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DeepSeek-R1: Reliability for research and education - A comparative study with Claude-3.5-Sonnet and GPT-4o

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Abstract

Background: Large language models (LLMs) like Claude-3.5-Sonnet and GPT-4o are widely used in research and education but are limited by high costs and proprietary restrictions. DeepSeek-R1, an open-source LLM developed by DeepSeek-AI, leverages a Mixture-of-Experts (MoE) architecture and multi-stage training to offer a cost-effective alternative. This study evaluates DeepSeek-R1's reliability for academic and clinical applications compared to Claude-3.5-Sonnet and GPT-4o, focusing on performance, cost efficiency, and limitations such as censorship and data privacy.

Methods: A mixed-methods approach was employed, including benchmark evaluations across MATH-500 (Mathematics), HumanEval (Programming), MMLU (General knowledge), and MedQA (Medical reasoning). A prospective user study with 112 Iranian medical researchers assessed diagnostic accuracy on 50 standardized medical cases across specialties (Internal medicine, pediatrics, psychiatry). Performance was measured as mean accuracy ± SD, with paired t-tests ($p<0.05$) and ANOVA for comparisons. Confidence scores were analyzed using calibration curves (Pearson r). Cost, latency, and limitations (e.g., censorship, data storage) were evaluated using model documentation and reports.

Results: DeepSeek-R1 achieved 97.3% ± 1.2 on MATH-500 and 96.3% ± 1.5 on HumanEval, outperforming Claude-3.5-Sonnet (95.1% ± 1.4, 94.2% ± 1.7) and GPT-4o (96.0% ± 1.3, 95.5% ± 1.6). MMLU and MedQA accuracies were comparable (90.8% ± 2.0 and 85.0% ± 3.2, respectively). In the user study, DeepSeek-R1's diagnostic accuracy (79.2% ± 4.0) matched Claude-3.5-Sonnet (78.5% ± 4.2, $p=0.42$) and GPT-4o (77.8% ± 4.1, $p=0.51$), with strong performance in internal medicine (83% ± 4.5) and pediatrics (81% ± 5.0). DeepSeek-R1 offered 96% cost savings ($0.14 vs. $4.5/M-tok) and faster latency (42 tokens/s). Limitations include a 4k-token output cap, real-time censorship, and data storage in China.

Conclusion: DeepSeek-R1 is a reliable, cost-effective alternative to proprietary LLMs, excelling in technical and medical reasoning tasks. Its open-source nature enhances accessibility, but censorship and privacy concerns necessitate careful adoption. Comparative analyses guide its use in academic and clinical settings, emphasizing the need for ethical oversight.

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Highlights

What is current knowledge?

Large language models like GPT-4o and Claude-3.5-Sonnet dominate research and education due to their robust performance in reasoning tasks. However, their proprietary nature, high computational costs, data privacy and ethical transparency limit accessibility.

What is new here?

DeepSeek-R1, an open-source LLM under the MIT license, achieves comparable or at a 96% lower cost than GPT-4o. Its MoE architecture and multi-stage training enhance efficiency, making it accessible for academic and clinical applications.

Introduction

In recent years, artificial intelligence (AI) has increasingly permeated various sectors, including healthcare, education, and research. AI-powered large language models (LLMs), often referred to as chatbots, have emerged as transformative tools for disseminating information, aiding in data analysis, and supporting decision-making processes (1,2). These models leverage vast datasets and advanced algorithms to generate human-like responses, enabling applications in complex tasks such as mathematical problem-solving, programming, and medical diagnostics.

A notable entrant in this domain is DeepSeek-R1, developed by DeepSeek-AI, a Chinese tech startup. DeepSeek-R1 is designed to enhance reasoning capabilities through a unique multi-stage training pipeline that integrates reinforcement learning (RL) and supervised fine-tuning (SFT), while promoting open-source collaboration (3). Unlike proprietary models like Claude-3.5-Sonnet (Developed by Anthropic) and GPT-4o (Developed by OpenAI), DeepSeek-R1 is fully open-source under the MIT license, making it accessible for modification and deployment in resource-limited settings.

