ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26oct921

Neural Signatures of AI-Assisted Cognition: EEG Profiles of AI Users and Non-Users and Implications for Brain Chemistry and Structure

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Publication Date: 2026/11/03

Abstract: This review combines EEG and fMRI studies of cognitive task completion with and without generative AI from the standpoint of the recent MIT "Your Brain on ChatGPT" study. Next, the results of these studies are used to make an inference about brain chemistry and brain structure through PET, MRS, and MRI/DTI studies of reward system functioning and intensive use of technological gadgets. The newly released OpenNeuro dataset ds008496 that provides EEG data collected when writing essays in conditions of interaction with various AI systems becomes the next step of this research line.

How to Cite: Darius Hadaegh (2026) Neural Signatures of AI-Assisted Cognition: EEG Profiles of AI Users and Non-Users and Implications for Brain Chemistry and Structure. *International Journal of Innovative Science and Research Technology*, 11(10), 2614-2616. https://doi.org/10.38124/ijisrt/26oct921

I. INTRODUCTION

EEG provides good temporal resolution, but is unable to track either neurotransmitter activity or tissue structure. Thus, the statement that "AI changes the brain's chemistry and structure" is based on three independent lines of research:

- Functional/Electrophysiological: EEG and fMRI research comparing AI-aided and non-AI tasks. Valid in generative-AI writing context.
- Chemical: PET and MRS research on dopaminergic reward mechanisms in the habitual use of technology.
- Structural: sMRI and DTI research on gray and white matter in technology addicts.

Categories 2 and 3 refer to internet and games "addiction" literature, not to generative-AI literature. There was never any single study combining EEG, PET/MRS, and structural MRI in AI users, so those paragraphs are speculative synthesis.

II. EEG EVIDENCE

➢ *Kosmyna et al. (2025)*

The 54 participants composed SAT-style essays in 4 sessions belonging to 3 categories: LLM (ChatGPT), Search Engine, and Brain-only. Those from the Brain-only category exhibited the highest connectivity, followed by those from the Search Engine category, and finally, the LLM category exhibiting the least connectivity.

For session four, the experimental condition was reversed for each participant. The LLM to Brain group showed low connectivity as well as under-engagement in the alpha and beta brain waves, which is referred to as "cognitive debt." On the other hand, Brain to LLM group exhibited better recall and re-engagement of the occipito-parietal and prefrontal brain areas.

➢ *Developmental and design-related findings*

- Comparison of children and adults (fMRI, 2025): Adults were found to have greater connectivity compared to 6-7 years old in the frontoparietal, salience and dorsal attention networks, indicating that the impact of AI on the brain is age-dependent.
- Creative design (EEG, 2025): AI that was well-designed as a partner did not cause any decline in learning outcomes and increased both self-reported and objective engagement.

This indicates that the EEG pattern is dependent on how much offloading is done by the AI.

➢ *What EEG Measures*

However, the variables of connectivity and alpha/beta/theta power are measures of coordination, selective attention and memory load rather than of neurotransmitter levels or brain size. Reduced connectivity when using AI assistance should be interpreted as coordination between fewer areas.

➢ *Brain Chemistry (Inference)*

EEG is not capable of measuring the dopamine levels or the presence of any other neurotransmitters. There are two related adjacent literatures:

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- Reward pathway research: PET and fMRI are used for understanding internet and video game addiction by linking compulsive use to similar dopamine secretion, along with lower levels of dopamine transporters and D2 receptors.
- EEG-neurochemistry relationships: The increase in alpha and beta powers correlates to dopaminergic restoration (L-dopa) while decrease in theta/delta powers correlates with cholinergic and noradrenergic deficits. This indicates that the changes in alpha/beta powers seen in AI writing studies might correlate with dopaminergic levels, but no such studies have been done.

It would be likely that the use of AI offloading uses the same reward pathways but there are no such studies which have measured the levels of dopamine receptors and synthesis in AI users.

➢ *Brain Structure (Inference)*

- Gray Matter: Meta-analyses of problematic internet use demonstrate gray matter deficits in the dorsolateral prefrontal cortex (DLPFC) and anterior cingulate cortex (ACC).
- Reward circuitry: Increased gray matter volume in the putamen and nucleus accumbens and decreased gray matter volume in the orbitofrontal cortex, similar to substance-use patterns.
- White Matter: Reviews of Internet Gaming Disorder highlight lower white matter density in areas involved in decision-making, inhibition, and emotional control, and in the cognitive-control network.

The prefrontal and cingulate cortices where LLM users have low EEG connectivity correspond with the areas where deficits of gray matter were found in problematic internet use. It is a fascinating finding that requires longitudinal MRI studies in AI users. Kosmyna et al. conducted a study for four months without MRI.

➢ *OpenNeuro Dataset ds008496*

EEG-Based Brain Connectivity in Student Essay Writing Tasks Under “Activeai” and “Passiveai” Through Gen-AI has EEG data from 15 students (age group 20–22) while writing essays under “activeai” and “passiveai”. It is similar to Kosmyna et al., but smaller in size and different in interaction styles.

As I have not downloaded or analyzed the raw data, no results can be presented here. The next steps would be re-analysis with directed transfer function or coherence metrics via EEGLAB or MNE-Python.

III. DISCUSSION

Table 1 Summary of Evidence for Functional, Chemical, and Structural Brain Changes Associated with AI Use

Level	Method	Status in AI-use research
Functional/electrical	EEG, fMRI	Directly measured; connectivity and engagement reliably lower under AI assistance, recoverable but "sticky" (cognitive debt)
Chemical	PET, MRS	Not measured in AI users; inferred by analogy to dopaminergic reward findings in internet/gaming research
Structural	sMRI, DTI	Not measured in AI users; inferred by analogy to gray/white matter findings in internet/gaming research

This gap makes a case for longitudinal research using EEG with PET/MRS and structural MRI scans. Before that, assertions of any chemical or structural changes caused by generative AI will continue to be speculations.

IV. LIMITATIONS

The main EEG studies are from a single non-peer-reviewed experiment (n=54; n=18 in session four).

Sections on chemistry and structure draw upon literature from gaming/chemistry, a separate though similar behavior.

None of the datasets, including ds008496, includes both EEG and PET/MRS/MRI data.

No new analysis of the raw signals in ds008496 was performed.

V. CONCLUSION

According to EEG, cortical network activity when writing decreases with increasing dependence on generative AI and stays suppressed even after removal of the tool. It is reasonable to apply the findings for dopaminergic and structural changes because of similarities with the internet and gaming studies. The next step would be conducting a longitudinal multimodal study with the use of, for example, dataset ds008496.

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ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26oct921

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