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Modeling the Impact of AI Tool Usage on Independent Thinking: Evidence from a Multivariate Regression Analysis

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Abstract: The rapid integration of Artificial Intelligence (AI) tools into academic and professional contexts has raised important concerns regarding their impact on cognitive processes, particularly independent thinking. This study aims to examine how different patterns of AI tool usage influence independent thinking using a multivariate regression framework. Data were collected from 181 students through a structured questionnaire, focusing on key variables such as time spent on AI usage, verification of AI responses, unverified AI reliance, and avoidance of thinking. The study adopts a quantitative research design and employs multiple linear regression analysis to examine the relationship between AI usage patterns and independent thinking. The analysis was conducted using the Google Colab platform, which provides a cloud-based environment for executing Python code. Data preprocessing and analysis were performed using libraries such as Pandas, NumPy, and Statsmodels. This approach enables efficient data handling, model estimation, and statistical validation, ensuring robustness and reproducibility of the results. By analyzing multiple dimensions of user interaction with AI tools, the study aims to provide a nuanced understanding of how technology-mediated behaviors influence cognitive outcomes. The findings contribute to the emerging literature on human AI interaction by highlighting the importance of user engagement patterns in determining cognitive implications. The study offers practical, policy, and technological insights, emphasizing the need for responsible and reflective use of AI tools to preserve independent thinking in increasingly technology-driven environments.

Keywords: Artificial Intelligence, Independent Thinking, Cognitive Offloading, Regression Analysis, AI Usage Behavior.

1 INTRODUCTION

The rapid growth of Artificial Intelligence (AI) tools has significantly transformed the way individuals access, process, and utilize information in academic, professional, and everyday environments. Digital technologies and internet-based platforms have increasingly become an extension of human cognitive activity, enabling users to obtain information instantly and complete tasks with minimal effort [1], [2]. The widespread integration of online systems and intelligent applications has altered traditional learning and thinking processes, raising important questions regarding their influence on human cognition and intellectual autonomy [3].

Recent technological advancements have further accelerated the use of AI-driven systems such as generative AI, conversational agents, and intelligent recommendation tools. These systems provide immediate responses, automate analytical tasks, assist in writing and design activities, and support decision-making processes across multiple domains [5], [6]. Although AI tools offer substantial benefits in terms of efficiency, productivity, and accessibility, researchers have expressed concerns regarding their possible cognitive consequences, particularly in relation to independent thinking and critical reasoning [4].

Independent thinking refers to the ability of individuals to evaluate information, analyze alternatives, and make reasoned judgments based on reflective and autonomous cognitive processes rather than depending entirely on external assistance. It plays a crucial role in problem-solving, creativity, innovation, and effective decision-making. However, excessive reliance on AI-generated outputs may reduce the need for deep cognitive engagement and reflective analysis. The concept of cognitive offloading explains this phenomenon, where individuals depend on external technologies to perform mental tasks that would otherwise require internal cognitive effort [12].

Earlier studies on digital behavior have similarly shown that people increasingly remember where information can be found rather than retaining the information itself, indicating a shift in cognitive processing patterns caused by technology dependence [1].The growing dependence on digital tools and AI systems has generated significant debate regarding whether these technologies enhance or weaken human thinking abilities.

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Some studies suggest that meaningful interaction with AI tools can support learning, improve self-directed learning competency, and strengthen critical thinking when users actively evaluate and interpret AI-generated information [7], [9]. AI-assisted educational and creative activities have also been found to improve certain cognitive abilities such as spatial thinking and collaborative problem-solving [10], [8]. At the same time, passive dependence on AI outputs without verification or reflective engagement may negatively affect analytical reasoning and intellectual independence [11].

Furthermore, the impact of AI technologies on cognition appears to depend not only on the extent of usage but also on the manner in which individuals interact with these systems. Active engagement, questioning, verification, and reflective analysis may help preserve independent thinking, whereas blind reliance on automated responses may contribute to cognitive disengagement and reduced analytical effort [2], [12]. This issue has become increasingly relevant in educational settings, where students frequently use AI-based tools for assignments, writing support, information retrieval, and problem-solving activities [5].