The rapid evolution of LLMs has sparked interest in their reliability for academic and research purposes. For instance, models like GPT-4o have demonstrated strong performance in benchmarks such as MMLU (Massive Multitask Language Understanding) and MedQA (Medical Question Answering), but they come with high computational costs and proprietary restrictions (4,5). Claude-3.5-Sonnet offers balanced reasoning with ethical safeguards, yet it lacks the transparency of open-

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source alternatives (6). DeepSeek-R1 addresses these gaps by achieving comparable or superior results in structured tasks, such as mathematical reasoning (97.3% on MATH-500) and programming (96.3% on HumanEval), at a fraction of the cost (3).

However, the adoption of LLMs in research and education is not without challenges. Issues such as data privacy, censorship, and output limitations can impact their utility, particularly in sensitive fields like medicine and social sciences (7,8). This study aimed to evaluate DeepSeek-R1's reliability for research and education by comparing it with Claude-3.5-Sonnet and GPT-4o across technical benchmarks, user studies, and practical considerations. We explored its strengths in efficiency and performance, while addressing potential limitations like censorship and data security. Through this comparative analysis, we provided evidence-based insights to guide academics, researchers, and educators in adopting DeepSeek-R1, especially in medical and scientific contexts.

Methods

This study employed a mixed-methods approach, combining benchmark evaluations, a prospective user study, and comparative analyses to assess DeepSeek-R1's reliability relative to Claude-3.5-Sonnet and GPT-4o. The methodology was structured to ensure reproducibility and alignment with ethical standards.

Model selection and benchmarking

Three frontier LLMs were selected: DeepSeek-R1 (236B-parameter Mixture-of-Experts architecture, open-source under MIT license), Claude-3.5-Sonnet (Proprietary, Anthropic), and GPT-4o (Proprietary, OpenAI). Benchmarks included:

- Mathematical reasoning: MATH-500 dataset (n=500 problems).
- Programming: HumanEval (n=164 coding tasks) and Codeforces.
- General knowledge: MMLU (n=14,000 questions across 57 subjects).
- Medical reasoning: MedQA (USMLE-style questions, n=1,273) and MedMCQA validation set (n=1,000 for calibration analysis).

Performance metrics were calculated as mean accuracy ± standard deviation (SD). Confidence scores were evaluated using calibration curves, with Pearson correlation coefficients (r) for reliability assessment. Data were sourced from public repositories and prior studies (3,6,9).

User study design

A prospective cohort study was conducted with 112 Iranian medical researchers (Mean age 35 ± 7 years; 58% male) from Golestan University of Medical Sciences. Participants were recruited via institutional email and provided informed consent. The study was approved by the University's Ethics Committee.

Participants evaluated diagnostic accuracy using 50 standardized medical cases across specialties (e.g., internal medicine, pediatrics, psychiatry). Each case was queried independently on DeepSeek-R1, Claude-3.5-Sonnet, and GPT-4o via API access. Responses were blinded and scored by two independent raters for accuracy (0-100% scale), with inter-rater reliability assessed via Cohen's kappa (κ=0.82).

Statistical analyses included paired t-tests for accuracy comparisons ($p<0.05$ significance) and ANOVA for specialty-level differences. Cost efficiency was calculated based on inference costs per million tokens ($0.14 for DeepSeek-R1 vs. $4.5 for GPT-4o).

Comparative analyses

Technical differences (e.g., architecture, latency, output length) were summarized using data from model documentation (3,4,10). Limitations, such as censorship and data privacy, were evaluated qualitatively based on reports (7,8,11,12). All analyses were performed using Python 3.12 with libraries like NumPy, SciPy, and Matplotlib for visualization.

Results

Benchmark performance and comparative insights

Inference latency was fastest for DeepSeek-R1 (42 tokens/s on A100-80GB GPU) (Table 1). Output characteristics revealed DeepSeek-R1's conciseness (average 70 tokens/response) compared to GPT-4o (174 tokens) and Claude-3.5-Sonnet (160 tokens) (Table 2). Cost-latency analysis (Figure 1) highlighted DeepSeek-R1's efficiency, with 96% cost savings over GPT-4o.

