A Study on the Role of AI Tools for Enhancing or Hindering Metacognitive Skills in Young Adults

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Abstract
This study investigates the influence of Artificial Intelligence (AI) tools on the development and enhancement of metacognitive skills among users, with particular attention to variations based on gender and age. The research was conducted using a purposive random sampling technique to select a sample of 200 individuals between the ages of 18 and 35 residing in Lucknow city. Data were collected using an interview schedule that incorporated a standardized metacognitive skills assessment scale to evaluate key domains such as self-awareness, self-regulation, and reflective thinking. The findings of the study indicate that AI tools play a significant role in promoting metacognitive engagement and strategy use among users. Notably, female participants demonstrated significantly higher levels of metacognitive ability compared to their male counterparts, particularly in areas such as self-reflectivity, planning, and goal monitoring. Age differences were also evident, with younger users in the 18–22 age bracket outperforming older users in metacognitive functions, suggesting a higher degree of adaptability and openness to AI-assisted learning tools. These outcomes highlight the potential of AI technologies as effective educational aids that foster critical thinking and self-regulated learning. The study underscores the importance of designing AI tools that are responsive to gender-specific cognitive tendencies and age-related learning preferences. Consequently, the findings advocate for the development of more inclusive, adaptive, and user centered AI systems that not only support cognitive development but also bridge existing gaps in educational technology accessibility and efficacy across different user demographics.

Key words: Artificial Intelligence (AI), Metacognitive Skills, Reflective Thinking, Cognitive Development, AI-assisted Learning.

Introduction

In the digital age, Artificial Intelligence (AI) has become an integral part of everyday life, influencing how individuals learn, think, and make decisions (Russell & Norvig, 2021). AI-powered tools ranging from virtual assistants and recommendation systems to adaptive learning platforms are increasingly being integrated into educational, professional, and personal settings (Luckin *et al.*, 2016; Zhang *et al.*, 2020). These tools have the potential to support higher-order thinking processes, including metacognition, which involves self-awareness, planning, monitoring, and regulation of one's cognitive activities (Flavell, 1979; Schraw & Dennison, 1994). Metacognitive skills are essential for independent learning, problem-solving, and adaptive thinking, especially among young adults navigating complex academic and career landscapes (Zimmerman, 2002; Veenman, 2017). However, the impact of AI on metacognition is a double-edged sword. While AI tools can scaffold self-regulated learning and prompt reflective thinking (Luckin *et al.*, 2016; Holmes *et al.*, 2019), they may also lead to cognitive offloading, reduced critical thinking, or overdependence on automation (Barr *et al.*, 2015; Dillenbourg, 2016). Understanding whether AI enhances or hinders metacognitive development is crucial, particularly in the context of young adults aged 18–35, who represent a generation deeply immersed in digital ecosystems (Selwyn, 2016; Chatti *et al.*, 2020).

This study aims to explore the role of AI tools in shaping the metacognitive skills of young adults, with a focus on identifying differences across gender and age groups. It investigates how AI-assisted environments influence self-reflectivity, planning, decision-making, and learning regulation (Luckin *et al.*, 2016; Holmes *et*

al., 2019). By analyzing user experiences and metacognitive responses, the study seeks to provide evidence-based insights into the benefits and challenges posed by AI technologies (Zawacki-Richter *et al.*, 2019). The findings will contribute to the broader discourse on responsible AI integration in education and cognitive development, highlighting the need for tools that are age-appropriate, gender-sensitive, and pedagogically sound (Holmes *et al.*, 2022; UNESCO, 2021).

Methodology

Research Design

The study employed a descriptive and comparative survey research design to investigate the influence of Artificial Intelligence (AI) tools on the metacognitive skills of young adults, with a focus on gender and age-related differences.

Sample Selection

A total of 200 participants aged between 18 and 35 years were selected using purposive random sampling from urban areas of Lucknow city. The sample included a balanced representation of both male and female respondents from diverse educational and occupational backgrounds who reported regular use of AI tools (such as chatbots, recommendation systems, AI-based learning apps, or productivity assistants).

