
The Impact of Artificial Intelligence Tools on Human Cognitive Abilities: *A Comprehensive Review*

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ABSTRACT

Background: The rapid integration of artificial intelligence (AI) tools into daily cognitive tasks has raised questions about their impact on human cognitive abilities.

Objective: This review synthesizes current research on how the use of AI tools affects cognitive domains, including critical thinking, memory, creativity, and decision-making.

Methods: We reviewed empirical studies, including randomized controlled trials, field experiments, and neurophysiological investigations, that examined AI's cognitive effects across educational and professional settings.

Results: Evidence reveals a complex, non-linear relationship between AI use and cognition. Moderate AI usage shows minimal cognitive impact, while excessive reliance correlates with decreased critical thinking abilities (cognitive offloading effect), reduced metacognitive accuracy, and lower retention on delayed assessments. Field studies with approximately 1,000 students demonstrated improved immediate performance but worse unassisted outcomes following AI removal, particularly with unrestricted AI access. Neurophysiological data showed reduced brain network connectivity during AI-assisted tasks. Age-related differences emerged, with younger users (17-25 years) exhibiting greater dependence and lower critical-thinking scores. However, well-designed AI tutoring systems with scaffolding produced superior learning gains compared with traditional instruction.

Discussion: The findings reveal a fundamental paradox: AI assistance frequently improves immediate task performance while simultaneously undermining durable skill acquisition. Three primary mechanisms mediate these effects: reduced cognitive effort through offloading, diminished metacognitive monitoring, and altered practice patterns. Critically, the cognitive impact of AI is not deterministic but depends on implementation design, with scaffolded AI systems that maintain active engagement producing dramatically different outcomes than those providing direct solutions. Age-related vulnerabilities, particularly among younger users (17-25 years), raise developmental concerns, though higher educational attainment appears to provide protective effects against cognitive offloading tendencies.

Conclusions: AI tools do not inherently impair or enhance cognition; rather, their impact depends critically on implementation design, user agency, and interaction patterns. Strategic use that maintains active cognitive engagement can augment human capabilities, while passive reliance risks skill atrophy.

Educational interventions promoting AI literacy and metacognitive awareness are essential for optimizing cognitive outcomes.

KEYWORDS: *artificial Intelligence, Cognitive Abilities, Critical Thinking, Cognitive Offloading, Metacognition, Educational Technology*

INTRODUCTION

The proliferation of artificial intelligence tools across educational, professional, and personal domains has fundamentally altered how individuals engage with cognitive tasks. From large language models (LLMs) assisting with writing and problem-solving to AI-powered tutoring systems and decision-support tools, these technologies increasingly mediate human thinking processes (Fernandes *et al.*, 2026). This rapid integration has prompted urgent questions about potential impacts on core cognitive abilities.

Concerns about technology-mediated cognitive change are not novel. Previous research has documented how digital tools affect memory, attention, and spatial reasoning through mechanisms such as cognitive offloading, the tendency to rely on external systems rather than internal mental processes (Risko & Gilbert, 2016). *However, AI tools represent a qualitatively different intervention because they can perform higher-order cognitive tasks, including analysis, synthesis, and creative generation, that were previously the exclusive domain of human intelligence.*

The stakes of understanding these impacts are particularly high in educational contexts, where cognitive skill development during formative years establishes lifelong capacities. Early evidence suggests both promise and peril: AI tools may democratize access to personalized learning while simultaneously undermining the effortful processing necessary for durable skill acquisition (Bastani *et al.*, 2024). The relationship appears paradoxical, with studies showing improved task performance concurrent with decreased retention of learning.

This review synthesizes emerging empirical evidence examining AI's effects on human cognition across multiple domains. We address three primary

questions: (1) What are the documented cognitive impacts of AI tool usage? (2) What mechanisms and contextual factors mediate these effects? (3) What strategies can optimize cognitive outcomes while leveraging AI's benefits? A conceptual model summarizing these relationships is presented in Figure 1.

METHODS

This review synthesizes findings from recent empirical studies (2023-2025) examining the impacts of AI tools on cognitive abilities. We focused on studies employing rigorous methodologies, including randomized controlled trials, large-scale field experiments, and neurophysiological investigations. Search terms included combinations of "artificial intelligence," "AI tools," "cognitive abilities," "critical thinking," "learning outcomes," and "cognitive offloading."