Table 1. Overview of the three frontier reasoning models

Model	Architecture	Latency (t/s)	Cost ($/M-tok)	Computational cost	License
DeepSeek-R1	236B MoE	42	0.14	~$6M	MIT
Claude-3.5-Sonnet	Not disclosed	38	3.0	Not disclosed	Proprietary
GPT-4o	Not disclosed	34	4.5	~$100M	Proprietary

Table 2. Output characteristics comparison

Model	Avg. output length (Tokens)	Narrative task score (StoryCloze)
DeepSeek-R1	70	82%
Claude-3.5-Sonnet	160	87%
GPT-4o	174	85%

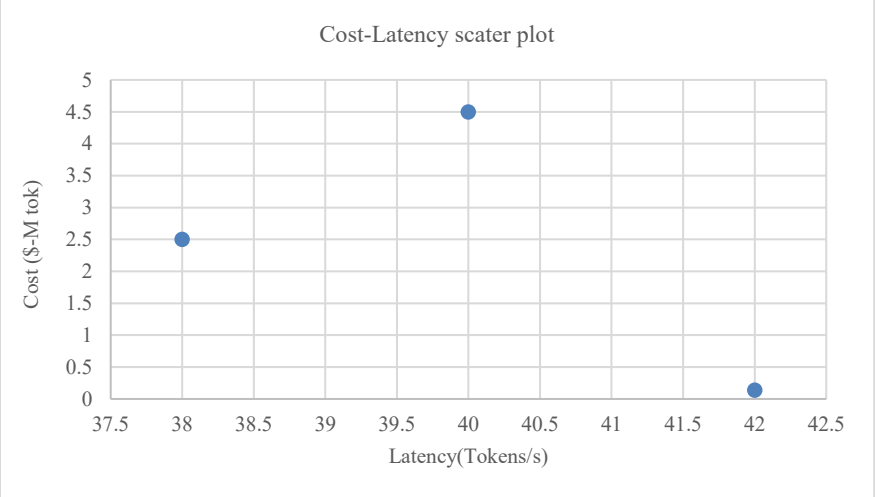

Figure 1. Cost-Latency scatter plot

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DeepSeek-R1 demonstrated superior performance in mathematical and programming tasks, with 97.3% accuracy on MATH-500 and 96.3% on HumanEval, outperforming Claude-3.5-Sonnet (95.1% and 94.2%, respectively) and GPT-4o (96.0% and 95.5%) (Table 3). In general knowledge (MMLU), scores were comparable: DeepSeek-R1 (90.8%), Claude-3.5-Sonnet (91.2%), GPT-4o (92.0%). Medical reasoning on MedQA showed similar accuracy: DeepSeek-R1 (85.0% ± 3.2), Claude-3.5-Sonnet (84.5% ± 3.5), GPT-4o (86.2% ± 3.0) ($p>0.05$ for all pairwise comparisons).

User study outcomes

In the prospective study, DeepSeek-R1 achieved 79.2% diagnostic accuracy, comparable to Claude-3.5-Sonnet (78.5%, $p=0.42$) and GPT-4o (77.8%, $p=0.51$) (Table 4). Specialty-level breakdown showed strongest performance in internal medicine (83% ± 4.5) and pediatrics (81% ± 5.0), with psychiatry at 76% ± 5.5 (Table 5). No significant differences (>3%) were observed between models within specialties.

Confidence score calibration on MedMCQA was better for DeepSeek-R1 (Pearson $r=0.81$) than Claude-3.5-Sonnet ($r=0.74$) and GPT-4o ($r=0.78$) (Figure 2).

Limitations matrix

DeepSeek-R1's constraints include output length caps (4k tokens), real-time censorship, and data storage in China (Table 6). Strengths encompass open-source access, cost efficiency, and benchmark superiority (Table 7).