Despite the increasing attention given to AI and cognition, empirical research examining how different dimensions of AI tool usage collectively influence independent thinking remains limited. Existing studies often focus on general technology usage or isolated cognitive effects without simultaneously examining behavioral variables such as time spent using AI tools, verification practices, reliance on unverified AI outputs, and avoidance of thinking processes. Understanding these behavioral dimensions is essential for evaluating the broader cognitive implications of AI adoption.

Therefore, the present study aims to examine the impact of AI tool usage on independent thinking using a multivariate regression framework. Specifically, the study investigates how behavioral factors associated with AI interaction influence reduced independent thinking among students. By analyzing multiple dimensions of AI usage simultaneously, the study seeks to contribute to the growing discourse on human–AI interaction and provide insights into the responsible and reflective use of AI technologies in educational and professional environments.

2 LITERATURE REVIEW

Betsy Sparrow, Jenny Liu, and Daniel M. Wegner [1] examined the cognitive consequences of internet dependency and introduced the concept popularly referred to as the "Google Effect." Their study demonstrated that individuals are more likely to remember the location of information rather than the information itself when they know it is easily accessible online. The findings suggest that digital technologies may alter memory processes and encourage dependence on external information systems, thereby influencing independent cognitive engagement. Patricia M. Greenfield [2] discussed the relationship between technology and informal education, emphasizing how digital media reshapes learning patterns and cognitive development.

The study argued that technology influences not only what individuals learn but also how they process information, often encouraging faster information access at the expense of deeper analytical engagement and reflective thinking. Joseph Firth et al. [3] explored how internet usage affects human cognition through the concept of the "online brain." The authors highlighted that constant interaction with online environments may influence attention, memory, and social cognition. Their work emphasized that increasing dependence on internet-based systems can reshape cognitive behaviors and alter traditional thinking processes.

Adrian F. Ward, Kristen Duke, Ayelet Gneezy, and Maarten W. Bos [4] investigated the effect of smartphone presence on cognitive capacity. Their findings revealed that even the mere presence of smartphones can reduce available cognitive resources, leading to diminished attention and analytical performance. The study suggested that digital dependency may negatively influence higher-order thinking abilities. Elke Kasneci et al. [5] examined the opportunities and challenges of ChatGPT and large language models in education.

The study highlighted that AI tools can support personalized learning, improve accessibility, and enhance academic productivity. However, the authors also warned that excessive dependence on AI-generated outputs may reduce students' critical thinking and independent reasoning abilities if not used responsibly. Yogesh K. Dwivedi et al. [6] presented multidisciplinary perspectives on generative conversational AI and discussed its implications for research, education, and policy. The study emphasized both the transformative potential and the risks associated with AI systems such as ChatGPT.

The authors argued that while AI can improve efficiency and creativity, overreliance on automated outputs may weaken originality, analytical reasoning, and intellectual autonomy. Ying Hu, Xiao Lan Curdt-Christiansen, and Jun Wang [7] investigated learner–AI interaction and its influence on critical thinking in English for Academic Purposes contexts. Their findings indicated that AI assistance can positively support critical thinking when learners actively engage with AI-generated content through questioning, interpretation, and evaluation rather than passive acceptance.

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Hong Zou, Meng He, and Zhen Liu [8] studied the integration of AI design tools into traditional workflows using the Push–Pull–Mooring framework. The study found that users are more willing to adopt AI tools when they perceive them as collaborative aids rather than replacements for human creativity and judgment. The findings emphasize the importance of balanced human–AI interaction in preserving cognitive autonomy. Xiaoyan Shen and Martin F. Teng [9] analyzed the relationship between critical thinking skills, self-directed learning competency, and AI-assisted writing using a three-wave cross-lagged model.

Their study revealed that students with stronger critical thinking and self-directed learning abilities are more capable of using AI tools effectively without becoming cognitively dependent on them. Arikan, A. Tosun, and E. Hiğde [10] examined the effect of AI-assisted activities on spatial thinking skills. The study demonstrated that AI-supported learning activities can improve cognitive abilities when learners actively participate in problem-solving and analytical tasks. The findings suggest that AI technologies can contribute positively to cognitive development under guided and reflective usage conditions.

