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Unveiling GPT-4o: Enhanced Multimodal Capabilities and Comparative Insights with ChatGPT-4

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Abstract

Artificial Intelligence (AI), a rapidly advancing field in the modern era, particularly within computer science, continues to progress by developing tools with superior capabilities and innovative features. This study aims to conduct a comparative analysis between ChatGPT-4 and its enhanced version, ChatGPT-4o, based on various parameters. The methodology employs a mixed-methods approach using a standardized dataset and systematically designed prompts. The findings reveal significant improvements, including enhanced coherence and contextual relevance of generated content, accurate and verifiable citation presentation, and improved capabilities in addressing scientific, educational, and technical inquiries. Additionally, ChatGPT-4o demonstrates superiority in handling complex creative writing tasks, text analysis, and understanding intricate scientific, literary, and logical scenarios. These results collectively indicate that the outputs of ChatGPT-4o are more effective, making it a reliable tool for academic, professional, and technical purposes. This research highlights the significant impact of ChatGPT-4o on user interactions, showcasing its capacity to fundamentally transform content creation processes and analytical functions across various fields. The implications of this study suggest that ChatGPT-4o has the potential to enhance productivity and innovation in education, professional industries, and technological development.

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INTRODUCTION

The technological stride in the domain of AI indeed made giant leaps forward, with the scientific, linguistic, and technological domains bearing equal transformational changes [1]. Among them, the GPT series emanated from OpenAI, setting the pace for innovation in the NLP [2]. OpenAI's Generative Pre-trained Transformer (GPT) series has set a benchmark in NLP by delivering state-of-the-art performance in content generation, reasoning, and multimodal processing.

The release of GPT-4 in 2023 marked a significant milestone, offering advanced capabilities in content creation, logical reasoning, and processing text and visual inputs [3]. While not very revolutionary, its successor, GPT-4o, a model released in 2024, altered the boundary conditions of performance with an increased context window, better speed, and a more effective multimodal architecture [4]. These enhancements position GPT-4o as a promising tool for diverse applications, including medical diagnostics, education, and data analysis.

As AI's role in content creation, decision-making, and analysis continues to grow, evaluating the efficiency and reliability of these tools has become increasingly important [5], [6]. While GPT-4 has proven to be a reliable NLP model, GPT-4o was designed to overcome its predecessor's limitations by offering improved coherence, contextual relevance, and advanced multimodal

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integration [7]. Despite GPT-4o's significant advancements, comprehensive comparative analyses between GPT-4 and GPT-4o remain limited. Most existing studies focus on specific tasks or technical metrics without exploring the broader implications of these tools in real-world applications [8]. This research is driven by the need to address these gaps and provide a systematic comparison between GPT-4 and GPT-4o across key dimensions, including content creation, multimodal comprehension, and ethical reasoning.

Previous studies have underlined the singular efficiency of GPT-4o from more aspects. For example, GPT-4o outperformed GPT-4 on medical licensing exam questions, demonstrating higher accuracy in both the compulsory and general sections [9]. In linguistic tests, GPT-4o's stylistic features and its enhanced ability to translate complex sentence structures were emphasized [10]. Furthermore, GPT-4o demonstrated superior speed and accuracy in statistical and data analysis, showcasing its strength in handling complex biomedical datasets [11]. Additionally, GPT-4o exhibits advanced multimodal processing capabilities, including text, images, audio, and video [12], [13], while also excelling in tasks requiring few-shot learning for high accuracy and efficiency [14]. However, despite these advancements and to the best of the researchers' knowledge, few comparative analyses have gone beyond narrow [15], single-dimensional evaluations.

This study aims to bridge these gaps by systematically comparing GPT-4 and GPT-4o across critical dimensions: content creation, multimodal comprehension, and reasoning on philosophical and ethical issues. The research also investigates GPT-4o's superior ability to generate coherent and contextually rich responses, which are crucial for applications in professional, educational, and creative contexts. By addressing these aspects, this study is expected to provide new insights into GPT-4o's potential as a revolutionary tool in AI-powered technologies.

