYWORDS

Generation Z; PISA 2022; cognitive decline; technological dependence; McLuhan; Desmurget; Haidt; digital hyperconnectivity; generative artificial intelligence; academic performance.

1. INTRODUCTION

The early twenty-first century has witnessed a profound reconfiguration of childhood, adolescence, and human cognition. Generation Z - those born roughly between 1995 and 2012 - has grown up in an environment characterized by constant digital connectivity, algorithmically curated social media, ubiquitous smartphone access, and the rapid emergence of artificial intelligence (AI) systems capable of automating cognitive tasks. While earlier generations interacted with technology intermittently and instrumentally, Generation Z is immersed in a digital ecosystem that permeates every dimension of life: education, social relationships, entertainment, identity formation, and self-perception.

At the same time, international assessments reveal an alarming decline in academic performance among adolescents. The 2022 edition of the Programme for International Student Assessment (PISA) - the largest comparative measure of educational achievement worldwide - documented the steepest drop in mathematics, reading, and science scores since the program's inception in 2000. Across OECD countries, reading scores declined by approximately 10 points and mathematics scores by nearly 15 points compared to 2018, equivalent to three-quarters of a school year of learning loss. Importantly, the OECD report underscores that these negative trends **predated the COVID-19 pandemic**, indicating enduring structural drivers rather than temporary disruptions.

This paradox raises a central research question: **How is it possible that the most digitally connected, informationally saturated generation in history is also the lowest performing in core academic competencies?**

To explore this question, this article advances the thesis that the cognitive, emotional, and behavioral consequences of digital hyper exposure - amplified by smartphones, social media, algorithmic platforms, and AI - constitute a major structural factor driving academic decline.
Four theoretical pillars structure the analysis:

1. **McLuhan's (1964) Media Theory**, which posits that technologies extend human capacities while simultaneously obsoleting others, providing an explanatory lens for cognitive erosion driven by digital media.
2. **Desmurget's (2019) Neurocognitive Critique**, documenting the negative developmental effects of excessive screen exposure on attention, language, memory, and executive function.
3. **Haidt's (2024) "Great Rewiring of Childhood"**, showing how smartphones and social media reconfigured developmental patterns, triggering a global mental health crisis that undermines motivation and learning.
4. **OECD PISA 2022 Empirical Data**, providing large-scale evidence linking digital distraction, device overuse, and reduced deep reading to declines in academic performance.

By integrating these perspectives, the article develops a comprehensive explanatory framework for the cognitive, developmental, and academic crisis affecting Generation Z.

2. LITERATURE REVIEW

The literature review synthesizes research from media theory, neuropsychology, sociology, and educational science. It demonstrates that Generation Z's cognitive decline emerges from the interaction of three reinforcing forces:

1. Technological cognitive restructuring (McLuhan).
2. Neurocognitive impairment from screen overexposure (Desmurget).
3. Sociopsychological vulnerability driven by smartphone-based development (Haidt).

This multidisciplinary foundation supports the argument that the digital ecosystem is reshaping the cognitive architecture required for academic success.

2.1. Technology as Human Extension According to McLuhan

Marshall McLuhan's seminal work *Understanding Media* (1964) argues that every medium should be analyzed not by its content but by its **structural transformations of human cognition and perception**. According to McLuhan, technologies function as **extensions** of human faculties: the wheel extends the foot, the book extends memory, and electronic media extend the nervous system.

However, technological extension comes at a cost. McLuhan's **Laws of Media**, formalized as a **tetrad**, explains that each new technology simultaneously:

1. **Enhances** certain human abilities,
2. **Obsoletes** others,
3. **Retrieves** older patterns of behavior, and
4. **Reverses into** negative effects when pushed to extremes.

This conceptual model is essential for understanding the digital ecosystem that shapes Generation Z's cognitive development. Digital technologies - smartphones, social media, search engines, algorithmic feeds, and AI - extend communication, information access, and productivity, but they also obsolete crucial cognitive skills: sustained attention, deep reading, long-term memory, independent reasoning, and metacognition.

The following matrix presents McLuhan's tetrad applied to contemporary digital technologies.

