

ChatGPT: The cognitive effects on learning and memory

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Abstract

As the integration of artificial intelligence (AI) into our daily lives and educational environments becomes increasingly prevalent, it is necessary to understand the way in which these technologies impact cognitive functions. AI models such as ChatGPT hold immense promise for advancing the field of education, making it easier than ever for educators to support personalized learning and for students to access information. However, there are risks associated with increased AI engagement; individuals may become over-reliant on AI, resulting in a reduced capacity for critical thinking, or a decline in memory retention. This article provides a comprehensive survey of these potential impacts, emphasizing the need for the judicious utilization of AI, and advocating for an integration approach that supplements, rather than supplants, human cognitive functions. The paper concludes by encouraging further research into the long-term cognitive effects of interacting with advanced AI models such as ChatGPT.

KEYWORDS

artificial intelligence, ChatGPT, cognitive effects, learning, memory

1 | INTRODUCTION

As the use of Artificial Intelligence (AI) has become increasingly prevalent across diverse sectors, its effects within the field of education have been particularly pronounced.^[1] These models, which include Generative Pre-trained Transformers (GPT) and other Large Language Models (LLMs), hold the potential to transform the educational landscape through the enhancement of pedagogical and learning processes, offering a range of benefits that include the improvement of reading and writing skills, the facilitation of personalized learning experiences, and the promotion of multilingual communication.

Among these models, OpenAI's ChatGPT has distinguished itself due to its advanced capabilities and widespread use.^[2] ChatGPT, which uses machine learning techniques to produce responses that are often read as uncannily human, operates by predicting the next word in a sentence, taking into account contextual cues provided by the preceding words. It is trained on a wide range of Internet texts, and can be further customized by fine-tuning it with datasets specifically tailored to various tasks. This technology has a wealth of applications, from drafting emails to coding and holds great promise as an educational tool.^[3] However, as with any powerful technology, it is essential to consider its effects on human cognition, particularly with

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regard to the impact it may have on learning and memory capabilities.

While prior research has explored the impact of ChatGPT on learning and memory to some extent,^[4,5] these studies have been predominantly focused on the basic functions and applications of ChatGPT. Because of this, there is a notable dearth of research examining how ChatGPT impacts human learning and memory processes, as well as limited research into the optimal methods for integrating it into educational environments. This paper aims to provide a comprehensive examination of ChatGPT's functionalities and the potential consequences it may have on learning and memory, providing new perspectives for educators and researchers. It also seeks to outline the potential issues that may arise from the increased employment of AI. Despite ChatGPT's potential to improve areas like personalized learning and information accessibility, AI use also comes with potential risks such as over-reliance on these systems, which may result in impaired critical thinking and altered memory retention. By outlining these potential repercussions, this article contributes to the ongoing discourse on the relationship between AI and cognitive function, offering valuable insights that can inform future research, policy, and practical implementations concerning the impact of AI on learning and memory abilities. Furthermore, it is worth noting that while this paper concentrates on ChatGPT, the perspectives articulated here are applicable to other LLMs.

2 | THE RISE OF CHATGPT

The GPT series, developed by OpenAI, is a progression of LLMs (Figure 1), encompassing GPT-1, GPT-2, GPT-3, and GPT-4. These models are based on a machine learning framework known as a transformer, which uses self-attention mechanisms to generate predictions^[6] and

Key points

What is already known about this topic?

- Existing literature acknowledges that ChatGPT has demonstrated substantial proficiency in text generation and conversational interaction. Consequently, current research has explored its practical applications across a variety of fields, including education and customer service.

What does this study add?