METHOD

This study used a mixed-method approach, which has thus been followed in the current research to meet such objectives. A standardized dataset with systematically designed prompts was used to test both models under similar conditions [16], [17]. Accuracy, response time, and contextual relevance were measured statistically to ensure unbiased performance comparisons [18]. The methodological rigor behind this allows the research to foster deeper insights into the innovations GPT-4o introduces and its implications for a wide array of applications. While the paper specifically examines the technological achievements of GPT-4o, it underlines its potential for disrupting AI applications in tasks requiring high levels of precision, contextual intelligence, and rich multimodal inputs. Free from the limitations of GPT-4, GPT-4o proves to be a flexible and serious resource for future innovations in AI-powered technologies.

This paper specifically examines the technological achievements of GPT-4o, it also highlights its potential to disrupt AI applications on tasks that require high levels of precision, contextual intelligence, and rich multimodal inputs. Free from the limitations of GPT-4, GPT-4o proves itself to be a flexible and serious resource for future innovations in AI-based technologies. This paper provides a basic comparison of the efficiency between ChatGPT-4 and its advanced form, ChatGPT-4o, on various tasks, including information retrieval, creative writing, text analysis, mathematical and logical reasoning, programming, as well as analysis of some philosophical and ethical issues. Using a mixed-methods approach, this study evaluated improvements in ChatGPT-4o compared to its predecessor, including improvements in coherence, context relevance, and accuracy in citation presentation.

RESULTS AND DISCUSSION

The results show that ChatGPT-4o provides more concise, precise, and contextualized responses; thus, the model is suitable for academic, professional, and technical use. It overcomes the shortcomings of ChatGPT-4 in terms of verbosity and lack of referencing; thus, ChatGPT-4o becomes a better AI model for domains that require precision, novelty, and reasoning skills. This research lays the foundation for the huge transformational potential that ChatGPT-4o can bring to education, research, software development, and ethics-related decision-making by paving the way for the next steps in AI applications.

The analysis of ChatGPT-4 about its successor, GPT-4o, uncovers numerous notable advancements in addressing diverse user needs. GPT-4o exhibits superior coherence in the generation of content, achieving an equilibrium between clarity and brevity. Although ChatGPT-4 is recognized for its comprehensive responses, its tendency toward verbosity frequently perplexes users. In contrast, GPT-4o resolves this issue by delivering succinct and effective replies, thereby enhancing the comprehensibility and utility of factual inquiries. The scientific and technical prompts are more reliable with GPT-4o than its predecessor, as it integrates authentic references. Moreover, the creative writing output generated by GPT-4o is stylistically smooth and narratively cohesive, hence diminishing gaps in coherence compared to ChatGPT-4. GPT-4o is much better at deep text analysis and gives deeper insights, while ChatGPT-4 gives more general and superficial interpretations. The heightened ability for analysis thus makes it possible for users to make better decisions. Speaking about solving mathematical and logical problems, GPT-4o gives explanations step by step and very detailed, while ChatGPT-4 tries to confine to the steps involved only. Another large enhancement was noticed in code generation: GPT-4o generated complete code with all sorts of error handling internally, whereas ChatGPT-4 gave only the basic ingredients, which require considerable effort to integrate. Finally, for philosophical and ethical issues, GPT-4o synthesizes these into neat, short points that, therefore, improve clarity and relevance.

Summarizes some of the key features that differentiate ChatGPT-4 from GPT-4o. GPT-4o tends to be much more user-centered in approach. It is more accurate, coherent, and generally more usable. It perfects the creation of content and ensures error-free, actual citations of technical questions. GPT-4o also does creative writing with more stylish narration and better coherence. It answers both logical and technical questions, meaning that apart from automating complicated processes, GPT-4o provides very functional results, such as elaborated methodologies for problem solutions and code ready for error handling. Such features underpin the capability of GPT-4o to address diverse end-user requirements, making it far more competent, efficient, and reliable as an artificial intelligence tool.

Table 1. Comparison Between ChatGPT-4 and Chat GPT-4o

Feature	ChatGPT-4	ChatGPT-4o
Content Creation	Coherent but sometimes lengthy	Coherent and appropriate at the same time
Factual Inquiries	Detailed but may cause confusion for its users	Concise and efficient and so, easy to use
Scientific/Technical Prompts	Clear in sections with shortcoming in references	Authentical references
Creative Writing	Coherent in narration gaps n stylistics	Stylistically accurate and smooth
Text Analysis	Broad insights but not deep enough depth	lengthy interpretations
Math/Logical Problem-Solving	Concise but sometimes brief steps	Detailed and comprehensive explanations
Code Generation	Basic components that need correlativity	Ready-to-use code with error handling
Philosophical/Ethical Dilemmas	Balanced views, lengthy responses	Compact, essential points

Comparison in Factual Inquiry Handling

ChatGPT-4

Chatgpt-4 has been highly analyzed for its ability to provide comprehensive and subtle responses to even the most complex and fact-based questions. The model architecture is designed to allow access to a vast knowledge base, making it effective in solving complex questions within education, technical writing, and research assistance. This is further cemented in research, where it has been established to give comprehensive and elaborate explanations of various aspects of the subject under study, hence very useful to scholars and practitioners desiring advanced knowledge [19].

