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论文题目：Electroencephalography Responses Evoked by AI-Generated Personalized Autobiographical Memory Cues Across the Alzheimer's Disease Spectrum

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Electroencephalography Responses Evoked by AI-Generated Personalized Autobiographical Memory Cues Across the Alzheimer's Disease Spectrum

Dingqi Chen

Abstract

Objective: Standard memory tests for Alzheimer's Disease Spectrum(ADS) often use the same materials for everyone, which may not reflect participants' real-life memory. **This study aims to evaluate the feasibility of the interactive cognitive testing program that uses AI- generated individualized memory cues and simultaneously records electroencephalography (EEG). Furthermore, it explores how mild cognitive impairment (MCI) and Alzheimer's Disease(AD) participants differ in behavioral performance as well as EEG temporal and spatial responses during the memory recall process.**

Methods: This study developed a software-based interactive cognitive testing program. It presents personal memory content and records EEG and behavior simultaneously. The program uses AI to create personal stories for each participant, combined with an 8-channel EEG system. The test structure was the same for everyone, including five stages: question presentation, initial reasoning and first attempt, post-first-response resting and cue observation, prompt viewing and secondary attempt, and narrative reinstatement. This was designed to mimic natural memory recall. Four participants (MCI=2, AD=2) were enrolled in this study.

Results: All participants completed the full test with stable EEG recordings, proving the software's operational feasibility. The MCI participants showed higher accuracy during the first attempt compared with AD participants. MCI participants tended to display more apparent event-related potential waveform across task stages, particularly in bilateral temporal regions within the 0–1000 milliseconds (ms) post-stimulus window than AD participants. Compared with AD participants, MCI participants showed a stronger positive

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connection between the central area and the left parietal lobe, and a stronger negative connection with the right parietal lobe.

Conclusion: This study evaluated the feasibility of AI-generated software for personalized autobiographical memory assessment in ADS. This paradigm is potentially a tool for more precise cognitive evaluation and individualized interventions.

Keywords: Autobiographical memory; Alzheimer's disease; Mild cognitive impairment; Electroencephalography; Large language model; Interactive cognitive testing

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1. Introduction

The Alzheimer's Disease Spectrum (ADS) is a brain disorder that gets worse over time. As shown in Figure 1, cognitive and behavioral functions decline with ageing. One of the dominating hypotheses involves two abnormal proteins: β-amyloid plaques and neurofibrillary tangles (Jellinger, K. A., 2022). The disease is further defined based on its clinical severity including preclinical, subjective decline, mild cognitive impairment (MCI), and finally Alzheimer's disease (AD) (Lv et al., 2025). A study published in The Lancet predicted that 153 million people will have AD by 2050, with a global cost of $14.5 trillion from 2020 to 2050 (Chen S. et al., 2024).

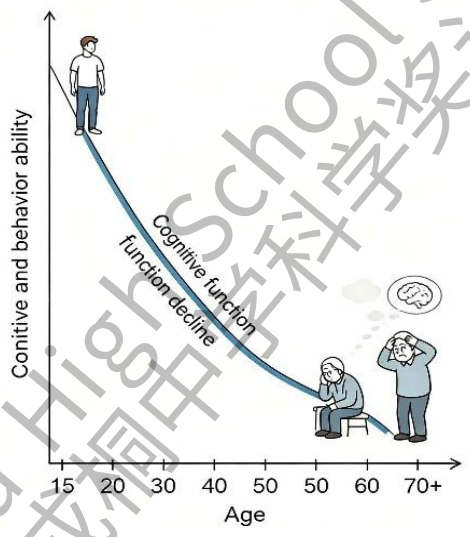


Figure 1. Age-related decline in cognitive and behavioral function.

ADS symptoms follow a general pattern, but each person's symptoms vary. In the early stage, MCI symptoms are often mild and selective (Duara, R. et al., 2022). The main problem is episodic memory impairment, for example, forgetting recent events—while language and executive function (like planning and organizing) stay mostly normal (Collie & Maruff, 2000). As the disease progresses to AD, symptoms spread from memory loss to other cognitive areas. One of the most noticeable symptoms is the gradual loss of autobiographical memory (memory of personal life events) (Stramba-Badiale et al., 2025).

Autobiographical memory is the memory of personal life experiences. It combines episodic details, general knowledge, and emotions (Svoboda et al., 2006). It depends on the

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hippocampal-neocortical circuit to quickly link sensory details and involves prefrontal areas in checking and judging memories (McCormick et al., 2015). It also keeps time and place tags, so people can mentally "re-experience" past events (Vatansever et al., 2021). Therefore, studying how autobiographical memory affects brain function can help us understand cognitive decline in ADS.

Currently, assessing autobiographical memory function in ADS faces challenges at multiple levels. Regarding diagnosis, early memory problems often appear before scores drop on common tests like the Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) (Therriault et al., 2022). But these tests are strongly affected by education and language background, so they are not sensitive enough to catch subtle memory problems. In cognitive rehabilitation and daily care, we lack personalized and engaging tools that can activate patients' remaining autobiographical memories. Most current rehabilitation programs use the same standard materials for everyone. They have little connection with patients' personal life experiences, so patients might lose interest, and the benefits might not transfer well to real life. Also, rehabilitation results are usually measured by behavior scales or caregiver reports, which may miss subtle brain changes related to memory improvement. **Therefore, tools that combine personalized memory content with objective brain measures are needed.**

Recent advances in artificial intelligence (AI), especially large language models (LLMs), have presented new opportunities for brain research. LLMs can take scattered personal stories from family members and turn them into coherent, highly personal memory materials. This gives us a practical way to make personalized memory content for each patient.