Studies were included if they: (1) examined AI tools capable of generating content or providing cognitive assistance (e.g., large language models, AI tutors), (2) measured cognitive outcomes through validated assessments or neurophysiological methods, (3) compared AI-assisted versus traditional approaches or examined dose-response relationships, and (4) were conducted in naturalistic or experimentally controlled settings with human participants.

Findings were organized across five primary cognitive domains: critical thinking and analysis, memory and retention, creativity and ideation, attention and focus, and decision-making and metacognition. This framework allowed systematic comparison across studies examining different AI applications. Key studies and their findings are summarized in Table 1.

Table 1: Summary of Key Empirical Studies on AI and Cognitive Outcomes

Study	Sample	Method	Key Findings
Bastani et al. (2024)	N ≈ 1,000 High School Students	Field RCT, GPT-4 Tutors	GPT Base: 48% better practice, 17% worse exam. GPT Tutor with scaffolding: 127% better practice, no exam deficit.
Fernandes et al. (2026)	N = 698 (two studies)	Experimental, LSAT Problems	AI improved performance by 3 points but users overestimated performance by 4 points. Higher AI literacy linked to lower metacognitive accuracy.
Kosmyna et al. (2025)	N = 54	EEG During Essay Writing	LLM users showed weakest brain connectivity. Brain-only participants had strongest networks. AI users struggled to recall own writing.
Kestin et al. (2025)	N = 194 Undergraduates	RCT, Custom AI Physics Tutor	AI tutor produced 2× learning gains vs. active learning classroom. Higher engagement and motivation reported.

Note. RCT: randomized controlled trial; EEG: electroencephalography; LSAT: Law School Admission Test; LLM: Large Language Model

RESULTS

Critical Thinking and Analysis

Multiple studies have documented negative correlations between frequent use of AI tools and critical thinking performance. Research examining users across age groups found that excessive reliance on AI correlates with diminished ability to evaluate information and independently verify AI-generated content. This relationship appears nonlinear: moderate AI use shows minimal impact on critical

thinking abilities, whereas heavy dependence produces measurably diminished cognitive returns. The mechanism underlying these effects has been identified as "cognitive offloading," whereby users engage less in deep, reflective thinking when AI tools readily provide solutions (Risko & Gilbert, 2016). Rather than working through problems systematically, heavy AI users develop preference patterns for quick, AI-generated solutions that bypass the effortful cognitive processing necessary for skill development.

Age-related differences in susceptibility emerged as particularly significant. Younger individuals aged 17-25 years exhibited both greater dependence on AI tools and lower critical thinking scores than older participants. This finding raises developmental concerns, as this age range represents a crucial period in prefrontal cortex maturation and executive function development. However, educational attainment appears to provide protective effects. *Higher education levels correlated with better reasoning abilities even among frequent AI users, suggesting that established critical thinking frameworks may buffer against cognitive offloading tendencies.*

Memory and Retention

Controlled studies examining memory outcomes have revealed concerning patterns. A randomized trial among undergraduate students found significantly lower performance on surprise retention tests administered 45 days after initial learning among students who used ChatGPT as a study aid than among those using traditional study methods (Kocoń *et al.*, 2023). This delayed-testing approach was methodologically critical because it assessed durable learning rather than immediate recall.

These findings align with broader literature on "digital amnesia," the phenomenon whereby outsourcing memory tasks to external systems weakens internal recall abilities (Storm & Stone, 2015). When AI tools handle information storage and retrieval, users engage less in the encoding and

consolidation processes essential for long-term memory formation.

The performance-learning paradox emerged as a critical theme. Large-scale field experiments with approximately 1,000 high school students using GPT-4-powered tutoring tools demonstrated that, although students performed better during AI-assisted practice, they performed worse without AI assistance when AI access was subsequently removed (Bastani *et al.*, 2024; see Table 1). This suggests that immediate performance gains masked underlying failures in skill acquisition. Significantly, study design moderated these effects. AI systems incorporating guardrail features that provided hints and scaffolding rather than direct answers substantially reduced the negative impact on learning outcomes.