- This paper provides a comprehensive survey of both the potential positive and negative effects of ChatGPT on learning and memory, exploring the impact of artificial intelligence (AI) on human cognitive functions, particularly as they apply to pedagogy and learning. Additionally, it outlines strategies for mitigating the potential drawbacks of increased engagement with AI and suggests specific avenues for future research, including comparative cognitive studies, longitudinal studies, and studies that investigate strategies for the integration of AI in educational contexts.

employs a combination of pretraining and fine-tuning techniques.^[7] GPT-1 pioneered language model pretraining, the method through which LLMs are taught to predict the next word or figure in any given sequence, and fine-tuning, a process where LLMs are adapted for specific tasks. GPT-2 built on this foundation, introducing larger model sizes and an incremental release strategy, while GPT-3 demonstrated even more impressive text generation capabilities. At present, GPT-4, the largest model in the series, has been released, with GPT-4.5 planned as an intermediate version, bridging the gap between GPT-4 and

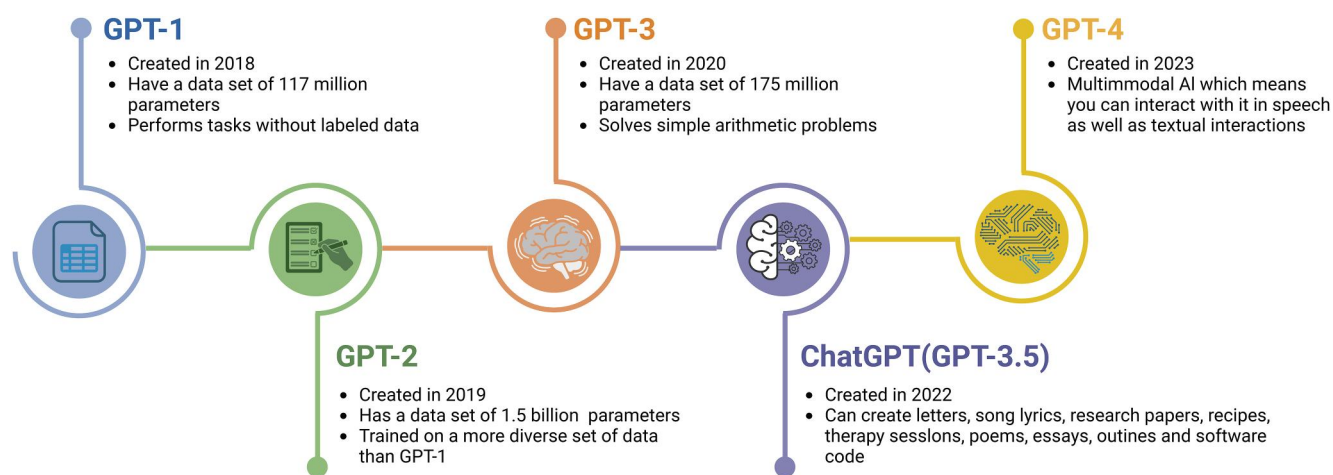


FIGURE 1 Illustration of GPT development history and the rise of ChatGPT. The development timeline of GPT and the emergence of ChatGPT, highlight key milestones and improvements in the model's capabilities. GPT, generative pre-trained transformers.

the forthcoming GPT-5.^[8] As of now, however, the release date of GPT-5 remains uncertain due to ongoing deliberations and concerns from public figures and technology leaders. This has resulted in a petition calling for Open AI to pause its work on the next GPT model, a development that underscores the mounting apprehension felt by many members of society who have only just begun to contemplate the potential risks associated with more advanced iterations of the GPT series.

ChatGPT, a variant of the GPT series specifically designed for conversational interaction, is a prime example of an AI language model. Like all GPT models, ChatGPT is based on transformer architecture,^[6] and is trained in three steps (Figure 2). The first step, supervised fine-tuning (SFT), involves fine-tuning ChatGPT using a limited amount of high-quality, human-curated data SFT: This is the first step where ChatGPT is fine-tuned using a small volume of high-quality human-curated data.^[9] During this phase, the model acquires the ability to generate outputs from a specific set of prompts, establishing the foundation for the subsequent steps. During the next stage of reward modeling (RM), human labelers rank multiple outputs generated by the SFT model.^[10] Subsequently, RM is trained on this dataset to

estimate the desirability of each model output to humans. In the final stage, proximal policy optimization, the SFT model undergoes further refinement using a reinforcement learning algorithm to optimize the RM. During this step, the current model is updated based on the actions taken and their associated rewards.