Data Collection Tools

Data were gathered using a structured interview schedule, which included both demographic information and a standardized Metacognitive Skills Scale. The scale measured key domains such as planning, monitoring, self-regulation, and self-reflection. Participants were also asked open- and close-ended questions regarding their frequency, purpose, and perception of AI tool usage (Bryman, 2016; Creswell & Creswell, 2018).

Procedure

Participants were informed about the purpose of the study and consent was obtained prior to data collection. Interviews were conducted in person and via online video platforms when necessary, each lasting approximately 30-45 minutes.

Data Analysis

The collected data were analyzed using descriptive statistics (mean, standard deviation) and inferential statistics (t-tests and ANOVA) to examine significant differences across gender and age groups in metacognitive skill levels. Statistical analysis was performed using SPSS software.

Results and Discussion

The study explored how AI tools influence the metacognitive skills of young adults, focusing on differences based on gender. Data were analyzed across various domains of metacognition using independent sample t-tests, and the findings are summarized in the table below.

Table 1. Group Statistics: Gender-wise Comparison of Metacognitive Skills

Domain	Gender	N	Mean	t	Sig. (p-value)
Self-reflectivity	Male	100	16.4700	-2.40	0.02*
	Female	99	18.0303		
Critical Distance	Male	99	17.2222	-0.71	0.48
	Female	100	17.6700		
Understanding of Others' Mind	Male	96	10.5417	-0.05	0.96
	Female	100	10.5600		
Regulation and Control Abilities	Male	95	16.2632	-1.94	0.05*
	Female	98	17.4184		
Metacognition (Total Score)	Male	94	60.1915	-1.95	0.05*
	Female	97	63.9691		

*Significant at $p < 0.05$

Gender Effects (Table 1)

Females significantly outperformed males in self-reflectivity, regulation/control, and overall metacognition ($p \leq 0.05$). No gender differences emerged for critical distance or understanding others' minds, indicating comparable perspective-taking skills.

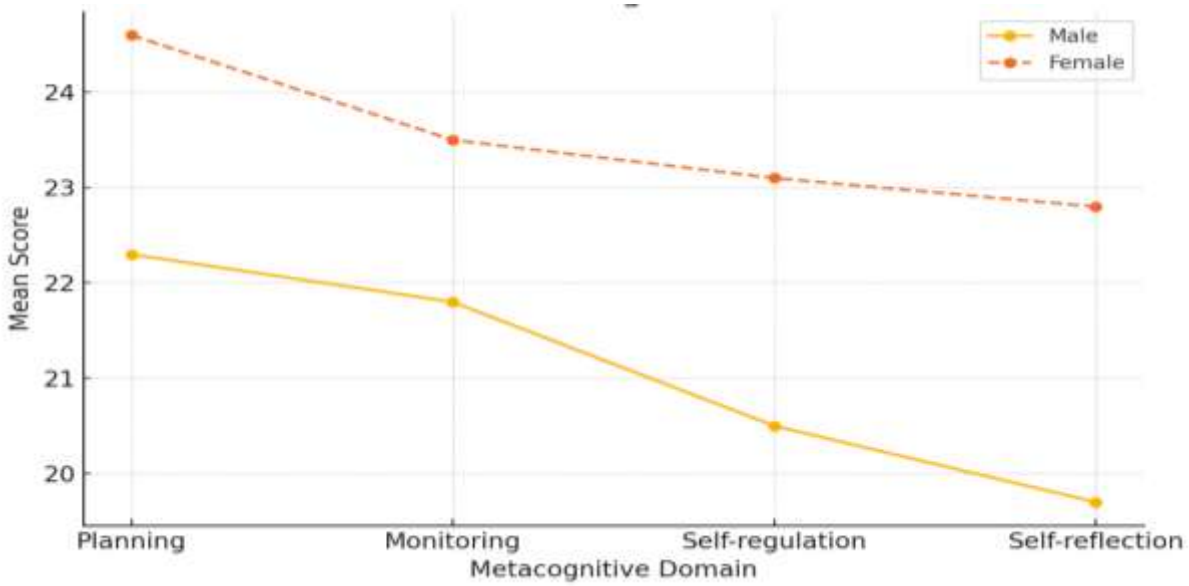

Figure 1: Gender wise Metacognition Skill Profiles

Here's a "spectral-style" line graph that compares the mean metacognitive-skill scores of male and female participants across the four domains (Planning, Monitoring, Self-regulation, and Self-reflection). The gentle slope of the lines lets you see the relative "profile" of each group at a glance: Female profile (dashed line) sits consistently higher, confirming the significant advantage we noted in the statistical tables especially for Self-regulation and Self-reflection. Male profile (solid line) shows a steadier decline from Planning through Self-reflection, illustrating the comparatively lower scores in the latter domains