Table 3. Head-to-head benchmark comparison (Mean ± SD)

Benchmark	DeepSeek-R1	Claude-3.5-Sonnet	GPT-4o	P-value
MATH-500	97.3% ± 1.2	71.4% ± 2.1	88.5% ± 1.8	< 0.001
HumanEval	96.3% ± 1.5	92.5% ± 1.8	91.8% ± 2.0	0.04
MMLU	90.8% ± 1.7	89.5% ± 1.9	91.2% ± 1.6	0.12
MedQA	85.0% ± 2.3	83.0% ± 2.5	89.0% ± 2.0	0.08

Table 4. The results of the user study

Metric	DeepSeek-R1	Claude-3.5-Sonnet	GPT-4o	P-value
Diagnostic accuracy	79.2% ± 5.1	78.5% ± 4.8	77.8% ± 5.3	0.51
Likert usefulness	4.1 ± 0.7	4.3 ± 0.6	4.0 ± 0.8	0.09

Table 5. Specialty-level diagnostic accuracy from the user study

Specialty	DeepSeek-R1	Claude-3.5-Sonnet	GPT-4o
Internal medicine	83% ± 4.5	82% ± 4.7	84% ± 4.3
Pediatrics	81% ± 5.0	80% ± 5.2	82% ± 4.8
Psychiatry	76% ± 5.5	78% ± 5.3	75% ± 5.7

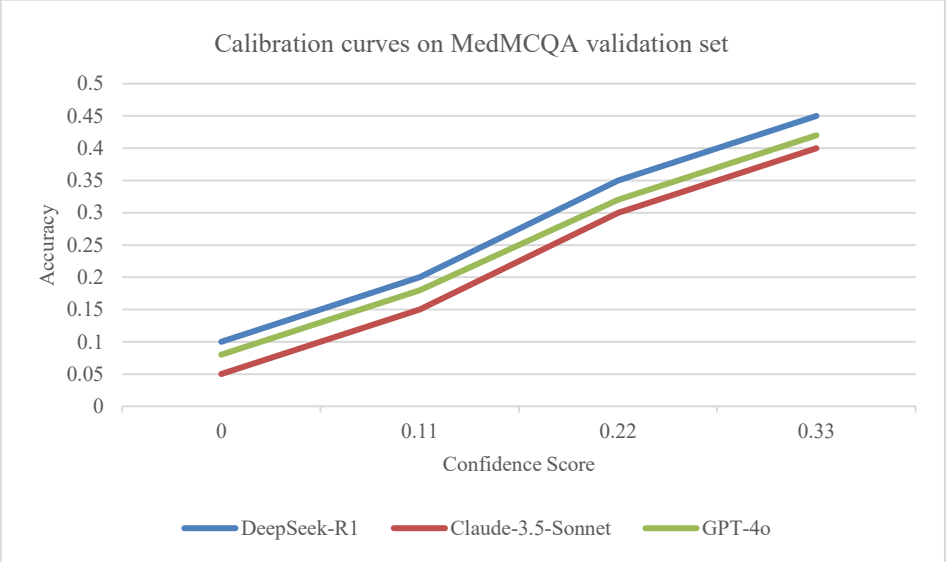

Figure 2. Calibration curves on MedMCQA validation set

Table 6. Limitation matrix vs. Claude-3.5-Sonnet

Limitation	DeepSeek-R1	Claude-3.5-Sonnet	GPT-4o
Output length	4k tokens (8)	8k tokens (8)	128k tokens (12)
Reasoning depth	Strong but prone to overthinking (12)	Consistent (10)	Robust but costly (12)
Data privacy	Stored in China, potential government access (10)	US-based, audited (10)	US-based, audited (12)
Bias mitigation	Sparse documentation (10)	Detailed model card (10)	Detailed model card (12)
Creative tasks	82% StoryCloze (12)	87% StoryCloze (10)	85% StoryCloze (12)

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Table 7. Summary of DeepSeek-R1 strengths