While ChatGPT is an undeniably powerful tool, it is not without certain challenges.^[11] A primary concern is the lack of transparency surrounding its training data, as there is little to no knowledge of what data sources it utilizes, where these data originates, and the intricacies of the system's architecture. This opacity has raised questions about the legality of the data used for training LLMs, particularly with regard to issues surrounding personal information and copyrighted material. Furthermore, as with other LLMs, ChatGPT is subject to the black-box nature of deep learning models, in which its mechanisms evade human comprehension. This presents a significant obstacle to comprehending and predicting the model's behavior, a concern that is augmented by ChatGPT's increased involvement in critical decision-making processes.

Current theories that seek to elucidate ChatGPT's operational dynamics are still in their nascency and thus often struggle to provide straightforward, practical insights. The

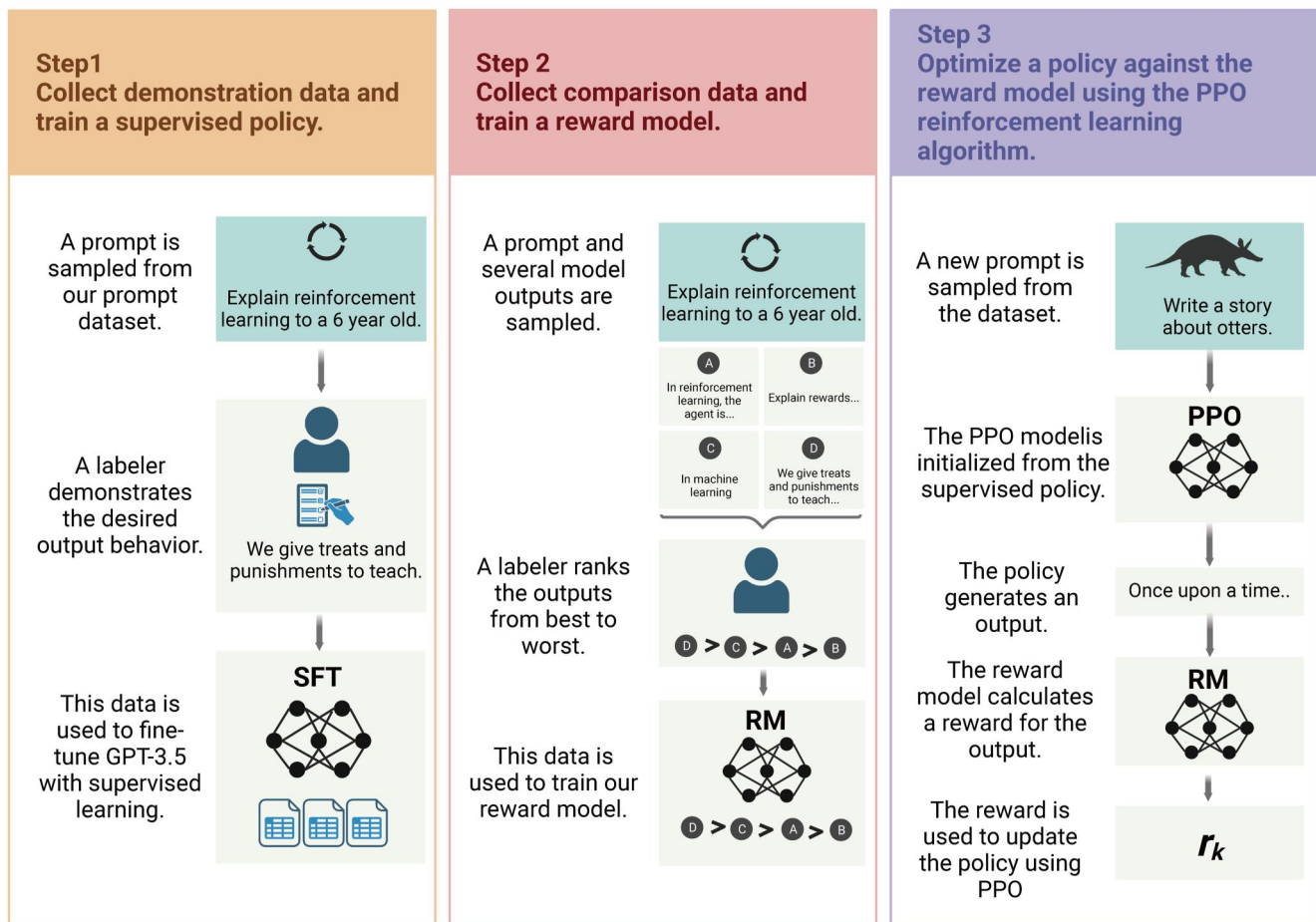


FIGURE 2 Illustration of ChatGPT training steps. Outlining the steps involved in training ChatGPT, from data collection and preprocessing to model training and fine-tuning, providing a comprehensive overview of how ChatGPT learns to generate text.



Benevolent Training Hypothesis,^[12] for example, posits that the intricacies of a deep neural network can be gleaned through an analysis of its training procedures. However, the efficacy of this theory in real-world applications remains untested. Consequently, there is a need for further research aimed at formulating more serviceable explanations for ChatGPT's operations. Such insights could mitigate the black-box nature of LLMs for the general public and increase transparency and accountability on the part of the companies that create them.

Another notable concern relates to ChatGPT's potential for generating incorrect information. Despite its impressive ability to produce human-like text, ChatGPT often encounters difficulties when confronted with elementary tasks, such as inquiries about mathematics and logic. These limitations can be attributed to the model's design, which constructs sentences incrementally, making a series of educated guesses to formulate responses. ChatGPT thus poses a risk of disseminating inaccurate information—a particularly disconcerting prospect in contexts where factual accuracy is critical, such as in the dispensation of medical advice or the relation of historical facts.

