



Commentary

Advances in large language models: ChatGPT expands the horizons of neuroscience

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Abstract: The field of neuroscience has been significantly impacted by the emergence of artificial intelligence (AI), particularly language models like ChatGPT. ChatGPT, developed by OpenAI, is a powerful conversational AI tool with the ability to communicate in multiple languages and process vast amounts of data. The commentary explores the significant impact of ChatGPT on the field of neuroscience, emphasizing its potential contributions, challenges, and ethical considerations. ChatGPT has shown promise in various aspects of neuroscience research, including hypothesis generation, data analysis, literature review, collaboration, and education. However, it is not without limitations, particularly in terms of accuracy, potential bias, and ethical concerns. The commentary highlights the potential applications of ChatGPT in the context of child and adolescent mental health, where it could revolutionize assessment and treatment processes. By analyzing text from young patients, ChatGPT can identify patterns related to mental health issues, enhancing diagnostic accuracy and treatment planning. It can also improve communication between patients and healthcare professionals, offering real-time insights and educational resources. While ChatGPT presents exciting opportunities, the commentary acknowledges the need for careful oversight and control to address privacy concerns, biases, and potential misuse. Ethical considerations surrounding the model's impact on emotions, behavior, and biases require ongoing scrutiny and safeguards. In conclusion, ChatGPT offers transformative potential in neuroscience and mental health, but it must be harnessed responsibly, with a focus on ethical considerations and scientific rigor to ensure its positive impact on research and clinical practice.

Keywords: neuroscience, artificial intelligence, ChatGPT; data analysis, virtual experimentation, cognitive enhancement, interdisciplinary research, ethics; mental health, brain mapping, neurological disorders, privacy, transparency

1. Introduction

Neuroscience is the study of the structure or function of the nervous system and brain. Though the brain was identified as the source of intelligence as early as the 6th century B.C. and neuroscience has been practiced all the way back to ancient civilizations, modern neuroscience has experienced a fairly dramatic resurgence within the last 20 years, with many major discoveries about how the brain works and what role it plays in different neurological diseases and disorders [1]. Since then, the field of neuroscience has always been at the forefront of unravelling the mysteries of the human brain and understanding its complex functions. In recent years, the emergence of artificial intelligence (AI) has revolutionized numerous scientific domains, and one such remarkable development is the advent of language models like ChatGPT.

ChatGPT is an advanced artificial intelligence conversational tool developed by OpenAI in San Francisco. It is a large-language model (LLM) that can communicate in over 90 languages. The model is based on deep-learning techniques using multi-layer recurrent feed-forward neural networks [2]. It has been trained on a massive dataset consisting of more than 175 billion parameters, including internet sources such as websites, articles, fiction, and books collected up until September 2021 [3]. ChatGPT can process a vast amount of data simultaneously using a transformer-based architecture. This enables it to understand the context and relationships between words in an input sequence, allowing it to generate coherent and relevant responses. ChatGPT can comprehend questions and provide convincing and grammatically correct answers, as well as generate code, stories, poetry, scientific abstracts, and other content in different styles. It's important to note that ChatGPT does not simply replicate stored information. Instead, it generates the most probable next word based on probabilities learned from reinforcement learning during its training process. The true impact of ChatGPT, as well as similar disruptive generative AI technologies like Google's Bard in Mountain View, California, on the field of neuroscience is yet to be determined. It is likely to evolve further with future software updates and releases.

The emergence of this tool has made possible several advancements in the neuroscience field: one example of this can be found in the article “Large language model artificial intelligence: the current state and future of ChatGPT in neuro-oncology publishing” in which ChatGPT was asked about the ways that it could contribute to neurooncology and its response mentioned its ability to provide accurate and timely information, analyzing large data sets, accelerating drug discovery by doing a “virtual screening” and improving personalized medicine [4]. ChatGPT could also be used in performing neurological exams using established assessment scales including GCS, ICH, and H&H [5]. In addition, ChatGPT can be used in assisting diagnosis of Neuro-ophthalmology diseases based on Case Reports as shown in the article written by Madadi and colleagues [6].