Nora B. Alotaibi [11] investigated the adoption of AI tools in education and their impact on students' critical thinking skills. The study identified several behavioral and technological factors influencing AI adoption and reported that excessive dependence on AI-generated responses may negatively affect students' analytical and independent thinking capabilities. Their work provided a theoretical foundation for understanding how dependence on digital technologies and AI systems may influence memory, reasoning, and independent cognitive functioning [12].

Collectively, the existing literature indicates that AI and digital technologies have both supportive and disruptive effects on cognition. While AI tools can enhance learning, creativity, and problem-solving when used reflectively, passive reliance and uncritical acceptance of AI-generated outputs may reduce independent thinking and cognitive engagement. However, most previous studies have focused on isolated cognitive dimensions rather than examining multiple behavioral aspects of AI usage simultaneously. Therefore, the present study attempts to address this gap by examining how different patterns of AI tool usage collectively influence independent thinking using a multivariate regression framework.

3 HYPOTHESIS

Based on the existing literature on cognitive offloading, AI dependency, and independent thinking, the present study formulates the following hypotheses to examine the relationship between AI usage behaviors and reduced independent thinking.

H1a: Time Spent on AI Usage

Time spent interacting with AI tools may influence the level of cognitive engagement and independent thinking among users. While prolonged usage may increase familiarity and reflective interaction with AI systems, it may also contribute to dependency depending on the nature of engagement. Therefore, the following hypotheses are proposed:

- **H_{01}:** Time spent on AI usage has no significant impact on reduced independent thinking.
- **H_{11}:** Time spent on AI usage has a significant impact on reduced independent thinking.

H1b: Verification of AI Responses

Verification of AI-generated responses reflects the extent to which users critically evaluate information obtained from AI systems. Individuals who actively verify responses may demonstrate greater analytical engagement and cognitive involvement. Accordingly, the following hypotheses are formulated:

- **H_{02}:** Verification of AI responses has no significant impact on reduced independent thinking.
- **H_{12}:** Verification of AI responses has a significant impact on reduced independent thinking.

H1c: Unverified AI Reliance

Reliance on AI-generated information without verification may reduce analytical reasoning and encourage passive acceptance of information. Such dependence may weaken cognitive autonomy and independent judgment. Therefore, the study proposes the following hypotheses:

- **H_{03}:** Unverified AI reliance has no significant impact on reduced independent thinking.
- **H_{13}:** Unverified AI reliance has a significant impact on reduced independent thinking.

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H1d: Avoidance of Thinking

Avoidance of cognitive effort while using AI tools may contribute to reduced independent thinking and lower intellectual engagement. Individuals who rely on AI systems to avoid reflective reasoning may become increasingly dependent on automated outputs. Hence, the following hypotheses are proposed:

- **H_{04}:** Avoidance of thinking has no significant impact on reduced independent thinking.
- **H_{14}:** Avoidance of thinking has a significant impact on reduced independent thinking.

4 RESEARCH METHODOLOGY

The present study adopts a quantitative research design to examine the relationship between patterns of Artificial Intelligence (AI) tool usage and independent thinking. A cross-sectional survey approach was employed to collect primary data from respondents at a single point in time. The quantitative approach was considered appropriate as the study aims to analyze the influence of multiple behavioral variables on reduced independent thinking using statistical techniques.

4.1. Research Design

The study is descriptive and analytical in nature, focusing on identifying the impact of AI usage behaviors on independent thinking. A structured questionnaire was used as the primary instrument for data collection to ensure consistency, reliability, and ease of quantitative analysis.

4.2. Data Collection

Primary data were collected through a structured questionnaire specifically designed to measure different dimensions of AI tool usage and their relationship with independent thinking. The questionnaire consisted of items related to variables such as:

- Time spent on AI usage
- Verification of AI responses
- Unverified AI reliance
- Avoidance of thinking
- Reduced independent thinking

The questions were designed to capture behavioral patterns associated with AI interaction and cognitive engagement among respondents.

4.3. Sample and Sampling Technique

The study was conducted among students who actively use AI tools for academic and related activities. A total of 181 valid responses were collected for analysis. The respondents were selected using a convenience sampling technique based on accessibility, availability, and willingness to participate in the study.