At the same time, electroencephalography (EEG) can record brain activity at the millisecond level. This means it can capture neural activity in real time during memory recall. Task-based EEG is more sensitive than resting EEG for detecting early brain network changes in MCI (Fischer et al., 2023). This makes it possible to study brain activity while patients process self-related information. Experts also agree that EEG oscillation and connectivity measures are valid biomarkers for tracking disease progression across ADS (Babiloni et al., 2020). **Therefore, combining LLMs and EEG presents a new research direction: connecting personalized content with objective brain measures.**

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Accordingly, this study combines LLM-generated personal content with EEG recording and develops a structured paradigm. Through interviews, we collected participants' life experiences and developed an interactive memory-testing program. This program uses AI to generate personalized memory content from these experiences, presents them as memory cues during recall, and simultaneously records EEG and behavioral responses. The goal is to use this content to trigger brain responses in ADS patients and to explore whether it can serve as a practical memory test and whether MCI and AD participants show different EEG responses.

Two hypotheses are proposed. First, AI-generated personal content can work as a practical memory testing tool. This would be shown by good task completion, stable EEG recordings, and reliable system operation. **Second,** personal memory cues may reveal EEG differences between MCI and AD participants. These differences could appear in space, such as abnormal oscillations in certain brain regions. They could also appear in time, such as different connectivity patterns across task stages.

Overall, this study proposes a personalized autobiographical memory assessment method based on real-life experiences. It uses an LLM to turn individual life experiences into memory materials with a unified structure. It also simulates the natural memory retrieval process and records EEG responses during recall. This method may more sensitively reflect cognitive and neural changes in ADS progression. It may also provide a new practical basis for future early screening and personalized cognitive rehabilitation for ADS.

2. Methods

2.1. Participant Demographics

This study enrolled four participants, including two clinically diagnosed with Alzheimer's disease (AD) and two with mild cognitive impairment (MCI). Participant recruitment was completed with the assistance of Guangdong Pharmaceutical University

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Guangzhou Fosun Chancheng Hospital in local general hospitals. Table 1 presents the specific information of the four participants.

Inclusion criteria required that all participants be definitively diagnosed with either MCI or AD by neurologists based on integrated evidence including detailed medical histories, neurological physical examinations, MMSE neuropsychological evaluations, and neuroimaging findings referenced to medial temporal atrophy (MTA) grading.

The specific group criteria were as follows. MCI participants: they had memory or cognitive complaints from themselves or family, but daily life was not affected. They did not meet dementia criteria and were diagnosed with MCI by doctors. MMSE scores ranged from 23 to 29. **AD participants: they** showed gradual cognitive decline, were diagnosed with AD by doctors, and had MMSE scores from 21 to 22. Imaging showed clear Medial Temporal Atrophy.

Participants were excluded if they had any of the following: severe vision, hearing, or language problems that prevented testing; major depression, schizophrenia, or drug/alcohol dependence; severe heart, liver, kidney, or lung disease, or terminal cancer; other types of dementia (vascular dementia, frontotemporal dementia, or dementia with Lewy bodies); poor expected cooperation with treatment and follow-up (such as being unable to attend regular visits, unwilling to cooperate, or having no family member to provide clinical information); or participation in other clinical trials at the same time.

The entire study was conducted in strict accordance with the Declaration of Helsinki and China's Measures for the Ethical Review of Biomedical Research Involving Human Subjects and was approved by the Ethics Committee of Guangdong Pharmaceutical University Guangzhou Fosun Chancheng Hospital. All participants signed a written consent form before joining the study.

All personally sensitive data of enrolled participants were de-identified to protect privacy.

Table 1. Demographic Data of the Participants.

ID	Diagnosis	Age(years)	Sex	MTA grade	Disease duration(months)	MMSE scores	Medication

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ID	Diagnosis	Age(years)	Sex	MTA grade	Disease duration(months)	MMSE scores	Medication
1	MCI	82	female	N/A	17	23	
2	AD	55	male	grade 2	26	21	Sodium Oligomannate Capsules
3	MCI	72	male	grade 1	15	29	Sodium Oligomannate Capsules
4	AD	63	female	grade 1	29	22	Memantine Hydrochloride Tablets

2.2. Question Bank Construction

A structured interview (Table 2) **was designed to gather personal episodic memories across four life stages: childhood, adolescence, adulthood, and old age.** During one-on-one interviews, participants reported their basic personal information and past life experiences. Since participants with cognitive impairment may produce biased or inaccurate self-recollections, all interview content was cross-validated and corrected through follow-up inquiries with reliable family members.

Table 2. A prototype of the question bank adopted in interviews.

Grandchild	1. Grandson's nickname is"Xiao Mu Zi" 2. Grandson is 7-8 years old currently. 3. Most memorable event during elderly years is the birth of grandson. 4. Primary daytime activities consist of caring for her grandson
Friends and Peers	1. Leader Zhang offered crucial guidance throughout her career 2. She and colleague Lee had collaborated for multiple years. 3. Neighbor Zhang was frequently visited for daily chats. 4. Harbors an inner aversion to individuals who engage in negative gossip behind others' backs
Residence	1. The kitchen serves as the primary space after her retirement. 2. Uses a delicate bag for storing essential belongings. 3. Currently, her address is No.30, Lujia Village Road, Shanghai 4. Born and raised in Xuzui Village
Family Timeline	1. Held the wedding ceremony in 1982 2. The eldest daughter was born in 1987

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	3. A son was born in 1989 4. She was born in August 1963 5. Started career in 1984
Childhood and Habit Memory	1. Keeps drinking boiling water as a morning routine for decades. 2. Sweet foods are consistently disliked 3. Mother would often sing "Huangmei" Opera to her before bedtime. 4. Held an impressive memory of receiving intravenous treatment for a high fever when she was seven years old. 5. A regular leisure activity after dinner consists of participating in square dancing

AI Prompt

Role: You are a narrative-cue generator for an autobiographical memory task designed for older adults with possible cognitive impairment.