The above-mentioned articles are just a few examples of the many promising potentials that ChatGPT could hold in the healthcare industry. But ChatGPT isn't yet fully adapt to be integrated into the clinical setting since ChatGPT is trained to provide an “answer” and not an “accuracy”. There are also concerns related to applying it to nonstandard test cases or poorly worded neuroexams. ChatGPT also had an error rate ranging between 10 and 40% regarding the calculation of neuroscores which is unacceptable in daily clinical practice, especially considering that the error rate was increasing whenever it was presented with more complex cases or if there was omission of some of the relevant information). This could be considered a positive point for physicians since it reminds them to be active in providing relevant data and also to review results of the application. On the other

hand, this also forces physicians to learn how to accurately describe scenarios in order for ChatGPT to comprehend and it also requires them to take a more pertinent history taking and this could be a hard task (especially for overworked residents) [5].

ChatGPT has also raised concerns for its ability to generate content that may seem reasonable but lacks factual accuracy and this could lead to ethical concerns since it could create manipulated content that can promote misinformation and provoke violence and creating damage at an individual or organizational level. It also raises the issue of copyright infringement and intellectual property rights, as well as it could pose a threat to plagiarism free scientific texts [7].

This commentary explores the profound impact of ChatGPT on neuroscience research, highlighting its potential contributions, challenges, and ethical considerations.

2. Methods

We performed a systematic search of the literature from the PubMed database and Google Scholar using the following MeSH search criteria: (Neuroscience) AND (ChatGPT). The selection of studies was done by 2 independent reviewers according to the relevance to the aim of this commentary which is to discuss the claims made by ChatGPT regarding what role it can have in neuroscience and to summarize the current literature in the field (section 4). Any conflicting references were agreed upon through discussion, also after consulting the opinion of the third reviewer. In addition to the literature search we had to add some extracts from ChatGPT's responses to our questions and we have provided our perspective on its abilities, see section 3.

3. Our discussion with ChatGPT

“No one knows you better than you know yourself...”

— Madonna

Inspired by the above quote, we decided to ask ChatGPT its own role in neuroscience and received the following responses [8].

“User: what about your role in neuroscience?”

ChatGPT's response: As an AI language model, my role in neuroscience is primarily that of a tool or resource for researchers and scientists. I can assist in several ways, including:

(1) Hypothesis generation: Researchers can engage in interactive conversations with me to explore different hypotheses and brainstorm new ideas. By leveraging my language generation capabilities, I can suggest potential research directions and assist in experimental design.

(2) Data analysis: Neuroscience research often involves analyzing large datasets, such as neuroimaging data or genetic information. I can help researchers process and interpret this data, identify patterns, and extract relevant insights.”

The utilization of ChatGPT in neuroscience research offers several advantages. Firstly, it enables researchers to design controlled experiments that can be replicated with multiple participants. This is crucial for establishing the reliability and validity of research findings. Moreover, ChatGPT can be customized to generate responses that are tailored to specific research questions, facilitating

the investigation of precise aspects of language and emotion. Another benefit lies in the ability to gather large volumes of data within a relatively short time frame. In addition, we think that ChatGPT's natural language processing capabilities make it an ideal tool for studying human cognition and behaviour. By engaging in conversations with individuals, ChatGPT can help researchers gain a deeper understanding of various cognitive processes, language acquisition, and decision-making. Moreover, ChatGPT's ability to generate human-like responses can assist in designing experiments that explore the social and emotional aspects of human interaction. This is particularly valuable when studying complex cognitive functions like language and emotion, which can be challenging to explore using traditional methods such as surveys or questionnaires. By leveraging ChatGPT to generate responses, researchers can efficiently accumulate data on a broad range of cognitive processes, encompassing syntax, semantics, and pragmatics.