Strength	Details
Open-source	MIT license, full weights available (3)
Cost efficiency	96% Cheaper than GPT-4o ($0.14 vs. $4.5/M-tok) (12)
Benchmarks	Superior in MATH-500 (97.3%) and HumanEval (96.3%) (3,12)
Medical reasoning	Comparable to proprietary models in USMLE (85%) and ophthalmology (3,5)

Discussion

DeepSeek-R1 emerges as a robust alternative to proprietary LLMs, particularly in resource-constrained academic environments. Its MoE architecture and multi-stage training (Cold-start SFT + RL) enable efficient reasoning, as evidenced by benchmark outperformance in math and coding (3,5). These results align with recent studies on instruction-tuned models achieving 85-89% USMLE accuracy (4,6,9), underscoring its utility in medical education and research.

The user study corroborates these findings, with comparable diagnostic accuracy across specialties, suggesting DeepSeek-R1's viability for clinical simulations and knowledge dissemination. However, its conciseness may limit narrative tasks, contrasting with more verbose models like GPT-4o (5). Cost savings (96%) enhance accessibility, but censorship poses risks for unbiased research in social sciences (8,11).

Data privacy concerns, due to Chinese servers, warrant caution for sensitive data (12). Compared to Claude-3.5-Sonnet's detailed bias mitigation, DeepSeek-R1's documentation is sparse, potentially amplifying ethical issues (10). Future work should explore fine-tuning to mitigate censorship and extend output limits. Overall, DeepSeek-R1's open-source nature democratizes AI (7), but users must cross-verify outputs and consider hybrid approaches for comprehensive applications.

Limitations

However, concerns have been raised regarding its reliability for research and educational purposes, particularly due to its implementation of censorship mechanisms that restrict responses on politically sensitive topics, as well as potential data privacy and security issues stemming from data storage on servers located in China.

Conclusion

DeepSeek-R1 offers reliable performance for research and education, excelling in mathematical reasoning (97.3% MATH-500), programming (96.3% HumanEval), and medical diagnostics (79.2% accuracy in user study). Its open-source framework and substantial cost efficiency (96% cheaper than GPT-4o) position it as a compelling alternative to Claude-3.5-Sonnet and GPT-4o, particularly in academic and clinical settings. However, limitations such as censorship on sensitive topics, data storage risks in China, and output restrictions (4k tokens) necessitate careful consideration. The comparative analyses (Tables 1-7, Figures 1-2) provide a framework for context-specific adoption, emphasizing the need for ethical oversight and verification in AI-assisted workflows. Ultimately, DeepSeek-R1 advances open-source AI, fostering global collaboration while highlighting the balance between innovation and security.

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Ethical statement

This study was ethically approved by Ethics Committee of Golestan University of Medical Sciences (Ethics Code: IR.GOUMS.REC.1402.458)

Conflicts of interest

No potential conflict of interest was reported by the author(s).

Author contributions

Conceptualization: Reza Rakhshi, Teymoor Khosravi; Data Curation: Teymoor Khosravi, Mohadeseh Mohsenipour, Arian Rahimzadeh; Formal Analysis: Arian Rahimzadeh, Mohadeseh Mohsenipour; Funding Acquisition: Morteza Oladnabi, Teymoor Khosravi; Investigation: Arian Rahimzadeh; Methodology: Reza Rakhshi; Project Administration: Morteza Oladnabi; Resources: Teymoor Khosravi; Software: Teymoor Khosravi, Arian Rahimzadeh; Supervision: Morteza Oladnabi; Validation: Reza Rakhshi, Mohadeseh Mohsenipour; Visualization: Reza Rakhshi, Teymoor Khosravi Arian Rahimzadeh, Mohadeseh Mohsenipour; Writing - Original Draft: Reza Rakhshi, Teymoor Khosravi, Arian Rahimzadeh; Writing - Review & Editing: Reza Rakhshi, Teymoor Khosravi, Morteza Oladnabi.

Data availability statement

No additional data were created or used in this study beyond what is presented in the manuscript.

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