4.4. Analytical Tools

The collected data were coded, processed, and analyzed using statistical techniques. Multiple Linear Regression analysis was employed to examine the impact of independent variables related to AI usage behavior on the dependent variable, namely reduced independent thinking. The analysis was performed using Python libraries within the Google Colab environment to ensure accuracy, reproducibility, and efficient data handling.

5 EXPLORATORY DATA ANALYSIS

Exploratory Data Analysis (EDA) plays a significant role in understanding the characteristics of the dataset before conducting statistical analysis. It helps in identifying missing values, checking data consistency, and examining relationships among variables.

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EDA also supports the assessment of important assumptions such as linearity and multicollinearity, thereby improving the reliability and validity of regression analysis. Furthermore, exploratory analysis provides a clear understanding of data patterns and strengthens the interpretation of research findings.

5.1. Multicollinearity Analysis

Correlation analysis was performed to examine the relationships among the independent variables and to identify the presence of multicollinearity. A correlation heat map was generated to visually represent the strength and direction of relationships among the variables included in the study. Fig. 1 shows the correlation heat map.

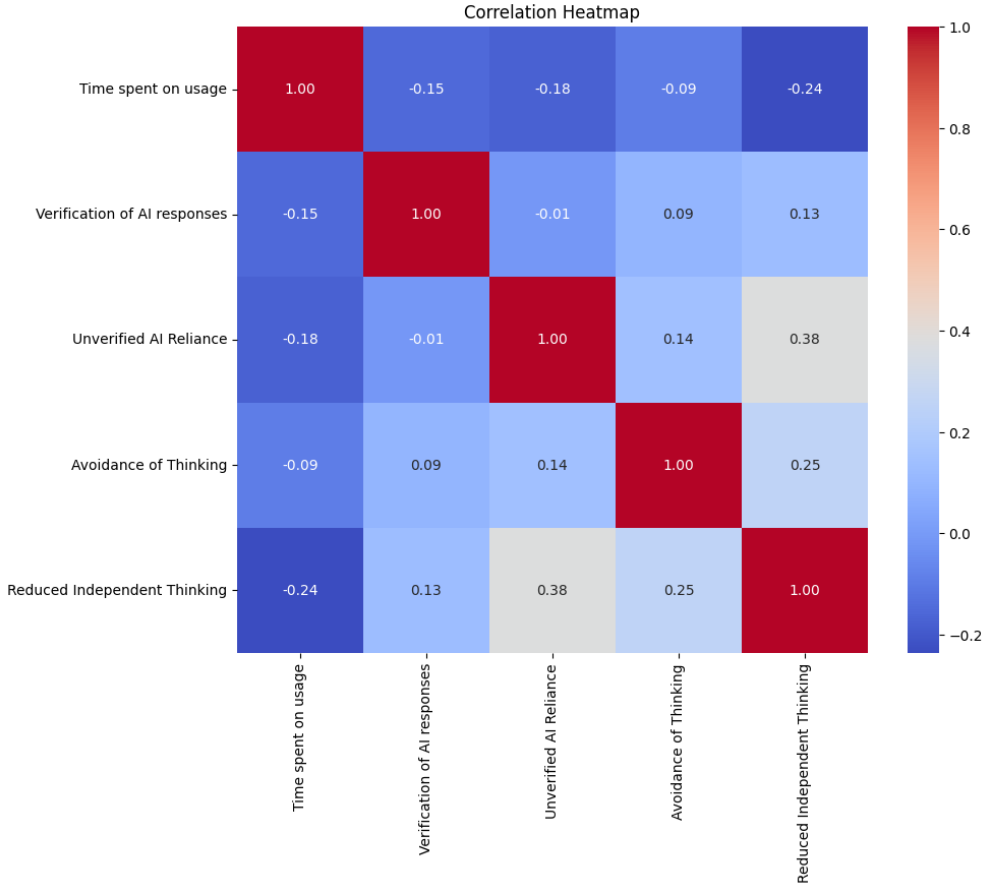

Fig. 1. Correlation Heat Map

The correlation analysis indicates that unverified AI reliance has the strongest positive association with reduced independent thinking (r = 0.38), followed by avoidance of thinking (r = 0.25). In contrast, time spent on AI usage demonstrates a negative relationship with reduced independent thinking (r = -0.24), suggesting that prolonged interaction with AI tools may encourage more reflective engagement. Verification of AI responses shows only a weak positive relationship (r = 0.13), indicating limited influence on independent thinking. The relatively low intercorrelations among the independent variables indicate the absence of severe multicollinearity problems. Therefore, all variables were retained for regression analysis.