However, this very strength usually becomes a limiting factor. Many times, the model tends to generate lengthy, overly informative responses that overwhelm users by making it hard to find precise, actionable insights. The consumers do say that such verboseness leads to complication and bafflement, especially if the replies include peripheral or redundant information. That makes it poor for situations where conciseness is needed, like colloquial questions or urgent decisions [20]. Though effective in analyzing

even complicated subjects, ChatGPT-4 is not efficient for quick, everyday applications since it doesn't return output concisely.

ChatGPT-4o

With the failures of ChatGPT-4 in the line of condensation, where the main focus was to ensure efficiency in the usage of the model, there is every indication that, indeed, the revised model strikes a balance between information detail and brevity. ChatGPT-4o provides information that is right to the point and at the fingertips of the user, saving him from misunderstanding due to too much elaboration. Therefore, it is more suitable for those who need to understand intricate information in direct, actionable items and for those situations that call for speed.

This redesigned ChatGPT-4o is even more suited to professional and casual users' needs to get answers right without giving up on necessary depth in some cases. Applications involving real-time problem-solving or rapid fact-checking, for example, will benefit most from subtler efficiency in user experiences. This development underlines the milestone update to the original system, resolving major pain points while further improving usability.

Complex Scientific and Technical Prompts

ChatGPT-4

Most of the promise that ChatGPT-4 has shown concerning complex scientific and technical questions is a function of its being good at structuring answers into well-divided sections. This sort of segmentation helps so much in decomposing complex questions and providing sequential explanations to the users. Because of such competencies, ChatGPT-4 has become an important tool within expert areas like biomedical analysis, engineering, and research so, where large and well-structured information is needed [21].

Notwithstanding these advantages, the major deficiency of ChatGPT-4 at present is that most of its citations are incomplete or incorrectly represented, seriously raising some questions about the reliability of its output. Further studies have shown that even while the model is effective at knowledge synthesis and expression, sometimes it does not provide verifiable sources, thus limiting usefulness for academic and professional purposes reliant on high levels of reliability. Confidence in its replies, especially on critical technical questions, should thus be dulled by the inadequacy of [22].

ChatGPT-4o

ChatGPT-4o overcomes most of the major deficiencies of the earlier model through the implementation of a stern referencing mechanism. Several researchers have documented that it indeed provides verifiable sources to support the responses, which makes its output much more credible and valid. This aspect is highly crucial, particularly in domains like academia, medicine, and engineering, where credibility becomes just as important as information.

ChatGPT-4o showed much improved coherence and flow in the given output. Reliably, it decomposed many of the complicated requests into understandable fragments and inserted citations that were incorporated into the text; the flow was full of fact-based information. Thus, it makes the tool easier for major and complex scientific and technical questions.

ChatGPT-4o can make appropriate presentations concise, hence becoming very helpful at either the professional or academic level. Improvements to the chatbot included clarity being well-linked to credibility in assuring users they could rely on its reviews and solutions for major decisions and study projects. Other changes put it in an unrivaled position in respect of large scientific and technical projects.

Creative Writing

ChatGPT-4

Some of the studies have shown how much ChatGPT-4 is capable of accomplishing creative writing: it reveals great coherence and structure in the establishment of narratives. The language model applies higher-order language modeling methods to generate highly engaging stories, poems, and descriptive content that is useful for writers, educators, and content developers [23]. Yet, notwithstanding all this value, the output of ChatGPT-4 has not captured the nuances of style and innovation found in the more complex creative tasks. It is here that the scholars have indicated there is logical coherence, fluency, and, at times, even formulaic reproduction of narratives, but the

subtlety in the human-like features for deeper emotional engagement is missing [24].