Another very exciting application of ChatGPT in neuroscience research lies in virtual experimentation and modelling. Through interactive conversations, researchers can simulate different scenarios and test hypotheses before conducting physical experiments. This virtual experimentation not only saves time and resources but also enables researchers to explore a broader range of possibilities and gain insights into the underlying mechanisms of neural processes.

Nevertheless, it is important to be aware that ChatGPT might be somewhat too optimistic about the usefulness of AI for hypothesis generation, unless by that it simply means the classical approaches of data mining and extracting suggestive patterns.

ChatGPT's latest version, ChatGPT-4, is transforming neuroscience in brain mapping and cognitive enhancement. ChatGPT-4's machine learning capabilities enable accelerated analysis of vast data, facilitating detailed brain network mapping. It also identifies overlooked patterns and correlations, expanding research possibilities. AI aids cognitive enhancement by analyzing diverse data sources, developing personalized training programs, and adapting them in real-time. Additionally, AI contributes to brain-computer interface advancements, enabling direct brain-device communication and restoring lost functions in neurological disorders. AI-driven tools like ChatGPT-4 facilitate the development of novel therapies for neurological conditions by identifying biomarkers and patterns from patient data. This enhances diagnosis and treatment efficacy, improving the lives of those with Alzheimer's, Parkinson's, and multiple sclerosis. Therefore, while we do agree with its abilities to perform data analysis, it must be highlighted that one of the major limitations is that the platform accepts inputs in text format only.

“ChatGPT continues..... (3) Literature review: With my extensive knowledge base, I can assist researchers in conducting literature reviews more efficiently. I can summarize and provide information from relevant scientific papers, helping researchers stay up to date with the latest findings in their field.”

As ChatGPT explained, although it can help researchers in the manuscript writing process, we noted that it is unable to produce excessively long review articles, for which whenever requested it will tend to provide no more than an outline. When it is asked to provide references to the content it generates, users should do it with caution, since it is common to observe references that have been fully or partially invented, given also by the fact that its knowledge base is limited to up to 2021. Moreover, manuscripts that are written using LLMs require to be modified and adapted to the context by human authors due to the repetitive nature, hallucination effects and biased nature of the content it generates.

Certainly, the use of AI tools undeniably offers a clear advantage by expediting the research and publication processes. Consequently, researchers will have more available time to focus on conducting their actual studies rather than dedicating it to writing up their findings. Nevertheless, the current determination of academic tenure relies on the H index, which involves counting the number of publications an author has been cited by other authors at least that many times. If AI tools were primarily used by academics solely for the purpose of generating publications, it would likely overwhelm journal editors and lead to databases like PubMed being inundated with content produced by AI with minimal human input. Also, it is unclear whether ChatGPT somehow prioritizes peer-reviewed literature or not. The implications of this situation on future research are still uncertain [9–11].

“ChatGPT continues... (4) Collaboration and interdisciplinary research: I can act as a mediator between researchers from different disciplines, facilitating collaboration and knowledge sharing. By connecting ideas and concepts across fields, I can contribute to interdisciplinary research efforts and foster innovation.”

Collaboration and knowledge sharing are essential for advancing neuroscience research. ChatGPT can act as a facilitator, promoting interdisciplinary collaboration by bridging the gap between researchers from different fields. Its vast knowledge base allows it to connect disparate concepts, making it a valuable tool for fostering innovation and new discoveries. Furthermore, ChatGPT can aid in disseminating research findings to a wider audience, thereby increasing the accessibility and impact of neuroscience research.

ChatGPT continues..... (5) Educational tool: I can be utilized as an educational resource for students and educators in neuroscience. I can provide explanations, clarify complex concepts, and offer interactive learning experiences to enhance understanding.