Bias stands out as another significant issue associated with ChatGPT. Because the model's training data consist of an extensive corpus of human-generated text and are thus inherently reflective of contemporary societal biases, ChatGPT's replies are likely to perpetuate those same biases. The model may consequently generate content that is discriminatory or offensive, a serious problem that requires attention from both the public and technology companies.

3 | THE FUNCTIONALITIES OF CHATGPT

ChatGPT, which is designed to generate human-like text based on input,^[13] has several critical functions:

- **Conversation:** ChatGPT can engage in conversations with users, a function that has a wide range of applications spanning diverse domains.
- **Language Translation:** ChatGPT is capable of translating text from one language to another, facilitating multilingual communication.
- **Educational Aid:** ChatGPT can act as an educational tool, expounding on a wide array of subjects, including complex scientific concepts and historical events.
- **Coding:** ChatGPT can generate code snippets and help debug code, making it a valuable resource for programmers.
- **Creative Content Generation:** ChatGPT is capable of generating creative content such as stories and poems, and can also give prompts to stimulate user creativity.

Chat GPT's many abilities highlight its role as a powerful educational resource,^[14] particularly in the domain of learning and memory, turning these foundational capabilities

into practical tools that enhance learning experiences, aid in memory recall, and facilitate skill development. These capacities can be seen in a number of ways:

- **Educational Resource:** ChatGPT can function as an educational resource, providing detailed explanations and summaries across a broad spectrum of subjects. This can help students acquire new knowledge and reinforce existing knowledge.
- **Language Learning Facilitation:** ChatGPT can be employed as a language learning tool, generating dialogs in various languages, offering language usage corrections, and providing translations, thus facilitating the acquisition of new languages.
- **Memory Enhancement:** ChatGPT can be used to aid memory recall. Users can reinforce their memory of a specific (general knowledge) topic by asking the model to provide information about it.
- **Skill Development:** ChatGPT can be used to develop various skills, such as critical thinking, problem-solving, and communication. It can assist with this by generating scenarios, providing feedback, and offering suggestions.
- **Research Support:** ChatGPT can assist academic research by summarizing complex papers, generating research topic ideas, and even assisting in the writing process.
- **Study Tool:** ChatGPT can function as a study tool, helping students review and recall information by summarizing key points, generating study notes, and providing helpful explanations.