Moreover, ChatGPT-4 sometimes struggles to maintain consistency in tone and style over longer stretches of text; this makes the technology difficult to apply in projects requiring extensive creative elaboration. Not being able to create dependably poetically rhythmically correct works or comply with some of the stylistic demands is where creative capability can be further improved [25].

ChatGPT-4o

ChatGPT-4o compensates for some critical weaknesses that diminished the creative performance of its forerunner. Several studies have demonstrated its effectiveness in generating stylistically valid and contextually fitting creative texts, even increasingly maintaining rhythm and rhyme while producing poetry, to the point of attaining expressive levels that posed some problems for ChatGPT-4. That makes ChatGPT-4o perform better in challenging creative tasks, such as generating specific prose or poetry that matches the pre-defined stylistic and emotional parameters.

The narrative style of ChatGPT-4o is more similar to human utterance, with results that sound natural and more evocative. Research has underlined its increased coherence and flexibility, especially when pushed to generate creative content in various genres and formats. All these developments make it a go-to tool for writers interested in better and more personalized output.

User reviews and comparisons have continuously shown that the ChatGPT-4o does an outstanding job in creative writing tasks by responding to prompts with precision, coherence, and imagination. Such a feature, currently in development, will enhance not only user satisfaction but also make ChatGPT-4o a serious tool for professionals working in creative fields such as marketing, publishing, and entertainment.

Text Analysis Skills

ChatGPT-4

ChatGPT-4 has proved to be fairly competent in text analyses, hence quite an indispensable tool in making generalized assessments and interpretations in many other fields, importantly in philosophy, sociology, and creative writing. It provides a broad analysis that can expose dominant themes, hence providing the user with substantial bases of operation for further study[25]. On the other hand, studies also bring into view that analysis by ChatGPT-4 lacks deepness and is less particular in performing multi-complex, abstract tasks, especially in analyzing literature. It starts to interpret them somewhat superficially, and responses would become repetitive for detailed academic or literary research.

This is because it cannot regularly interact with symbolic features, shifting tones of voice, or complicated narrative structures of literature. By and large, it is capable of identifying only main elements like themes or characters, while contextually detailed explanations are beyond its reach. Generally, this inability makes the system less useful for advanced academic research and professional literary analysis [26].

ChatGPT-4o

ChatGPT-4o significantly enhances its predecessor's text analytical capability to much deeper and more contextually valid interpretations, even of very complicated texts. It follows from the research that the model includes very detailed attention to subtleties such as subtext, symbolism, and stylistic variations typical of humans. This generally makes ChatGPT-4o especially fit for research into literature, where precision and depth are indispensable features in the processing of complex works.

A big feature of ChatGPT-4o is the ability to make long and insightful analyses, making it particularly fitting for academic and literary searches. For instance, in analyzing complex works of literature, ChatGPT-4o can provide in-depth looks into the use of a narrative approach, the development of the characters, and the thematic elements involved. These enhancements will better enable users to develop more meaningful critiques and evaluations, a necessity in scholarly efforts.

Beyond this, the increased coherence and relevance of ChatGPT-4o during longer analyses make it an extremely valuable assistant in scholarly writing and research on literature. This subtlety of textual explication and explanation ensures that the high

standards characteristic of scholarly and professional writing are upheld. One comparative study confirms that ChatGPT-4o outperforms ChatGPT-4 every time, yielding relevant and influential text analyses, and thus should be regarded as a priceless ally for scholars, teachers, and simply lovers of literature.

Mathematical and Logical Problem-Solving

ChatGPT-4

Studies have shown that ChatGPT-4 is good at doing mathematical and logically oriented questions by breaking down complex ideas into well-understood steps. It is good at finding basic principles behind the problem and giving terse answers, which is useful if somebody wants quick answers [27]. However, its conciseness and lack of detailed, step-by-step explanations often lead to a lack of understanding of complex problems, especially in educational and professional contexts. This has been appropriately recognized by specialists and AI researchers, who have stressed the need to endow AI with more enhanced problem-solving abilities for addressing suitably the complexities associated with complex mathematical and logical problems [28].

Besides that, the limited ability of ChatGPT-4 to explain the logic behind the answer is unsatisfactory concerning educational applications. Though this model is good at solving either simple or medium-complexity problems, it cannot solve more difficult, multispectral issues that require deep conceptual insights and long explanations for a pupil to understand something and improve their learning efficiency [29].