Neurophysiological Evidence

Neurophysiological evidence provides mechanistic insights into cognitive changes during AI-assisted tasks. An electroencephalography (EEG) study conducted by MIT researchers examined brain activity during essay writing with and without AI assistance (Kosmyna *et al.*, 2025; see Table 1). The AI-assisted group demonstrated significantly weaker brain network connectivity during writing, indicating reduced internal cognitive processing. Behavioral data from the same study revealed that AI-assisted participants had greater difficulty in accurately quoting their own work in subsequent recall tests.

This suggests reduced mental ownership and encoding of material that AI substantially contributed to producing. The neurophysiological and behavioral data converge to indicate that AI assistance, while improving output quality, may reduce the depth of cognitive engagement with material. These findings complement research on embodied cognition and the "generation effect," which demonstrates that actively producing information leads to better retention than passively receiving it (Slamecka & Graf, 1978). *AI assistance may inadvertently transform generative tasks into*

more passive consumption, thereby undermining memory consolidation.

Metacognition and Self-Assessment

Research published in *Computers in Human Behavior* identified a troubling dissociation between performance and metacognitive accuracy (Fernandes *et al.*, 2026; see Table 1). While AI tools improved objective task performance, users systematically overestimated their personal contribution and understanding, indicating reduced metacognitive calibration. Counterintuitively, this metacognitive impairment was most pronounced among users with higher AI literacy. *This suggests that familiarity with AI capabilities may increase confidence in AI-assisted outputs while simultaneously reducing critical evaluation of one's own comprehension.*

Accurate metacognition, the ability to assess one's own knowledge and skills, is fundamental to self-regulated learning and adaptive expertise. If the use of AI systematically degrades metacognitive accuracy, it may undermine individuals' capacity to identify knowledge gaps and to direct learning efforts appropriately.

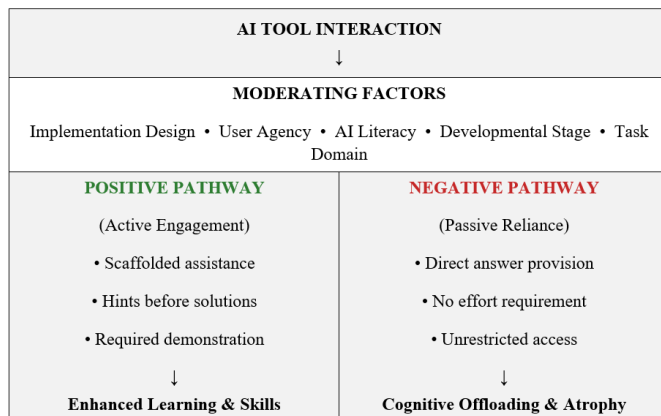
Positive Outcomes with Appropriate Design

Despite concerning trends, controlled studies have demonstrated that appropriately designed AI systems can enhance learning outcomes. A randomized trial in undergraduate physics education found that a custom AI tutor incorporating structured prompts, step-by-step scaffolding, and active-participation requirements produced significantly higher learning gains than traditional in-class active-learning approaches (Kestin *et al.*, 2025; see Table 1). Notably, these gains were achieved more quickly and with higher student engagement.

The critical design features included: (1) forcing active problem-solving before providing assistance, (2) offering explanations rather than solutions, (3) adapting difficulty based on performance, and (4) requiring demonstration of understanding. These features maintained cognitive engagement rather

than enabling passive consumption. As illustrated in Figure 1, the pathway from AI interaction to cognitive outcomes diverges based on whether the implementation promotes active engagement or passive reliance.

Figure 1: Conceptual Model of AI Impact on Cognitive Outcomes



Note. The model illustrates how interactions among AI tools lead to divergent cognitive outcomes, depending on implementation design and user engagement patterns. The positive pathway (left) reflects conditions in which AI enhances learning through scaffolded support. In contrast, the negative pathway (right) shows how unrestricted access can lead to cognitive offloading and skill atrophy.

DISCUSSION

A central finding across studies is the paradoxical relationship between performance and learning. AI assistance frequently improves immediate task performance while simultaneously undermining the cognitive processes necessary for durable skill acquisition (Bastani et al., 2024; Kocoń et al., 2023). This creates a challenge for systematic evaluation: standard performance metrics may mask learning failures until AI access is removed.