Considering these applications, it is evident that ChatGPT can be a valuable asset for learning. However, while the above examples illustrate some of the powerful functionality of ChatGPT, it is important to recognize its limitations and the need for cautious and responsible usage.

4 | POTENTIAL POSITIVE EFFECTS ON LEARNING

ChatGPT has the potential to significantly enhance the learning experience through its unique features. Some of its potential benefits as an educational tool are.

- **Personalized Learning:** ChatGPT can customize educational content, offering students a personalized learning experience and saving teachers' time, allowing them to focus on creating engaging lessons.^[11]
- **Round-the-clock support:** ChatGPT is accessible at any time, allowing learners to study or get assistance at their convenience.
- **Repetition and Spaced Learning:** ChatGPT can help facilitate effective learning techniques such as repetition and spaced learning. It can present the same information multiple times or at spaced intervals, which has been shown to improve memory recall.

- **Interactive Learning:** ChatGPT can provide an interactive learning environment, which may increase engagement and motivation.^[15] Additionally, active engagement with the learning material can result in improved comprehension and retention
- **Reduced Pressure:** Some learners might prefer to interact with AI rather than a human tutor because the dynamic is less pressured. This can foster a more relaxed educational environment, potentially improving the learning process.

It is important to note that the effectiveness of ChatGPT in enhancing learning and memory can vary based on user preferences, subject matter, and the specific implementations of the tool. Moreover, ChatGPT should be used as a supplement to traditional learning methods rather than as a replacement for them. Ethical and privacy considerations should also be thoroughly addressed when integrating ChatGPT into educational settings (Figure 3).

5 | POTENTIAL NEGATIVE EFFECTS ON LEARNING

While ChatGPT can have a positive impact on learning and memory abilities, it may also present potential negative consequences. In this regard, some considerations are.

- **Overreliance on AI:** Learners may become overly dependent on AI tools like ChatGPT, potentially diminishing their motivation to learn and destroying their capacity to retain information, as their memory abilities deteriorate due to underutilization.^[16,17]
- **Impaired Critical Thinking:** The wealth of easily accessible information that ChatGPT provides may prevent students from developing their critical thinking skills. Effectively relies upon the ability to analyze, evaluate, and form judgments, processes that may not be fully evolved if students become overly reliant on AI.^[18]

- **Accuracy of Information:** Because ChatGPT generates responses based on patterns in its training data, it lacks a true understanding of the external world. This can sometimes result in the propagation of inaccurate or misleading information, which clearly has a detrimental impact on learning.^[19]
- **Superficial Engagement:** Because ChatGPT can provide instant answers to almost any query, it may prevent students from developing an in-depth understanding of topics. This superficial engagement can negatively impact the long-term memory formation.
- **Reduced Human Interaction:** Overutilization of ChatGPT can lead to fewer opportunities for human interaction, which plays a pivotal role in learning and memory processes.^[20] Collaborative learning (which ChatGPT can facilitate but not provide) as well as discussions with peers and teachers are critical for the comprehension and retention of course or lesson material.
- **Demotivation:** ChatGPT can make learning feel too effortless, as students rely on AI for answers rather than attempting independent problem-solving. This lack of mental stimulation could lead to a decrease in cognitive development and diminished memory capabilities.^[19]

While ChatGPT certainly has the potential to enrich learning experiences, it is thus imperative to critically examine its potential negative impacts as well. These concerns should be addressed through the deliberate integration of pedagogical strategies that promote independent thinking and the judicious use of AI.