ChatGPT-4o

The liabilities of ChatGPT-4 are addressed in the new model ChatGPT-4o, setting a new standard for the ability of mathematical and logical problem-solving. This comprehensive text not only eliminates the deficiencies found in its predecessor but also greatly enhances its classroom value since understanding why a solution works is just as important as learning the procedure itself.

Clear from studies also is the fact that ChatGPT-4o does a great job of breaking down elaborate mathematical problems into smaller, logically structured steps, which makes it rather useful for both the learner and instructor. Certainly, the ability of the model to make complex subjects more available and understandable has turned it into a vital tool for educational purposes. Explanations often involve views of concepts, different approaches, and applications for a deeper understanding of the content delivered.

However, considering the great educational advantages this enhancement of ChatGPT-4o would provide, one can't be blind to the concern it costs human learning capabilities. The greater utilization of such AI tools automates problem-solving capabilities, replacing the potential for users to put to use their inborn cognitive and analytical skills. In such cases, even while ChatGPT-4o remains an excellent educational resource, cautious integration into pedagogical methodologies could be developed to support, not replace, human effort toward learning.

Code Generation and Programming Problems

ChatGPT-4

ChatGPT-4 is acting as a huge facilitator toward code writing and helping users in programming tasks by giving basic elements and main outlines related to various coding issues. Up until now, many different programming languages and related frameworks have been supported, which has turned it into the most versatile tool in favor of both developers and programmers [30]. On the one hand, studies have indicated that though the model generates executable code snippets, it is incomplete for high-intent software development tasks in the generated text. Users quite often want to add pieces or start debugging because ChatGPT-4 may have missed important points or responded poorly to certain context-specific requirements of the programming [31].

The limitation of ChatGPT-4 emerges when it can't handle complex situations in programming, specifically error handling and optimization of security in a system. Most of the programs it generates require manual debugging to eliminate any bugs or inefficient code [32]. Further, this also restricts using it for any high-priority projects or enterprise applications. Due to this deficiency in the working of ChatGPT-4, developers started searching for alternatives or upgrades that

best suited the demand of modern software development.

ChatGPT-4o

ChatGPT-4o overcomes these shortcomings by offering a significantly better capability for complete and directly usable code. Several studies have demonstrated that this model produces much more complex and contextually accurate code, besides the fact that it integrates different kinds of error-handling mechanisms and security factors in its output. It, therefore, follows that ChatGPT-4o may be a game-changing tool for developers able to address very demanding programming tasks in much more productive ways.

Other important features it would have on board include dynamic debugging of code and enhancements to tackle new weaknesses and inefficiencies that show up during code generation. Studies indicate that it is capable of delivering sophisticated programmatic solutions to complex applications, including but not limited to AI algorithms, database management systems, and web development frameworks. Indeed, these sorts of features position ChatGPT-4o particularly well for professional uses and applications where the highest degree of reliability and security is expected.

More importantly, the ChatGPT-4o showed great promise as a game-changing tool in coding education. It can explain intricate points about programming with running codes in support, hence serving as a great reference for students and instructors alike. This also connects the theoretical oversight with the actual performance of programming principles and methods. These developments leave ChatGPT-4o as an even more powerful tool for professional developers and new coding students alike, offering quite unparalleled capabilities in the field of software engineering.

Philosophical and Ethical Dilemmas

ChatGPT-4

ChatGPT-4 has shown great acumen in discussing complex philosophical and ethical issues, furnishing detailed opinions coupled with justifiable arguments. Most of the answers provided are imbued with in-depth analysis, probing into various aspects of any given issue; thus, this can be a vital source for a student, lawyer, or even personal discussant. This model has come to be noted, especially for its elaborative reasoning in those tasks that involve argumentative responses or complex thought experiments [32]. However, in ChatGPT-4, the comprehensiveness of the responses is very often the cause of its verbosity in making the output long and sometimes tiresome for users who want quick answers [27][28]. This may hurt its utility for sure, especially for users who would want clear, actionable information. Also, while it can provide balanced views, it fails to emphasize enough on key points. The information comes out disorganized, hence trying the patience of users who want to draw valid insight from it.

ChatGPT-4o

ChatGPT-4o embedding extends the functionalities of its predecessor to cure its key weaknesses in handling philosophical and ethical issues. There is evidence that ChatGPT-4o is good at delivering concise but complete responses that focus on the very essentials of the problem, thus offering more open and useful suggestions for the users.