Task: Transform the interview-derived memory items from one memory domain into a single coherent autobiographical narrative cue. The narrative will be presented during the cue-observation phase to support memory retrieval before the participant's second response attempt.

Generation requirements:

1. Use only the information explicitly provided. Preserve all names, relationships, dates, ages, locations, activities, and event sequences without adding, inferring, correcting, or embellishing details.
2. Integrate the items into one coherent paragraph. Follow the stated chronological order; if no order is provided, do not assume one.
3. Use clear, concrete, and grammatically simple language suitable for older adults, maintaining a warm, respectful, and emotionally neutral tone.
4. Produce one paragraph of 60–100 English words or 100–160 Chinese characters, consisting of three to five sentences, without headings, lists, questions, or explanations.
5. Internally verify that every statement is supported by the input. If the information is contradictory or too ambiguous to integrate reliably, output "MANUAL REVIEW REQUIRED" and briefly identify the issue.

2.3. Generation of Personalized Autobiographical Narratives

This study used GPT-4.0, an LLM, to create personalized test items and distractors. First, the model summarized and analyzed raw interview records to build personal narrative cues. All content came from the interviews. Then, based on the life events collected from real interviews, five question banks were developed for each participant. Each bank had 3 to 5 single-choice questions based on the participant's real-life experiences across different ages. Each question had one correct answer matching the participant's true memory and three similar distractors, controlling task difficulty and ensuring valid cognitive testing.

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This design made sure all test materials matched each participant's real life, while keeping the structure of the questions consistent across trials. **The final questions, options, and narrative cues were then used in the interactive cognitive assessment task.**

I reviewed all GPT-4 output. If any content was not in the interview records, I either revised it or removed it. This helped make sure that all cues came from the participants' own real-life memories.

2.4. Interactive Cognitive Testing

To reduce participants' test pressure and improve task engagement, an interactive cognitive testing module using the GDevelop engine was developed. The interface and interaction logic were simplified to fit the cognitive characteristics and acceptance level of elderly individuals with cognitive impairment. The task followed a fixed set of rules. **The complete cognitive task was divided into five sequential stages** according to participants' memory-related behavioral states: **question presentation (QP), initial reasoning and first attempt (R1), post-first-response resting and cue observation (Cue), prompt viewing and secondary attempt (R2), and narrative reinstatement (NR).** The narrative cues generated by the LLM are specifically used in the Cue phase, aiming to guide participants to better recall relevant life events in the R2 phase. The design of these five stages simulates the process of retrieving and recollecting episodic memories in real-life situations.

The specific task logic was as follows: for each question, participants first made an initial attempt. If the first attempt was correct, the Cue and R2 phases were skipped, and participants clicked a "Continue" button to proceed to the next question. If the first attempt was incorrect, the system displayed a mild reminder cue and allowed a second attempt; after the second submission, regardless of its correctness, participants clicked "Continue" to advance to the next question. No real-time accuracy feedback or scoring results were presented during the entire test process, so as to prevent negative emotional fluctuations that might interfere with task performance. After participants completed all items in one question bank, the NR phase was presented for that bank, during which the system generated a behavioral summary of response characteristics. Each participant completed tests covering a

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total of five question banks. To mitigate comprehension biases arising from reading impairments, audio playback was synchronously presented at every step within the program. **Figure 2 presents the flowchart of this program alongside simple diagrams of the testing scenario.**

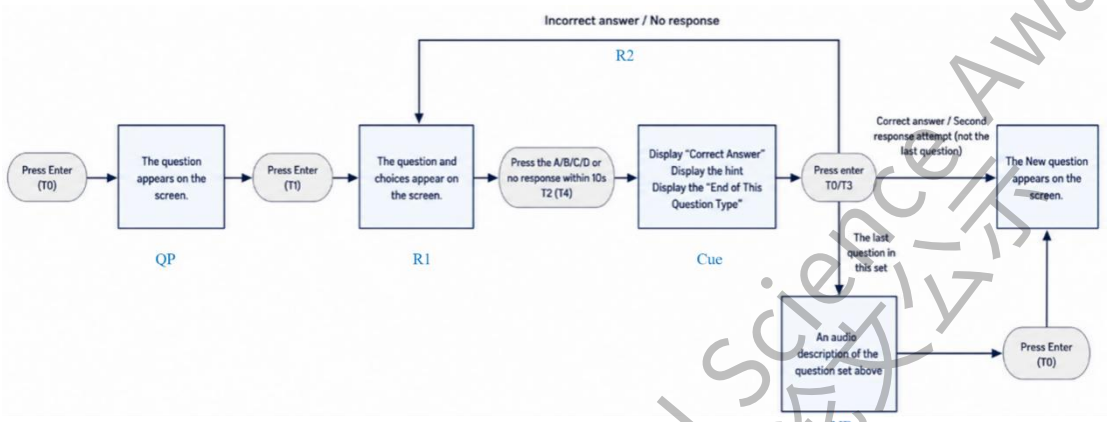


Figure 2 illustrates the overall response-task workflow, depicting transitions between different task phases.

In terms of technical implementation, Python was responsible for integrating the interactive cognitive testing module with the EEG acquisition system—achieving event marking, synchronized triggering, and coordination of signal recording throughout the entire procedure. Behavioral data and task performance records, after manual archiving, were processed through Python for sorting, cleaning, and precise timestamp-based alignment with EEG signals, thus preparing preprocessed data files for subsequent analysis. Further analysis of EEG data—including power spectrum computation, temporal dynamic feature extraction, and brain region connectivity analysis—as well as the generation of all statistical figures, was performed using MATLAB.