McLuhan's Tetrad Applied to Digital Technologies Used by Generation Z

Tetrad Dimension	Guiding Question	Specific Impacts of Digital Technologies on Generation Z
Enhancement	What does technology enhance?	Instant access to information; permanent connectivity; accelerated communication; multitasking capacity; immediate content creation and dissemination; cognitive automation through AI systems.
Obsolescence	What does technology render obsolete?	Sustained attention; deep reading; long-term memory; independent reasoning; analytical processing; in-person social interaction and play; patience; emotional regulation; attentional self-control.
Retrieval	What does the technology retrieve?	Amplified orality; micro-narratives; fragmented communication; digital tribalism; horizontal peer-driven sociability; public reputation mechanisms similar to pre-modern social surveillance (likes, followers, instant feedback).
Reversal	What does the technology reverse into when pushed to extremes?	Chronic anxiety; digital dependency; social withdrawal; loss of cognitive autonomy; attentional collapse; ideological polarization; information overload; substitution of critical thinking with AI-based cognitive outsourcing.

Note. This matrix applies McLuhan's (1964) Laws of Media - enhancement, obsolescence, retrieval, and reversal - to contemporary digital technologies shaping the cognitive and developmental environment of Generation Z, including smartphones, social media, search engines, algorithmic platforms, and generative artificial intelligence.

Discussion

When applied to smartphones, social media, and algorithmic platforms, the tetrad reveals a powerful contradiction:**digital technologies enhance informational access while simultaneously eroding the cognitive foundations required to use the information productively.**

This paradox helps explain why Generation Z, despite unprecedented informational abundance, performs worse on PISA assessments that require:sustained reasoning, deep comprehension, analytical problem-solving, and the integration of complex information.

McLuhan's framework demonstrates that digital environments do not merely deliver content - they **reshape cognitive architecture**. They promote speed, fragmentation, novelty seeking, and shallow processing, displacing the slower, deeper, and reflective cognitive modes essential for academic achievement.

Thus, the McLuhanian perspective indicates that the decline in PISA scores is not an isolated educational problem but a **civilizational cognitive shift** driven by pervasive media environments.

2.2. Neurocognitive Effects of Digital Overexposure: Desmurget's Contribution

Michel Desmurget's *La fabrique du crétin digital* (2019) provides one of the most rigorous neuroscientific critiques of early and excessive exposure to digital devices. Synthesizing decades of research from cognitive neuroscience, developmental psychology, and epidemiology, Desmurget demonstrates that screen overuse exerts profound negative effects on children's and adolescents' cognitive development - effects directly relevant to the academic decline captured in PISA assessments.

2.2.1. Disruption of Attention and Executive Function

One of Desmurget's central insights concerns the **fragmentation of attention** produced by digital environments. Frequent interruptions, notifications, and rapid content switching weaken the brain's capacity for: sustained attention, inhibition control, goal-directed behavior, and executive planning.

These functions are essential for academic performance, particularly in mathematics and reading comprehension, which require prolonged cognitive engagement.

Desmurget documents that adolescents with high levels of digital multitasking display lower working memory capacity, impaired flexible thinking, and increased distractibility.

PISA 2022 results align with these findings - students distracted by digital devices or by classmates using smartphones score significantly lower across all domains.

2.2.2. Impaired Language Development and Reading Proficiency

Language acquisition and reading comprehension depend on deep, linear processing of text. However, digital media encourage rapid skimming, superficial reading, and reliance on multimedia stimuli. Desmurget shows that screen overexposure compromises vocabulary acquisition, narrative comprehension, syntactic processing, and inferential reasoning.

These limitations correlate directly with PISA's documented drops in reading proficiency, especially in tasks requiring interpretation of complex written material, evaluation of evidence, and integration across textual sources.

2.2.3. Working Memory and Mathematical Reasoning

Mathematics achievement is strongly associated with working memory capacity, mental manipulation of symbols, and inhibition control. Desmurget cites multiple studies demonstrating that adolescents who engage heavily in social media and high-frequency screen use perform worse in arithmetic reasoning, symbolic manipulation, algebraic thinking, and problem-solving under time pressure.

Similarly, PISA 2022 indicated that students with heavy leisure screen use scored substantially lower in mathematics. Digital multitasking competes with cognitive resources needed for abstract reasoning, suggesting a causal link between technology habits and declining math performance.