5.2. Multiple Linear Regression Analysis

Multiple Linear Regression analysis was employed to examine the impact of AI usage behaviors on reduced independent thinking. The regression model considered time spent on AI usage, verification of AI responses, unverified AI reliance, and avoidance of thinking as independent variables, while reduced independent thinking was treated as the dependent variable. Table 1 shows the multiple linear regression results and Table 2 shows the model summary.

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Table 1. Multiple Linear Regression Results

Variables	Coefficient (β)	Std. Error	t-value	p-value	Result
Constant	1.0193	0.309	3.303	0.001	Significant
Time Spent on Usage	-0.1558	0.073	-2.137	0.034	Significant
Verification of AI Responses	0.0839	0.061	1.379	0.170	Not Significant
Unverified AI Reliance	0.3127	0.065	4.832	0.000	Highly Significant
Avoidance of Thinking	0.1657	0.061	2.723	0.007	Significant

Table 2. Model Summary

Statistical Measure	Value
R-squared (R^2)	0.219
Adjusted R^2	0.201
F-statistic	12.35
Prob (F-statistic)	7.11E-09
Number of Observations	181
Durbin-Watson	2.121

The regression results reveal that the model explains 21.9% of the variance in reduced independent thinking ($R^2 = 0.219$). The overall regression model was statistically significant ($F = 12.35$, $p < 0.001$), indicating that the selected AI usage variables collectively influence reduced independent thinking. Among the predictor variables, unverified AI reliance emerged as the strongest positive predictor ($\beta = 0.3127$, $p < 0.001$), suggesting that reliance on AI-generated outputs without verification significantly reduces independent thinking. Avoidance of thinking also showed a significant positive effect ($\beta = 0.1657$, $p < 0.01$), indicating that cognitive disengagement contributes to increased dependence on AI tools.

In contrast, time spent on AI usage demonstrated a statistically significant negative relationship with reduced independent thinking ($\beta = -0.1558$, $p < 0.05$), implying that greater interaction with AI tools may encourage reflective engagement rather than passive reliance. However, verification of AI responses was not found to be statistically significant ($\beta = 0.0839$, $p > 0.05$), suggesting that verification alone may not meaningfully influence independent thinking unless accompanied by deeper analytical reasoning.

5.3. Hypothesis Testing and Interpretation

H1a: Time Spent on AI Usage

The regression results indicate that time spent on AI usage has a statistically significant negative impact on reduced independent thinking ($\beta = -0.1558$, $t = -2.137$, $p = 0.034$). This finding suggests that individuals who spend more time engaging with AI tools may develop more thoughtful interaction patterns rather than passive dependence. Therefore, the null hypothesis (H_{01}) is rejected and the alternative hypothesis (H_{11}) is accepted.

H1b: Verification of AI Responses

Verification of AI responses was found to be statistically non-significant ($\beta = 0.0839$, $t = 1.379$, $p = 0.170$). This indicates that verification practices alone do not significantly influence reduced independent thinking. Hence, the null hypothesis (H_{02}) cannot be rejected.

H1c: Unverified AI Reliance

Unverified AI reliance emerged as a highly significant predictor of reduced independent thinking ($\beta = 0.3127$, $t = 4.832$, $p < 0.001$). The findings indicate that individuals who depend on AI-generated outputs without verification are more likely to experience diminished independent thinking. Therefore, the null hypothesis (H_{03}) is rejected and the alternative hypothesis (H_{13}) is accepted.

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H1d: Avoidance of Thinking

Avoidance of thinking was also found to be statistically significant (β = 0.1657, t = 2.723, p = 0.007). This suggests that individuals who avoid cognitive effort tend to exhibit lower levels of intellectual autonomy and independent reasoning. Accordingly, the null hypothesis (H_{04}) is rejected and the alternative hypothesis (H_{14}) is accepted.