2.5. EEG Acquisition

During the entire task execution, 8-channel EEG using the Open BCI Cyton system at 250 Hz was recorded. Electrodes were placed according to **the international 10–20 EEG placement standard, including Fz, F7, F8, Cz, P7, P8, Pz, and Oz.** These EEG channels

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were positioned over the prefrontal cortex, bilateral anterior temporal cortex, sensorimotor cortex, posterior parietal-temporal association cortex, medial parietal cortex, and primary visual occipital cortex.

As shown in Figure 3 (A/B), Fz, F7, and F8 reflect frontal activity linked to attention, reasoning, and executive control. Cz reflects central sensorimotor activity. P7, P8, and Pz refer to episodic memory retrieval and cognitive processing. Oz reflects visual processing during question presentation.

This study used the Python programming language to combine the interactive cognitive task and EEG recording into one program. This allowed event marking, synchronized triggering, and signal recording to run together. Python was also used to sort and clean the behavioral data saved in comma-separated values (CSV) files. At the start of each task stage, a time marker was added to the EEG data, so behavioral events and brain signals could be aligned precisely. Figure 3 presents a random example of EEG signal traces and the location of EEG electrodes. All data were saved offline for later analysis.

To compare brain activity between AD and MCI participants during memory retrieval and error adjustment, this study focused EEG analysis on the last four core stages (R1, cue, R2, NR) and excluded the QP stage.

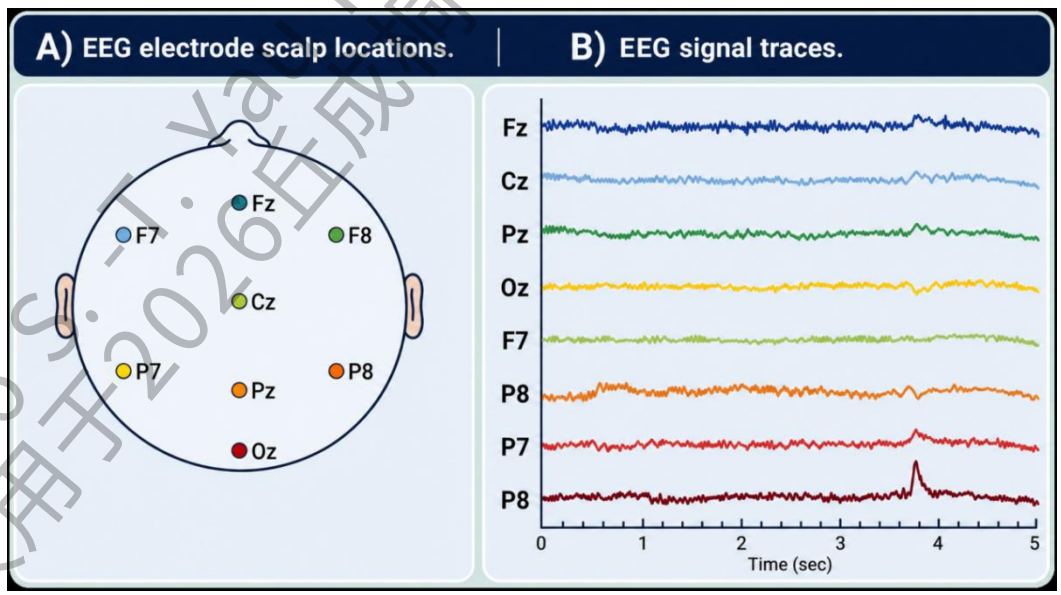


Figure 3. EEG channel configuration and representative signal recordings. (A) Scalp distribution of the eight EEG channels (Fz, F7, F8, Cz, P7, P8, Pz, and Oz) and their

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corresponding primary cortical regions. (B) Representative EEG recordings from a randomly selected participant.

2.6. Experimental Procedure

The experiment consisted of two consecutive phases. The first phase involved a structured, in-depth interview conducted with each participant and their family caregiver. Each interview lasted approximately 90 minutes. During the interview, personal information across four life periods: childhood, adolescence, adulthood, and old age was collected. This included hobbies, life experiences, and relationships.