6 | STRATEGIES FOR MITIGATING NEGATIVE EFFECTS

Several strategies can be implemented to mitigate the potential negative effects of ChatGPT on learning. These measures aim to ensure that ChatGPT serves as a

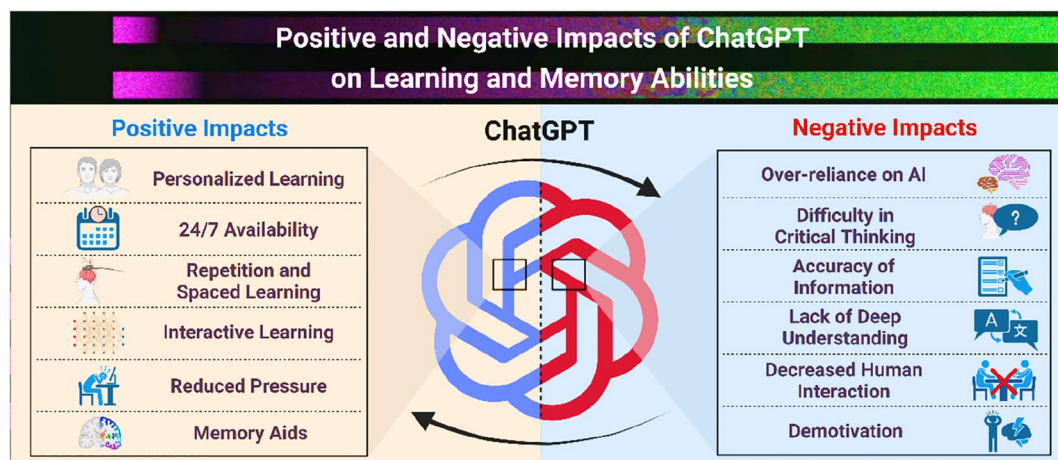


FIGURE 3 Impacts of ChatGPT on learning and memory abilities. Presenting a visual summary of the positive and negative impacts of ChatGPT on learning and memory abilities, offering a balanced view of the potential benefits and challenges associated with using ChatGPT.



supplementary educational tool rather than a replacement for human learning. The suggested strategies are as follows:

- **Integration of Blended Learning Approaches:** These approaches involve the integration of ChatGPT with conventional pedagogical methods, and can be achieved by using ChatGPT as an adjunctive resource within a traditional classroom environment. Educators might, for example, ask ChatGPT to provide additional information or clarification during a lesson, while still retaining their role as the primary facilitator of class activities and discussions. Alternatively, ChatGPT may be useful for providing personalized assistance to students beyond regular class hours, thereby complementing the in-class instruction they receive.
- **Development of Critical Thinking and Problem-Solving Skills:** Educators should incorporate activities that promote the cultivation of critical thinking, problem-solving abilities, and self-directed learning in conjunction with the use of ChatGPT. For example, educators can design assignments requiring students to critically evaluate responses generated by ChatGPT. Additionally, the model can serve as an initial reference point for research projects, encouraging students to verify, elaborate upon, or even challenge the information provided by the AI.
- **Promotion of Collaborative Learning Environments:** Educators should emphasize collaborative learning opportunities that encourage peer engagement and knowledge exchange. Activities that involve group work, discussions, and project-based learning can promote social interaction and provide occasions for learners to critically assess each other's viewpoints, explore diverse perspectives, and cultivate interpersonal skills. ChatGPT can also be used to facilitate collaboration by assisting in the formation of study groups or by offering real-time feedback to enhance group dynamics during collaborative tasks.
- **Encouragement of Continuous Professional Development for Educators:** ChatGPT can provide opportunities for ongoing professional development, allowing educators to gain insight into the capabilities and limitations of ChatGPT within an educational context. Educators should be equipped with the requisite knowledge and skills that would enable them to effectively incorporate resources such as ChatGPT into their pedagogical practices, design meaningful learning experiences integrating AI, and provide guidance to students on the appropriate utilization of AI in a classroom setting. This proactive approach will ensure that educators can leverage ChatGPT as an adjunctive tool in the learning process.
- **Construction of Ethical Frameworks for AI Design and Evaluation:** Tech companies must institute ethical guidelines governing the development and assessment of tools like ChatGPT, particularly with regard to their use in educational settings. These guidelines must prioritize transparency and accountability within AI algorithms,

addressing concerns such as bias mitigation, privacy safeguards, and data security. Regular audits and evaluations of systems like ChatGPT can help identify and rectify potential biases or unforeseen repercussions, thereby ensuring equitable access and unbiased treatment for all learners.