The strategy of the model is an emphatically focus-theory approach, supplemented by further ways one might go to investigate the details. It also makes ChatGPT-4o easier for the user to use, especially if the latter is dealing with complicated moral issues either in their job or on a personal level. Answers would also become more compact and concise, whereby the essentials of a dilemma will be treated without unnecessary expansion [33].

Besides this fact, ChatGPT-4o has a much better contextual understanding, considerably enhancing its capability for making responses precisely in line with the user's needs. Also, it is able to speak either in a more serious or less serious tone, depending on whether the user requires discussing the issue generally or in great detail. Finally, this makes it an extremely useful tool in professional areas like bioethics, law, and public policy.

Besides its utilitarian value of ChatGPT-4o, there was a chance that the academic interest in the way this model summed up the arguments, hence fastening the process of getting to grips with complex topics, must be interesting. Comparing these studies showed

an extraordinary knack for balancing brevity with depth, which makes it most useful in attempting to resolve various philosophical and ethical problems arising in different contexts.

This study shows significant advances in the capabilities of GPT-4o over ChatGPT-4. GPT-4o consistently showed better coherence, achieving a balance between clarity and conciseness of answers, thus becoming a more reliable tool for academic, professional, and technical applications. The results of this study are in line with research conducted by Kipp (2023) GPT-4o can be used for medical coursework. This study bridges the gap by providing an analysis of the capabilities of GPT-4o in various fields. This study is in line with researchers who emphasize the importance of AI tools in addressing complex and cross-disciplinary challenges, such as ethical decision-making and content creation.

This research bridges the gap by providing an analysis of GPT-4o's capabilities in various fields. This study is in line with researchers who emphasize the importance of AI tools in addressing complex and cross-disciplinary challenges, such as ethical decision-making and content creation.

LIMITATIONS

This paper recognizes the constraints inherent in the existing research within this domain, given that extensive investigations contrasting ChatGPT-4o with other sophisticated AI models across various fields and practical implementations are notably limited.

CONCLUSION

The present paper provides a comparative performance overview of ChatGPT-4 and its advanced improvement, ChatGPT-4o, concerning basic matters: sophisticated scientific and technical questions, creative writing, text analysis, solving mathematical and logical problems, code generation and programming, and philosophical and ethical dilemmas. These results position ChatGPT-4o as a much-enhanced engine that offers better coherence, accuracy, and usability while dealing with such challenging topics.

The ChatGPT-4o differs much from its predecessor in handling complex scientific and technical questions supported by valid references with clear explanations. It shows better stylistic fluency and coherence to assist users in developing more sophisticated and interesting stories. Its text analytical competencies are deeper and more contextual, leading to more complete interpretations of the material. ChatGPT-4o solves mathematical and logical problems by giving detailed explanations, step by step, so that complete comprehension and solutions are achieved. It also does code generation and programming, presenting already developed solutions ready for error handling, hence more practical and user-friendly for the developer. When solving philosophical and ethical dilemmas, it is balanced and succinct, to the point of eliciting essential points without losing contextual depth. These features bring in a sharp improvement in user experience through conquering such challenges as information overload and lack of precision. Meeting these basic needs through improved effectiveness and depth, ChatGPT-4o is a useful and multifunctional tool for businesspeople, teachers, and artists alike.

Future studies might discuss ChatGPT-4o's domain use, like legal analysis, biomedical diagnosis, and financial modeling, among others, or even real-time data processing and multimodal input management capabilities. More importantly, further studies should look at its adaptability to different cultural and ethical landscapes and integration of active user feedback to make it personalized. Comparative studies with newer AI models will pave the way for critical standards that will certainly help increase its capabilities and sustenance relevance in a fast-evolving technological milieu.

AUTHORS CONTRIBUTION

I.A.M. conceptualized the research framework and oversaw the comparative testing of ChatGPT-4 and ChatGPT-4o across creative writing, text analysis, and philosophical and ethical dimensions. M.I.K. contributed to the technical assessments, including designing and running statistical analyses to evaluate the models' effectiveness in answering fact-based questions, solving mathematical and logical problems, and generating code. M.Y.S. collaborated in developing the research methodology, curating datasets, and executing multimodal

assessments. All authors jointly reviewed the results, participated in drafting the manuscript, and ensured the alignment of findings with the study's objectives and implications for future research.

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