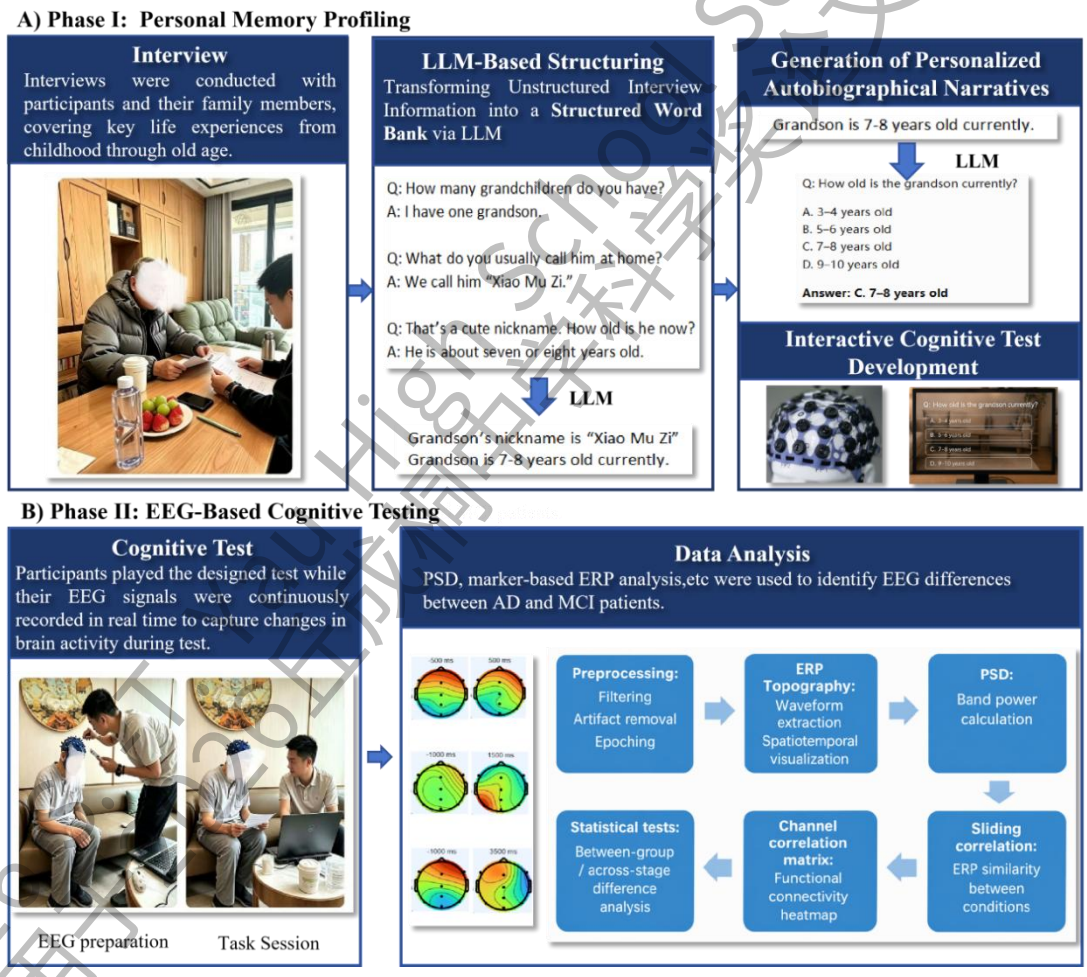


Figure 4 illustrates all of the critical steps throughout the whole process of the experiment. It includes two phases. (A) Phase I is to do Personal Memory Profiling, which covers: one-on-one interview, LLM-based information organization, and generation of personalized autobiographical narratives. (B) Phase II is to synchronize the test with EEG in a real-world

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environment to verify the feasibility of the experiment. The process includes interactive cognitive test processing and data analysis.

After the interview, question banks were built based on the participants' self-reported information. These materials were used to create cognitive tasks. Then, the study postponed at least 15 days between the interview and the second phase (Testing & EEG data recording). On the testing day, participants sat in a quiet room. I applied conductive paste and placed electrodes according to the 10–20 system (Fz, F7, F8, Cz, P7, P8, Pz, Oz). Then participants did the cognitive tasks while I recorded 8-channel EEG. The whole session lasted about one hour. The experiment started only after all electrode impedances were below 10 kΩ.

2.7. EEG Preprocessing

All raw EEG data were preprocessed using the EEGLAB toolbox in MATLAB. The specific steps were as follows: extracting marker information, setting channel locations, bandpass filtering from 4 to 45 Hz, notch filtering from 49 to 51 Hz, and independent component analysis (ICA) to remove eye and muscle artifacts. Rejected components were limited to no more than one-third of all components. **Then the study applied common average referencing across the eight channels and segmented the data into epochs based on markers.** Each epoch started 1 second before the marker and ended 5 seconds after it. Baseline correction used the 1-second pre-marker interval.

After preprocessing, customized MATLAB scripts with EEGLAB functions were used to extract neural features. For each participant, brain activation maps and time-domain activity graphs were generated for all eight channels across the four core task stages. The resulting EEG patterns and response trends were then compared between the MCI and AD participants in an exploratory manner.

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2.8. Event-Related Potential (ERP) Extraction and Topography Generation

Each participant's ERPs were obtained at each memory processing stage by averaging trials from the preprocessed data. Summary figures were generated to show the results. Each figure displayed ERP waveforms from all 8 channels across the whole-time window in one view. This clearly showed the voltage changes of each electrode over time. Sequential ERP scalp topographic maps were also produced. These maps could be combined to show the continuous changes in brain wave power. These visualizations were used to compare EEG differences across task stages and between participants.

2.9. Power Spectral Density (PSD)

PSD was computed using the Welch method in MATLAB with the built-in Welch function. A Hamming window of 1 second (250 Hz sampling rate) with 50% overlap was used. The frequency resolution was 0.1 Hz, and the analyzed range was 1–45 Hz. This included theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz), and gamma (30–45 Hz) bands.

PSD values were calculated for each preprocessed segment. These values were then averaged within each condition to get the PSD result for each state, channel, and participant. The results were used to compare EEG power across task stages and frequency bands.

2.10. Channel-based ERP Correlation Analysis

At each memory processing stage (R1, Cue, R2, NR), the average ERP waveform was calculated for every channel. The goal was to compare the similarity of ERP waveforms across different task conditions. During this process, a sliding time window of 500 ms was used. Within each window, the Pearson correlation coefficient (corrcoef) function in MATLAB and its significance levels were computed between the average ERP series of each marker pair (i.e., R1-Cue, Cue-R2, R1-Cue, R1-R2) for every channel.

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2.11.Functional Connectivity

This study also used Pearson correlation to examine functional connectivity between EEG channels. For each stage (R1, Cue, R2, NR), the average ERP waveform of each channel was correlated with those of all other channels. This produced a connectivity value for each pair of the eight channels that reflects how channels were connected at different memory stages. The correlation coefficient (r) and its statistical significance were recorded. The correlation coefficients (r) were visualized as functional connectivity matrix heat maps. Finally, a heat map of the connectivity matrix was generated for each stage. The heat map had a fixed range of [-1, 1] and was displayed with a color bar.

2.12.Statistical Analysis

Data were exported and sorted into Excel datasets for comparison. To ensure analytical stability, **the average data came from the epoched data of each channel under each individual stage, calculated for every participant.** Based on these averages, within-person and between-group comparisons were made to explore possible EEG differences between MCI and AD participants. **Independent-samples t-tests were used as exploratory analyses to compare EEG measures between the MCI and AD participants.** Repeated-measures

Analysis of Variance (ANOVA) was used to explore changes across different experimental stages. Pearson correlation analysis was used to examine relationships among EEG channels. All statistical analyses were carried out using SPSS 27.0.