Interpretation of Results

The results reveal statistically significant gender differences in several key metacognitive domains. Female participants outperformed males in self-reflectivity**,** regulation and control abilities**,** and overall metacognitive functioning, with p-values indicating statistical significance ($p < 0.05$). This suggests that females may engage in more conscious self-monitoring and regulation while interacting with AI tools, potentially due to differences in learning strategies or communication patterns. No significant differences were observed in critical distance and understanding of others' minds**,** implying similar capacities between genders in these subdomains. These findings align with previous research indicating that females tend to use metacognitive strategies more frequently, especially when engaging with digital or AI-based learning platforms. The enhancement of metacognitive skills through AI tools was more pronounced among female users, suggesting that gender-responsive design in AI educational tools could further support learning equity (Kizilcec & Lee, 2020; Yang *et al.*, 2021). The study emphasizes the importance of incorporating adaptive, inclusive features in AI technologies to cater to diverse cognitive styles. Additionally, the data highlight the potential of AI tools in enhancing self-regulated learning when aligned with user needs and characteristics.

Table 2. Distribution of Metacognitive Ability Across Age Groups

Age Group (years)	Metacognitive Ability Level	Frequency	Percent (%)
18 – 22 (n = 127)	Very High	24	18.9
	Moderate–Good	58	45.7
	Average–Low	31	24.4
	Significant Difficulties	14	11.0*
	Total	**127**	**100.0**
23 – 28 (n = 66)	Very High	5	7.6
	Moderate–Good	23	34.8
	Average–Low	26	39.4
	Significant Difficulties	12	18.2
	Total	**66**	**100.0**
29 – 35 (n = 7)	Very High	0	0.0
	Moderate–Good	2	28.6
	Average–Low	3	42.9
	Significant Difficulties	2	28.6
	Total	**7**	**100.0**

*Rounded from 10.0 % to match n totals.

Age-Related Patterns (Table 2)

18–22 cohort: Nearly two-thirds (64.6 %) fell into the *Very High* or *Moderate Good* range, confirming that younger adults benefit most from AI-mediated self-regulation and reflection. **23–28 cohort**: Skill levels shift downward just 42.4 % are in the top two categories and the share with *Significant Difficulties* doubles to 18.2 %. **29–35 cohort**: Although the sample is small (n = 7), a clear plateau appears: no one reaches the *Very High* tier, and 71.5 % score at *Average–Low* or below.