5.4. Individual Variable Significance

To provide a clearer understanding of the contribution of each independent variable, individual variable significance analysis was conducted.

Table 3. Individual Variable Significance

Variable	Coefficient (β)	t-value	p-value	Significance Level	Result	Interpretation
Time Spent on Usage	-0.1558	-2.137	0.034	$p < 0.05$	Significant	Negative effect on reduced independent thinking
Verification of AI Responses	0.0839	1.379	0.170	$p > 0.05$	Not Significant	No meaningful impact
Unverified AI Reliance	0.3127	4.832	0.000	$p < 0.001$	Highly Significant	Strong positive effect
Avoidance of Thinking	0.1657	2.723	0.007	$p < 0.01$	Significant	Positive effect on reduced independent thinking

The results presented in Table 3 indicate that unverified AI reliance is the most influential factor affecting reduced independent thinking, followed by avoidance of thinking. Time spent on AI usage demonstrates a significant negative relationship, whereas verification of AI responses does not show a statistically meaningful effect. Overall, the findings support the hypotheses related to time spent on AI usage, unverified AI reliance, and avoidance of thinking. However, the hypothesis related to verification of AI responses is not supported due to the absence of statistical significance.

6 IMPLICATIONS

The findings of this study contribute to the growing body of literature on AI usage and cognitive behavior by reinforcing the relevance of cognitive offloading theory, which explains how individuals tend to rely on external tools to reduce mental effort (Evan F. Risko & Sam J. Gilbert, 2016). The significant positive impact of unverified AI reliance and avoidance of thinking supports the argument that passive interaction with AI tools can weaken independent thinking abilities**.** At the same time, the negative relationship between time spent on AI usage and reduced independent thinking suggests that active and prolonged engagement may foster deeper cognitive processing**,** extending existing theories by highlighting the quality of interaction rather than mere usage.

Furthermore, the non-significant effect of verification indicates that verification alone may not be sufficient to enhance independent thinking. The findings highlight key practical, policy, and technological implications of AI usage. Educational institutions should integrate AI with critical thinking activities and train students to question and evaluate outputs. Students must avoid blind reliance and use AI for deeper learning through reasoning and crosschecking. Organizations should promote analytical thinking and human AI collaboration to prevent overdependence. Policymakers and developers should ensure ethical AI use and design systems that encourage reflection, positioning AI as a "thinking partner."

7 CONCLUSION

This study examined the impact of AI tool usage on independent thinking using a multivariate regression framework. The findings reveal that AI usage does not uniformly influence cognitive outcomes; rather, its effects depend significantly on how individuals engage with these tools. The regression results indicate that unverified AI reliance and avoidance of thinking have a significant positive impact on reduced independent thinking, suggesting that passive dependence on AI-generated outputs can diminish cognitive autonomy. In contrast, time spent on AI usage demonstrates a significant negative relationship with reduced independent thinking, implying that sustained and potentially more engaged interaction with AI tools may support reflective thinking rather than hinder it.

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The variable related to verification of AI responses was not found to be statistically significant, indicating that verification alone may not be sufficient to influence independent thinking unless accompanied by deeper cognitive processing.
Overall, the model explains a moderate proportion of variance in reduced independent thinking, highlighting that while AI usage patterns are important, independent thinking is also shaped by broader behavioral and contextual factors.

These findings contribute to the emerging discourse on human–AI interaction by emphasizing that the cognitive implications of AI are not inherently deterministic but are contingent upon user behavior and engagement patterns. The study underscores the importance of fostering mindful and reflective use of AI tools in educational and professional settings. Rather than restricting AI adoption, there is a need to promote responsible usage practices that encourage critical evaluation, active engagement, and cognitive effort.

By doing so, AI can be positioned as a tool that augments human intelligence rather than substitutes it. Future research may build on these findings by exploring longitudinal effects, incorporating diverse populations, and examining additional moderating variables such as digital literacy and cognitive styles to further understand the evolving relationship between AI and human thinking.

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This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ETHICS STATEMENT
This study did not involve human or animal subjects and, therefore, did not require ethical approval.

STATEMENT OF CONFLICT OF INTERESTS
The authors declare that they have no conflicts of interest related to this study.

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