Because of the small sample size, these correlation analyses were exploratory. They were interpreted as descriptive and initial rather than as conclusive group-level effects.

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3. Results

3.1. AI- Generated Personalized Narratives

Figure 5 shows a partial screenshot of the experimental program. The interface had a clear and consistent style, and page transitions ran smoothly in real time. The program also stored trial data reliably in CSV format for later analysis.

Across the four task stages (R1, Cue, R2, NR), all participants completed the full testing procedure in a real-world setting. This shows that the system is practical to use. The software ran stably, and EEG signals were recorded together with the behavioral tasks without major data loss or technical problems. **Both MCI and AD participants could perform the memory tasks at each stage, suggesting that this paradigm may be suitable for clinical populations.**

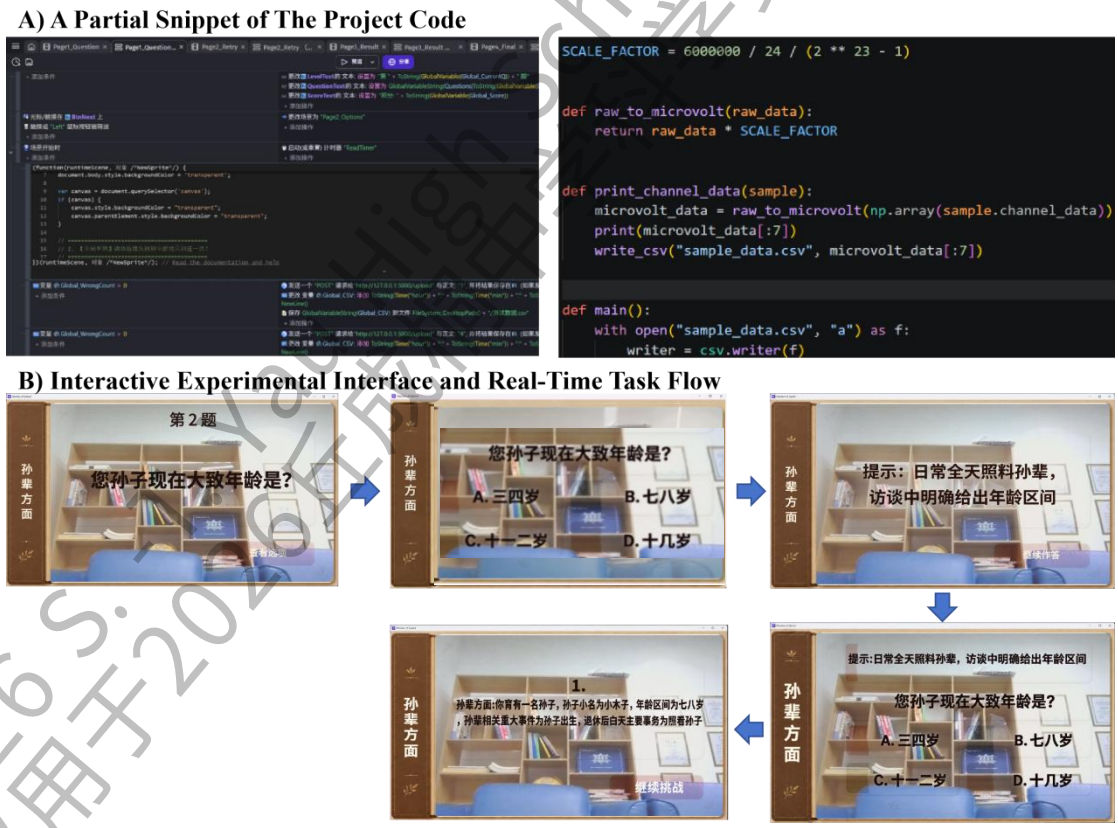


Figure 5: A. The core logic for CSV data storage. B.A partial snippet of the experimental program, demonstrating interface styling, real-time page transition.

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3.2. Power Spectral Density (PSD)

Brain wave power at each electrode was examined under different task conditions, and power was compared across frequency bands. Figure 6 shows scalp maps of brain wave power for each frequency band in each condition.

During R1, brain wave power was relatively higher around electrode P7. This pattern appeared in the theta, alpha, beta, and gamma bands. During the two cue-retrieval stages, power was more widely spread over the outer scalp areas, mainly the prefrontal, temporal, and occipital areas. Power in the central areas (Fz, Pz, Cz) was relatively lower. Based on these spatial patterns, electrodes F7, F8, P7, and P8 were selected for further analysis of temporal region EEG responses.

However, repeated-measures ANOVA did not show significant differences in band-specific power across stages, and these findings were considered preliminary and exploratory.