- **Advancement of Research and Evidence-Based Practices:** It is important to advocate for ongoing research and evidence-based practices to assess the influence of ChatGPT on learning outcomes. Researchers must conduct thorough investigations to evaluate the efficacy of the various applications of ChatGPT, identify best practices, and guide the further development of AI-driven tools and interventions. The dissemination of research findings and the promotion of collaboration among researchers, practitioners, and policymakers can significantly contribute to informed decision-making and the continuous advancement of the field.

Through the adoption of these strategies, ChatGPT can be effectively integrated into educational environments, functioning as a complement to human capabilities. This dynamic promotes critical thinking and improves educational outcomes, all while mitigating potential adverse effects. Fundamental to this approach is the preservation of a learner-centered environment, with ChatGPT serving as a supplementary tool for both.

7 | POTENTIAL APPLICATIONS

Despite its limitations, ChatGPT holds the potential to transform the fields of education and memory as it not only changes the way that information is obtained but also alters how this information is understood, retained, and applied (Figure 4). It is clear, then, that ChatGPT should not be disregarded as a powerful educational tool. Accordingly, this section outlines several of its prospective applications:

- **Personalized Tutoring:** An extension of the concept of personalized learning, which seeks to customize lessons to accommodate each student's needs and skill level, ChatGPT has the potential to serve as a one-on-one tutor.^[21] It can guide students through complex topics at an individualized pace, provide instant feedback, and even present them with customized problem sets. Preliminary studies have indicated the efficacy of AI support in improving learning outcomes,^[22] suggesting that this approach can yield a more personalized and engaging learning experience. Using ChatGPT in this way may also have some negative effects, leading to issues concerning data privacy, disparities in student engagement, and unequal distribution of educational resources. However, these problems can be addressed through the implementation of rigorous data privacy protocols, the advancement of teacher training and supervision, and the availability of ChatGPT to all students.



FIGURE 4 Future implications of ChatGPT. Exploring potential future uses of ChatGPT in the context of learning and memory, highlighting areas such as individualized tutoring, interdisciplinary learning, and metacognition, among others.

- Enhancement of Human Capacities:** ChatGPT can serve as a tool to bolster human learning and memory.^[23,24] By automating routine tasks, ChatGPT can allow users to conserve mental energy, thereby facilitating higher-order cognitive functions such as creativity and problem-solving.^[25–27] This can empower learners to actively participate in more complex and meaningful educational undertakings. Nevertheless, it is important to acknowledge that an overreliance on ChatGPT may result in the deterioration of fundamental skills, and hence, the suitability of this particular application may vary across subjects and learning styles. Consequently, educators and students must remain cognizant of these potential issues by utilizing ChatGPT as a supplement to existing pedagogical methods, rather than as a complete substitute for them.
 - Interdisciplinary Learning:** ChatGPT's ability to generate text based on a wide array of data can be harnessed to support interdisciplinary learning. It has the potential to help students recognize associations between various subjects, encouraging creative thinking and promoting a more comprehensive understanding of course material. This has the potential to be a particularly effective application of ChatGPT because fostering these connections necessitates both critical thinking and reflection on the part of the learner.
 - Multilingual Education:** ChatGPT's proficiency in both generating and comprehending text in multiple languages holds the potential to revolutionize language acquisition and multilingual education. Its ability to provide instant translations, clarify grammatical conventions, and facilitate conversational practice in an array of languages can expand access to language learning and promote intercultural communication.^[28]
 - Metacognition and Self-Regulated Learning:** The integration of ChatGPT within educational contexts can cultivate metacognitive awareness and promote self-regulated learning. Students must acquire an understanding of both the proficiencies and constraints of systems like ChatGPT, develop the capacity for critical thinking skills needed to assess the information generated by it, and actively monitor their individual learning processes. However, it is imperative that ChatGPT be regarded as a tool that supports learners' metacognitive development rather than replacing their cognitive capabilities.^[29]
 - Continual Learning and Adaptability:** The rapid development of ChatGPT necessitates that learners embrace an ethos of lifelong learning and adaptability. As ChatGPT continues to evolve, learners must cultivate skills such as information evaluation, problem-solving, and effective learning methodologies. The focus should be on developing a strong foundation in critical thinking, creativity, and emotional intelligence, thus complementing the capabilities of ChatGPT.^[30]
 - Continuous Evaluation and Improvement:** The integration of ChatGPT in educational contexts requires educators to be committed to the continuous evaluation and improvement of these systems. Sustained research efforts are needed to gauge the efficacy of these applications of ChatGPT, both to provide information about their impact on learning outcomes and to identify areas where these uses can be refined.^[31] Employing evidence-based methodologies and rigorous evaluation frameworks are also fundamental requisites for informing the future use of ChatGPT in educational settings.
- With regard to research methodologies, future studies should consider adopting a variety of approaches, employing a combination of quantitative and qualitative methods to address these questions. Longitudinal studies that track a number of individuals as they interact with ChatGPT, monitoring their cognitive development over an extended period of time, could provide valuable insights into the long-term