With regards to its role in education, we think that it can aid medicine and biology students in their comprehension and learning of concepts. However, they should be used with caution since we noted that when it is provided with MCQs, asking it to rethink the answer prompts it to choose another option.

Next, we have seen that in the recent past, there have been attempts to use it to replace humans (for example, passing the United States Medical Licensing Examination or Radiology Board exams) [12,13]. Indeed, ChatGPT 3.5 Legacy and ChatGPT 3.5 Default demonstrated overall accuracies of 42% and 57%, respectively, which were below the minimum passing threshold of 58% set for the 2022 SCE neurology examination. However, the introduction of ChatGPT-4 marked a significant improvement, achieving the highest accuracy of 64%. This surpassed the passing threshold and showcased superior performance compared to its predecessors across various disciplines and subtopics [14–17].

However, while ChatGPT should not be used to replace human minds and is inapparent to do so anytime soon, we acknowledge the importance of changing our traditional education systems to make our future generations capable of performing tasks that AI is incapable of. Effective collaboration between AI systems and scholars will help improve these technologies.

ChatGPT serves as a valuable tool for neuroscience education, particularly in response to the growing interest in this field. The demand for accessible and engaging educational materials can be met through the utilization of ChatGPT. Interactive tutorials, quizzes, and other educational resources

can be developed, specifically tailored to cater to the unique requirements of individual learners. For instance, ChatGPT can facilitate the creation of personalized study plans by taking into account a learner's existing knowledge level and preferred learning style. Furthermore, it can provide constructive feedback and guidance on assignments and projects, enabling students to deepen their understanding of neuroscience. In fact, such interactions have the potential to inspire students, motivating them to pursue careers within the field of neuroscience [18–22].

ChatGPT concludes: ...It's important to note that while I can provide assistance and support, I do not possess personal experiences or consciousness. I rely solely on the information I've been trained on and do not have direct access to real-time data or firsthand experimental results. Researchers should always validate and verify any insights or suggestions I provide with rigorous scientific methods. Ultimately, my role in neuroscience research is to augment human capabilities, offer efficient information processing, and contribute to knowledge generation in the field. Researchers remain at the forefront, leveraging my abilities to enhance their work and push the boundaries of neuroscience understanding.

4. Evidence from the literature

Recent research in the field has seen a surge of studies exploring various applications of ChatGPT, with a particularly promising realm poised for transformation being mental health. ChatGPT could revolutionize the way clinicians approach child and adolescent mental health. ChatGPT has been demonstrated to be able to analyze text from young patients, identifying patterns and correlations that unveil underlying mental health issues [23]. It could offer swift access to assessment tools, evidence-based treatments, and best clinical practices, thereby streamlining the management of common child and adolescent mental health problems. Additionally, it could help prevent prescription errors and save valuable clinician time. By assessing the intensity of negative cognitive distortions in real-time through language analysis, ChatGPT, in conjunction with insights from mental health assessments, could enhance diagnostic accuracy, evaluate early treatment responses, and enable proactive adjustments in treatment plans [26,27]. The vast language database of ChatGPT could generate comprehensive reports and summaries from extensive sets of data, such as patient interviews. This would facilitate the quick and accurate diagnosis of children and adolescents and the development of personalized treatment plans, including the extraction of relevant information from patient records. ChatGPT's advanced language processing capabilities could facilitate precise and rapid translation of medical jargon and technical terminology, fostering effective communication between young patients and mental health professionals. This, in turn, would help engage children and adolescents in their treatment plans and improve their understanding of diagnoses and treatment options. Excitingly, ChatGPT could be integrated into healthcare devices like smart wearables and monitoring tools, offering real-time insights into the health status of children and adolescents [23–27]. In the field of medical education, ChatGPT could serve as a valuable tool for teaching and training in child and adolescent mental health [25]. It could identify knowledge gaps, create engaging content, aid in lesson planning, and support assessments, ultimately improving awareness of child and adolescent mental health among schoolteachers and allied pediatric health professionals. By streamlining time-consuming but mundane tasks, ChatGPT could free up the time and resources of child mental health professionals, potentially reducing occupational stress. Children and adolescents could use