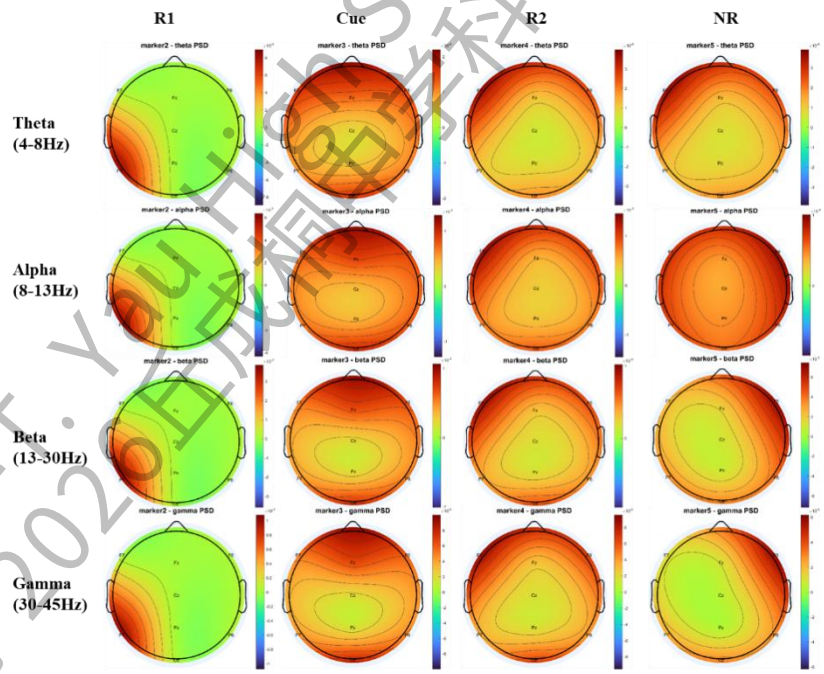


Figure 6: Topographical maps of oscillatory power (θ, α, β, γ) across the four stages (R1, Cue, R2, NR). Power was locally enhanced at P7 during R1, whereas in Cue and R2 it shifted to a broader lateral distribution (frontal–temporal–occipital) with diminished midline activity.

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3.3. Event-Related Potential (ERP)

Based on the PSD results, **this study further analyzed ERP changes in the left and right temporal lobes during the R1, Cue, and R2 stages.** Figure 7 shows the ERP waveforms for both temporal lobes under the three conditions. The analysis time window goes from 1 second before the event to 5 seconds after it. Specifically, the left temporal ERP was calculated by averaging the signals from electrodes F7 and P7. The right temporal ERP was calculated by averaging the signals from F8 and P8.

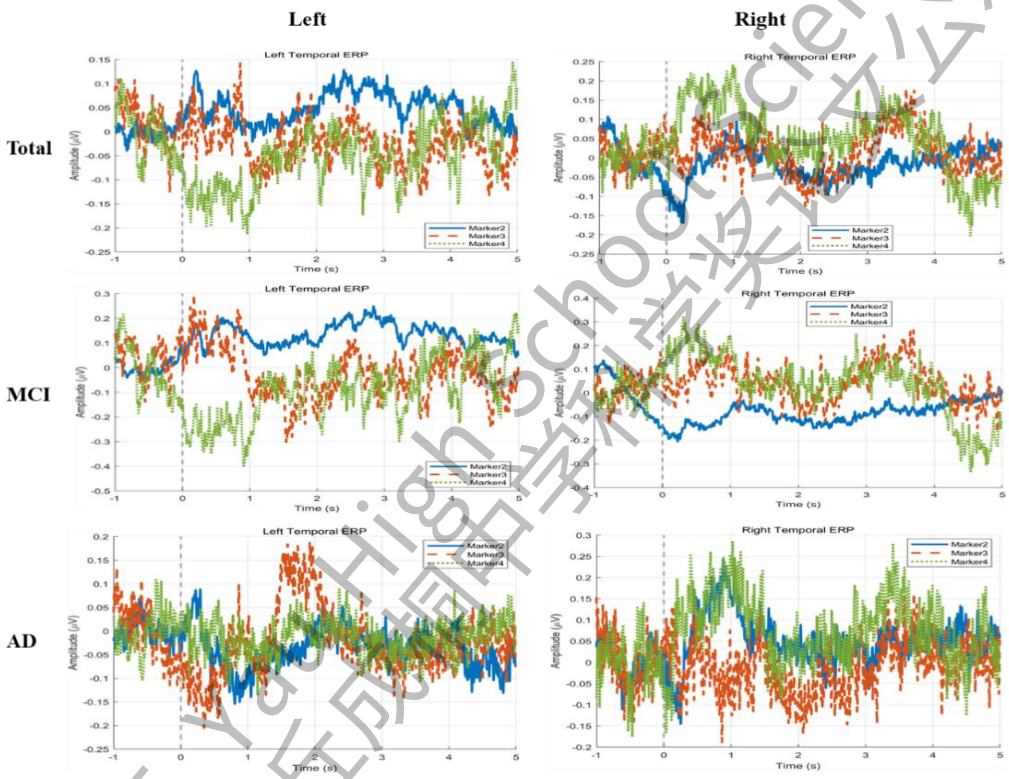


Figure 7: ERP waveform changes in the bilateral temporal regions under three experimental conditions. MCI showed greater phase-dependent ERP modulation (concentrated in R2: 0–1000 ms) than AD, which exhibited stable waveforms with minimal inter-phase differences, indicating dissociable temporal dynamics.

The results showed that ERP waveforms changed over time in all three conditions. After the event began, R1, Cue, and R2 stages each produced potential responses of different sizes, and these responses also differed in both amplitude and timing.

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Comparing the left and right temporal lobes showed different response patterns. The clearest ERP modulation appeared in the R2 stage, mainly within 0–1000 ms after the event. Whole-brain topographic maps for one MCI and one AD participant were examined within this time window (Figure 8). These maps showed how scalp potentials changed across task phases. Since only eight channels were recorded, these maps showed scalp-level potential distribution, not whole-brain activity.

ERP patterns were also compared between MCI and AD participants. The two MCI participants showed relatively clearer ERP changes across stages, with waveform changes concentrated in specific time windows. The two AD participants showed less varied ERP waveforms throughout, with smaller differences between stages. These observations suggest possible differences in EEG temporal dynamics between the two groups. Admittedly, a larger sample is needed for confirmation.