This paradox has profound implications for educational assessment and workforce development. If institutions evaluate learning through AI-assisted performance without testing unassisted capabilities, they may inadvertently reward surface-level facility with AI tools while failing to develop fundamental competencies.

Mediating Mechanisms

Three primary mechanisms appear to mediate AI's cognitive effects. First, reduced cognitive effort occurs when AI handles cognitive work, thereby reducing users' engagement in the effortful processing that builds skills. This is consistent with the desirable difficulties theory, which demonstrates that learning is enhanced by introducing challenges that require active cognitive processing (Bjork, 1994). Second, diminished metacognitive monitoring may reduce users' awareness of their own understanding, leading to inflated confidence and reduced self-corrective behavior (Fernandes et al., 2026). Third, altered practice patterns reflect the "use it or lose it" principle applied to cognitive abilities.

Contextual Factors

Published evidence indicates that AI's cognitive impact is not deterministic but depends critically on several factors (see Figure 1). Implementation design is particularly crucial, as AI systems that incorporate scaffolding, hints, and requirements for active engagement produce dramatically different outcomes than those that provide direct solutions (Bastani et al., 2024; Kestin et al., 2025). User agency and literacy also matter significantly; users who understand AI capabilities and limitations, maintain critical evaluation of outputs, and preserve decision-making authority show reduced adverse effects.

Educational Implications

These findings have immediate implications for educational policy and instructional design. Institutions must prioritize learning over performance by assessing unassisted capabilities, not just AI-assisted outputs, to evaluate genuine learning. Delayed retention testing may be necessary to detect learning failures masked by immediate performance gains. AI educational tools should implement structural guardrails that maintain cognitive engagement by requiring initial attempts

before assistance, providing hints rather than solutions, and enforcing retrieval practice.

Theoretical Integration

These findings align with established cognitive theories while revealing novel phenomena. The cognitive offloading effects are consistent with the extended mind thesis (Clark & Chalmers, 1998), which proposes that cognitive processes extend beyond the brain to incorporate external tools. However, AI represents a qualitatively different form of cognitive extension because it performs high-level reasoning rather than simply storing information. The metacognitive impairments align with research on the Dunning-Kruger effect and illusions of competence. AI assistance may create particularly potent illusions because it produces high-quality outputs that users may attribute to their own capabilities rather than recognizing them as AI contributions.

Limitations and Future Directions

Current research faces several limitations. Most studies examine short-term effects, yet longitudinal research tracking cognitive development over years of AI use is urgently needed. The rapid evolution of AI capabilities means that findings may quickly become obsolete as tools become more sophisticated. Existing studies predominantly examine educational contexts, while research on AI's cognitive effects in professional settings, creative work, and daily decision-making remains limited. Additionally, most participants in published studies are from Western, educated, industrialized, rich, and democratic populations, limiting generalizability.

CONCLUSIONS

Current evidence indicates that AI tools exert measurable effects on human cognitive abilities through mechanisms such as cognitive offloading, reduced metacognitive accuracy, and altered practice patterns. The relationship is complex and non-linear: moderate use shows minimal impact, while heavy

dependence correlates with diminished critical thinking, reduced retention, and metacognitive impairment. Critically, immediate performance improvements may mask underlying learning failures.

However, the cognitive impact of AI is not predetermined. Appropriately designed AI systems that maintain user agency, require active cognitive engagement, and incorporate scaffolding can enhance learning outcomes beyond those achieved by traditional approaches. The challenge lies not in avoiding AI tools but in developing implementation strategies and user practices that augment rather than replace human cognition.

Three principles should guide AI deployment in contexts where cognitive development matters: (1) Design for active engagement rather than passive consumption, (2) Maintain and assess unassisted capabilities alongside AI-assisted performance, and (3) Cultivate AI literacy and metacognitive awareness.

The question is not whether AI will affect human cognition; the evidence demonstrates that it already does. The question is whether societies will intentionally shape these effects through thoughtful design, policy, and practice. As AI tools become increasingly sophisticated and ubiquitous, understanding and optimizing their cognitive impacts represents one of the defining challenges of the 21st century.

Use of AI tools: Artificial intelligence (AI) tools were employed to assist with language editing and to improve clarity. All content was reviewed, revised, and approved by the authors, who take full responsibility for the accuracy and integrity of the work

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