effects of AI engagement. Additionally, experimental studies that contrast the learning outcomes of students who use AI models with those who do not could shed light on the effectiveness of these tools in educational contexts. Furthermore, Qualitative studies involving interviews or focus groups of students, teachers, and parents could provide a more nuanced understanding of the experiences and perspectives of those directly involved in the integration of AI and education.

8 | AVENUES FOR FUTURE RESEARCH

While there are many potential areas for future research investigating ChatGPT's impact on learning and memory, the following three areas are of particular significance and should therefore be prioritized by future scholarship:

- **Comparative Cognitive Studies:** Researchers should conduct comparative studies that analyze the cognitive capabilities of humans, contrasting them with the capabilities of ChatGPT. This research may involve an examination of the model's attention mechanism as it generates text in response to various inputs. Such investigations have the potential to provide insights into the cognitive effects of interacting with advanced AI models.^[32] These studies could also extend their purview by examining how cognitive load varies when learners interact with ChatGPT as opposed to more traditional educational resources.
- **Long-term Effects:** Longitudinal studies can be conducted to explore the long-term effects of integrating ChatGPT into learning and memory processes. Such research could analyze ChatGPT's influence on learning outcomes, critical thinking skills, and retention of acquired knowledge over an extended period of time. Of particular interest would be an investigation of how sustained engagement with ChatGPT impacts the development of metacognitive skills and the ability to engage in self-regulated learning.
- **Optimal Integration:** It is necessary for future research to identify optimal strategies for integrating tools like ChatGPT with established pedagogical methods. These inquiries should consider factors such as learner personality, chosen subject matter, and learning objectives. Potential strategies for conducting this research could include analyzing the use of ChatGPT in flipped classrooms, collaborative learning environments, or as a tool for personalized feedback.

By addressing these research questions, it is possible to gain a more profound understanding of the ramifications of ChatGPT, particularly with regard to their impact on learning and memory. This improved understanding may be able to facilitate the development of even more effective ChatGPT-centered educational interventions, thus promoting evidence-based practices that optimize the positive impact of tools like ChatGPT while simultaneously mitigating potential drawbacks.

9 | CONCLUSION

The primary objective of this paper has been to conduct a critical evaluation of ChatGPT's impact on learning and memory, offering a comprehensive view that outlines both its potential benefits and drawbacks. This investigation has underscored that even as ChatGPT has the ability to serve as a powerful educational tool, it concurrently raises concerns about overreliance on AI and the potential deterioration of critical thinking skills. For educators, the salient takeaway is the necessity for a balanced pedagogical approach that incorporates both AI and traditional teaching methods. For researchers, on the other hand, there is an imperative to focus on studies that explore the long-term cognitive effects of AI interaction and on developing ethical guidelines for AI in educational settings. By addressing these key areas, we can pave the way for responsible and effective integration of AI tools such as ChatGPT in educational contexts.

AUTHOR CONTRIBUTIONS

Long Bai: Writing – original draft. **Xiangfei Liu:** Writing – original draft. **Jiacan Su:** Writing – review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

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