2.2.4. Sleep Disruption and Cognitive Impairment

Desmurget also emphasizes the role of **sleep deprivation**, often induced by nighttime smartphone use. Exposure to blue light and continuous social stimuli delays melatonin production and disrupts circadian rhythms. Sleep deficiency, in turn, impairs memory consolidation, learning acquisition, emotional stability and academic motivation.

School systems worldwide report chronic sleep deprivation among adolescents - an effect also documented by Haidt (2024). Given the established link between sleep and learning, this phenomenon contributes to the academic decline captured in PISA.

2.2.5. The Displacement Effect

One of Desmurget's most important findings is the **displacement effect** - time spent on digital devices replaces activities that are cognitively enriching, such as reading books, doing homework, engaging in outdoor play, socializing face-to-face, participating in sports or music, and sleeping.

This displacement compounds cognitive deficits. Even if screen time was cognitively neutral - which it is not - the substitution of other essential developmental activities creates a net negative effect.

Desmurget's analysis strongly supports the argument that digital environments are structurally detrimental to the academic and cognitive development of Generation Z.

2.3. The Great Rewiring of Childhood: Haidt's Analysis

Jonathan Haidt's *The Anxious Generation* (2024) offers a complementary sociopsychological perspective on digital immersion, presenting compelling evidence that the smartphone era fundamentally reconfigured childhood after 2010. Haidt argues that the transition from **play-based** to **phone-based** childhood created unprecedented levels of anxiety, depression, loneliness, attentional dysregulation and social fragility.

These emotional and social disruptions in turn undermine learning and academic engagement.

2.3.1. The Decline of Free Play and Its Cognitive Consequences

Haidt identifies the loss of real-world, unsupervised, physically active play as a structural cause of reduced:resilience, social competence, creativity, autonomy, impulse control and executive functioning.

Free play is a critical mechanism for developing cognitive skills necessary for academic success. Its displacement by passive digital consumption and algorithmic social comparison weakens the foundation for learning.

2.3.2. Anxiety, Depression, and Academic Performance

Haidt shows that mental health disorders among adolescents surged after 2012, coinciding with the mass adoption of smartphones and social media. Symptoms of anxiety and depression correlate strongly with reduced motivation, impaired working memory, avoidance behavior, lower persistence, and decreased school engagement.

These findings align with PISA data showing rising absenteeism, reduced enjoyment of reading, and lower academic self-efficacy among adolescents.

2.3.3. Sleep Degradation and Learning Loss

Haidt reinforces Desmurget's argument that digital nighttime use severely damages sleep. He notes that adolescents increasingly sleep with phones in hand, social media trigger fear-of-missing-out (FOMO), and nighttime messages and notifications interrupt sleep cycles.

Chronic sleep loss has neurological consequences: lower concentration, impaired memory, diminished emotional stability, and reduced learning motivation.

2.3.4. Social Comparison, Identity Fragility, and Cognitive Load

Instagram, TikTok, and similar platforms amplify social comparison, aesthetic insecurity, peer surveillance, and identity fragmentation.

These psychological stressors increase cognitive load and reduce attentional control. The result is a compromised capacity to perform academically demanding tasks, reinforcing PISA's finding that digital distraction significantly reduces performance.

2.3.5. Gendered Effects and Learning Disparities

Haidt highlights gender differences:

- **Girls** are disproportionately harmed by social media (anxiety, depression).
- **Boys** are disproportionately harmed by gaming and pornography (attention and motivation deficits).

Both pathways diminish academic performance.

3. CONCEPTUAL FRAMEWORK: THE CEDI MODEL

To integrate the theoretical and empirical insights from McLuhan, Desmurget, Haidt, and the OECD, this article proposes the **Cognitive Erosion Through Digital Immersion (CEDI)** model.

The CEDI model is built on the premise that the digital environment surrounding Generation Z simultaneously reshapes cognitive structure, emotional stability, and academic behavior across three domains:

1. **Technological-Cognitive Restructuring**
   (McLuhan's extension/obsolescence dynamics)
2. **Neurocognitive Impairment**
   (Desmurget's screen-based developmental harms)
3. **Sociopsychological Vulnerability**
   (Haidt's "rewiring" and mental health crisis)

These three domains converge to produce measurable declines in academic performance - the phenomenon captured by PISA 2022.