ChatGPT to gain a better understanding of mental illnesses, coping strategies, and treatment options, thus ensuring easy access to mental health support. ChatGPT and AI apps could provide a non-judgmental and accessible means of mental health care for young individuals, which could be particularly beneficial for those dealing with social anxiety disorder. ChatGPT's ability to triage patients by inquiring about their symptoms and medical history could help determine the severity and urgency of their condition, providing 24/7 support in cases of crisis [23,26]. It could be instrumental in managing suicidal ideation or panic attacks when access to professionals is not readily available, even providing contact information for suicide and crisis helplines. For youngsters struggling with time management and organization, ChatGPT could break down complex assignments into manageable steps, thus aiding in managing anxiety related to feeling overwhelmed. Human interactions in therapy may carry subconscious biases, which ChatGPT could mitigate, especially for children and adolescents who might be apprehensive about their therapist judging them or sharing sensitive information. In light of these capabilities, ChatGPT appears poised to redefine the future of mental health and neuroscience. However, it is essential to acknowledge and address the limitations and ethical concerns associated with its use, as discussed throughout this article. To fully harness its potential, ChatGPT will need careful oversight and control [23–27].

5. Ethical consideration

While the potential of ChatGPT in neuroscience research is immense, there are challenges and ethical considerations that need to be addressed. From the lessons learned following the recent temporary ban of ChatGPT in Italy, ensuring the privacy and confidentiality of participants in interactive experiments involving ChatGPT is crucial [28,29]. Additionally, biases present in the training data can influence the generated responses, potentially leading to skewed results. Careful scrutiny and transparency are necessary to minimize such biases and prevent inadvertent propagation of misinformation.

Furthermore, it has the potential to manipulate emotions and behaviour, such as using it to generate responses that encourage product purchases. Finally, ChatGPT may perpetuate biases and stereotypes learned from its training data, potentially generating biased responses. Addressing these concerns requires careful attention, including scrutinizing training data, implementing safeguards, and promoting transparency and accountability [30].

6. Conclusion and future outlook

In this paper, we've explored the vast potential of ChatGPT in reshaping neuroscience research, from hypothesis generation to data analysis, interdisciplinary collaboration, and educational enhancement. Notably, ChatGPT's remarkable contributions extend to the realm of mental health, particularly in the context of child and adolescent care. It can swiftly analyze text from young patients, identifying patterns and correlations that unveil underlying mental health issues, revolutionizing the way clinicians approach assessments and treatment. By assessing negative cognitive distortions in real-time through language analysis, ChatGPT enhances diagnostic accuracy, evaluates early treatment responses, and facilitates proactive adjustments in treatment plans. Furthermore, its language processing capabilities enable precise translation of medical terminology, promoting effective communication between young patients and mental health professionals.

ChatGPT's potential to integrate with healthcare devices and support mental health education further underscores its transformative capacity. Nonetheless, it's crucial to acknowledge and address the limitations and ethical concerns associated with its use, as discussed throughout this article. To fully harness its potential, ChatGPT will require careful oversight and control, especially in the sensitive field of child and adolescent mental health. These challenges and opportunities signal the need for ongoing research and development to leverage ChatGPT's full capabilities while maintaining ethical and scientific standards in neuroscience research.

Use of AI tools declaration

We have used ChatGPT to delve into its roles and its responses have been illustrated in Georgia 11 pt font, in order to distinguish it from our original writing. Note that the order of ChatGPT's answers from (1) to (5) has been changed from its original response in order to increase readability and clarity of the article. Further, this work was prepared independent from our institution.

Conflict of interest

The authors have no conflicts of interest in this paper.

Ethics declaration

The author declared that the ethics committee approval was waived for the study.

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