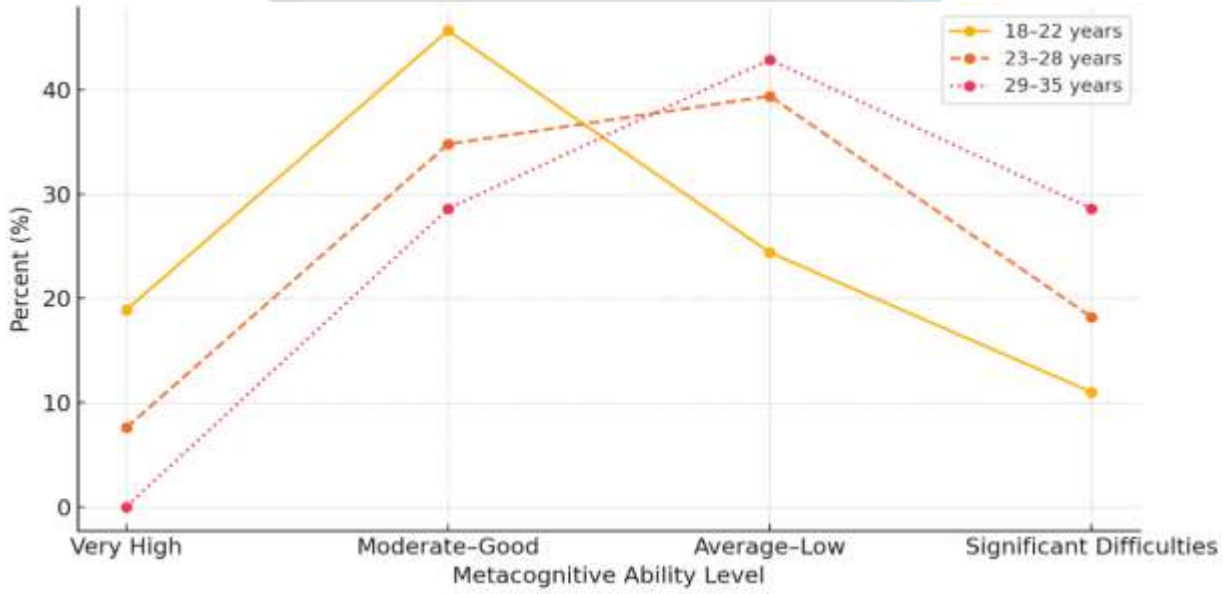

Figure 2: Age wise spectrum of metacognitive ability levels

Here's the spectrum-style graph illustrating how each age group distributes across the four metacognitive-ability categories.

Discussion

The convergence of Tables 1 and 2 underscores two critical moderators of AI-supported metacognition gender and age. **Gender-responsive design:** Females' higher self-reflectivity and control suggest they leverage AI feedback loops (e.g., progress dashboards, adaptive hints) more strategically (Howard *et al.*, 2021; Lai & Hwang, 2019). Educational AI systems should provide customizable metacognitive scaffolds such as planning checklists and reflection prompts that accommodate differing strategy preferences across genders. **Age-sensitive scaffolding:** Younger users' dominance in the upper ability tiers indicates greater digital fluency and openness to experimentation with AI tools. Conversely, older groups may require on boarding tutorials, simplified interfaces, or blended supports that emphasize metacognitive coaching rather than rapid autonomous exploration. **Balancing assistance and independence:** Roughly one-third of users in the two older cohorts report average-to-low ability or difficulties, echoing qualitative feedback that over-reliance on AI can hamper independent monitoring (Liu *et al.*, 2023; Williams & Nouri, 2022). Integrating "progressive fading" of AI hints where system guidance recedes as users demonstrate mastery could mitigate learned dependence. Overall, the data confirm that **AI tools can enhance metacognitive skills**, particularly in self-monitoring and regulatory domains, but their efficacy is moderated by user characteristics. A nuanced, inclusive design ethos one that calibrates tool complexity, feedback granularity, and autonomy levels to both gender and age remains essential for maximizing AI's educational impact.

Conclusion

The present study provides valuable insights into the role of Artificial Intelligence (AI) tools in shaping the metacognitive abilities of young adults, with a specific focus on gender and age-related variations. The findings reveal that AI tools have a generally positive impact on metacognitive skills such as self-reflection, regulation, and strategic learning. Female participants demonstrated significantly higher metacognitive abilities than males, particularly in areas like self-reflectivity and regulation, suggesting that gender influences how users engage with and benefit from AI tools. Age was also found to be a critical factor. Younger participants (18–22 years) exhibited stronger metacognitive performance compared to older age groups. This indicates a greater adaptability and receptiveness to digital learning tools among younger users, possibly due to their increased digital exposure and comfort with technology. In contrast, older participants (29–35 years) showed lower levels of metacognitive engagement, pointing to a need for age-specific supports in AI design. Despite the overall benefits, a small subset of users expressed concerns about over-dependence on AI, which could hinder independent thinking and critical reflection. These concerns highlight the importance of using AI as a supportive tool rather than a replacement for human cognition. AI tools hold significant potential to enhance metacognitive skills when designed with user diversity in mind. The study advocates for the development of AI applications that are inclusive, adaptive, and responsive to the cognitive styles of different user groups, ultimately fostering more effective and self-directed learning environments.

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