The **Cognitive Erosion Through Digital Immersion (CEDI)** model synthesizes interdisciplinary evidence to explain the mechanisms through which digital technologies alter cognition and undermine educational outcomes.

3.1. Components of the CEDI Model

3.1.1. Technological–Cognitive Restructuring (McLuhan)

Digital media reconfigure cognitive priorities, privileging speed over reflection, novelty over depth, reactivity over analysis and fragmentation over coherence. These structural changes "retrain" the cognitive system, supplanting capacities that PISA assessments are designed to measure.

3.1.2. Neurocognitive Impairment (Desmurget)

Screen overexposure damages fundamental cognitive systems attention, working memory, executive function, language development and reading comprehension. These impairments translate directly into academic difficulties.

3.1.3. Sociopsychological Vulnerability (Haidt)

Digital environments induce anxiety, depression, sleep disruption, social comparison and identity instability.

These emotional states reduce motivation, concentration, and persistence, compounding cognitive erosion.

3.1.4. CEDI Model Summary

Digital immersion = **Cognitive Erosion + Emotional Dysregulation + Academic Decline**

The model explains why PISA performance has collapsed globally among adolescents raised in highly digital environments.

4. MECHANISMS LINKING DIGITAL IMMERSION TO ACADEMIC DECLINE

Drawing on the CEDI framework, this section details the specific mechanisms through which digital dependence erodes cognitive functioning.

4.1. Attention Fragmentation and Loss of Cognitive Endurance

Smartphone use leads to chronic **attentional switching**, weakening sustained attention, concentration span, and task persistence.

Students conditioned by fragmented media struggle with PISA's long, complex tasks that require deep engagement.

4.2. Decline of Deep Reading and Rise of Skimming

Digital media habituate adolescents to: brief content, superficial scanning, and low-effort engagement.

Deep reading - central to reading comprehension - is increasingly rare. OECD data show dramatic declines in the number of adolescents who read for pleasure.

4.3. Working Memory Overload and Mathematics Decline

Multitasking hampers the brain's ability to maintain information in working memory. Mathematics especially depends on this function. Digital distraction therefore exerts a disproportionate effect on math reasoning, explaining the steep PISA math decline.

4.4. Cognitive Offloading to AI Systems

Generative AI enables students to outsource academic writing, summarization, problem-solving, and reasoning tasks.

Long-term reliance on AI risks diminishing cognitive autonomy, reinforcing McLuhan's prediction that technologies that extend human capacities eventually **reverse into their opposite**, making individuals dependent.

4.5. Sleep Disruption and Learning Impairment

Nighttime screens use damages sleep cycles, impairing: memory consolidation, learning acquisition, emotional stability, and attentional control.

PISA 2022 documented a strong correlation between sleep deprivation and academic underperformance.

4.6. Emotional Instability and Motivation Collapse

Social media platforms induce anxiety, depression, insecurity, and social withdrawal. Emotional dysregulation reduces academic persistence, executive functioning, resilience, and willingness to engage with challenging tasks.

5. INTERNATIONAL CASE STUDIES

This section presents evidence from four countries whose educational trajectories illustrate the consequences of digital immersion.

5.1. Finland: The Collapse of a Once-Model System

Finland's PISA performance has declined since 2006, with reading scores falling by more than 60 points. Government reports cite excessive smartphone use, declining reading habits, and reduced attention spans.

These trends closely mirror McLuhanian obsolescence patterns.

5.2. France: Neurocognitive Decline and Digital Dependence

French studies show that students who spend more than two hours per day on social media perform significantly lower in mathematics and language. France has since implemented smartphone bans in schools, acknowledging digital overexposure as a systemic academic threat.

5.3. United States: The Mental Health - Academic Crisis Link

Haidt's data show that depression among teenage girls doubled after 2012,anxiety levels skyrocketed, and academic motivation declined sharply.

These emotional patterns correlate strongly with academic underperformance and reduced engagement - consistent with PISA trends among U.S. students.

5.4. Brazil: Structural Digital Saturation and Learning Gaps

Brazil demonstrates one of the world's highest rates of adolescent screen use. Reading and mathematics proficiency stagnate at low levels, and PISA results show limited improvement despite expanded school access. Cultural, economic, and technological saturation interact to exacerbate cognitive erosion.

6. POLICY RECOMMENDATIONS

Given the severity of cognitive decline, urgent interventions are needed at multiple levels.

6.1. School-Level Interventions

- Smartphone-free school environments (as adopted by France).
- Mandatory deep reading programs to restore cognitive endurance.
- Regulation of classroom technology - technology should support learning, not distract.
- Limits on AI-generated work and integration of AI literacy into curricula.

6.2. Family-Level Measures

- Delay smartphone ownership until age 14 or later.
- Establish digital curfews and bedroom-free device policies.
- Promote physical play, reading, sports, and hobbies.
- Family-based digital contracts or agreements.

6.3. Government and Policy Actions

- Public policies regulating algorithmic platforms that exploit adolescents' psychological vulnerabilities.
- National guidelines for safe digital exposure.
- Public health campaigns on sleep hygiene.
- Public investment in literacy programs targeting deep reading.

6.4. AI Governance in Education

- Require transparency when students use AI.
- Promote human-centered cognitive practices.
- Integrate AI as a tool, not as a replacement for thought.
- Ensure that digital learning platforms bolster, rather than replace, foundational skills.

7. CONCLUSION

The decline of Generation Z's academic performance is not an isolated educational problem, but a profound cognitive and social transformation driven by digital technologies. The paradox of the digital age is now evident: **Information has never been more abundant, yet the cognitive ability to process, analyze, and learn from it has weakened dramatically.**

McLuhan predicted that technologies extend human capacities only to obsolete them. Desmurget demonstrated the neurocognitive harm of excessive screen time. Haidt revealed the mental health consequences of smartphone-based childhood. PISA quantified the academic consequences of these transformations.

Unless societies act decisively to redesign digital environments and implement evidence-based policies, the cognitive decline of new generations may deepen, threatening educational systems, workforce readiness, and democratic stability.

The challenge ahead is not to reject technology, but to govern it responsibly - ensuring that digital innovation enhances, rather than erodes, the cognitive foundations of human development.

REFERENCES

[1] Carr, N. (2010). The shallows: What the internet is doing to our brains. W. W. Norton.

[2] Degen, R. J. (2024). Technology as extension of ourselves enhances and obsoletes our capabilities. Anais do XIII EGEPE. Curitiba(PR) UFPR, 2024. Disponível em: www.even3.com.br/anais/xiii-egepe-encontro-de-estudos-sobre-empreendedorismo-e-gestao-de-pequenas-empresas-381278. ISBN: 978-65-272-0636-1DOI: doi.org/10.29327/9786527206361

[3] Degen, R. J. (2025). Tecnologia como extensão humana e os desafios da governança antecipativa. In Jardim, J. & Oliveira, L. (Eds.). Educação Empreendedora e Inovação Social: Construindo Pontes para Criar Valor. SkillsResearch.

[4] Desmurget, M. (2019). La fabrique du crétin digital: Les dangers des écrans pour nos enfants. Seuil.
[5] Floridi, L., & Cowls, J. (2019). A unified framework of five principles for AI in society. Harvard Data Science Review, 1(1). https://doi.org/10.1162/99608f92.e0f1f8c5
[6] Haidt, J. (2024). The anxious generation: How the great rewiring of childhood is causing an epidemic of mental illness. Penguin Press.
[7] McLuhan, M. (1964). Understanding media: The extensions of man. McGraw-Hill.
[8] OECD. (2023). PISA 2022 results (Volume I): The state of learning and equity in education. OECD Publishing. https://doi.org/10.1787/3197152b-en
[9] Przybylski, A. K., & Weinstein, N. (2019). Digital screen time and adolescent well-being: Evidence from a population-representative study. Nature Human Behaviour, 3, 173–175.
[10] Twenge, J. M. (2018). iGen: Why today's super-connected kids are growing up less happy—and completely unprepared for adulthood. Atria Books.
[11] UNESCO. (2021). Recommendation on the ethics of artificial intelligence. UNESCO Publishing.
[12] World Health Organization. (2024). Global report on adolescent mental health. WHO.