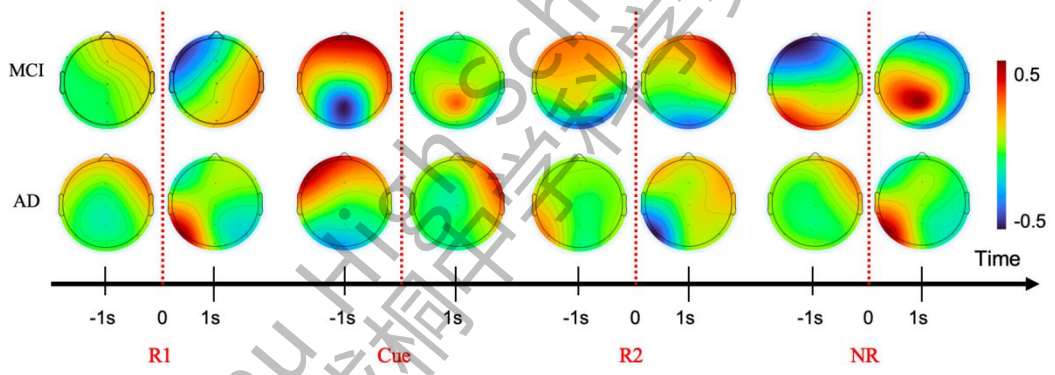


Figure 8: ERP waveforms of partial participants (one MCI, one AD) across four time epochs (R1, Cue, R2, NR). Notable waveform fluctuations can be observed in the pre-0-s and post-0-s time windows.

3.4. Brain Functional Connectivity

In order to observe brain regions interacting during memory stages, this study calculated corrcoef between every pair of the eight EEG channels. Figure 9 presents connectivity patterns for the total sample, MCI, and AD participants across the four task stages.

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Different correlation patterns appeared across task stages and between MCI and AD participants. **This suggests that relationships between EEG channels may change during different stages of the personalized memory task. Overall, channel connectivity showed relatively stable functional coupling patterns**. Strong positive correlations were found between Cz–Pz and Fz–F7. This indicates strong functional synchronization within central-parietal and frontotemporal regions. In the MCI participants, a relatively strong positive correlation was observed between Fz and F7. Negative correlations were observed between Oz–P8 and Cz–P8. This suggests different response patterns between these channel pairs**.** In AD participants, a positive correlation was observed between Cz and Pz, while negative correlations were observed between Oz–Fz and F7–P7. **These findings suggest that the two groups showed different inter-channel correlation patterns across anterior, posterior, and bilateral recording sites.**

However, no statistically significant differences were observed between the MCI and AD participants. Since each group had only two participants, these correlation patterns should be seen as early observations, not definite group differences.

In addition, substantial individual variability was also noted**.** During the R1 stage, channels Fz–P8 showed strong correlations in participant 1(MCI) and participant 2(AD), but only weak correlations in participant 3(MCI) and participant 4(AD). During the R2 stage, participant 2 showed unique strong correlations among Fz–Cz, Fz–Pz, and Cz–Pz.

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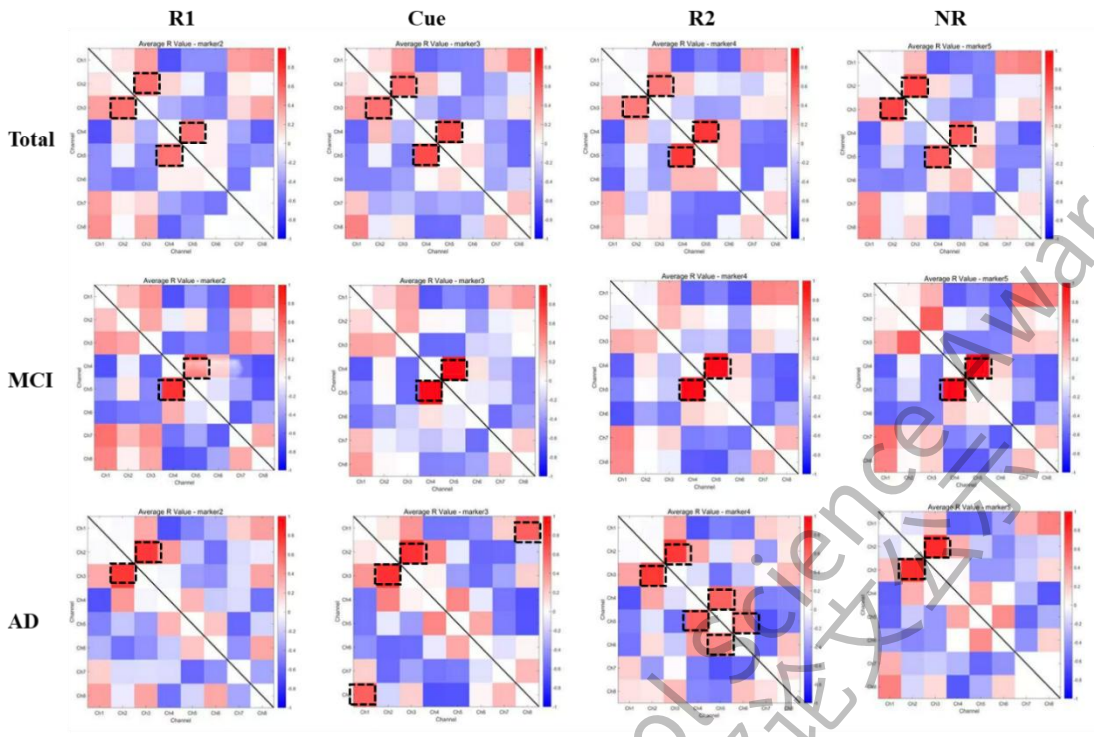


Figure 9 illustrates the connectivity patterns in AD participants, MCI participants, and the total participant cohort. The dashed black box highlights a clear, strong correlation between two channels. Colors represent the correlation coefficient (r value) between two channels, ranging from -1 to 1 (red = 1, blue = -1).

3.5. Question Bank Accuracy

The experiment calculated the average accuracy of MCI and AD participants across five question banks. In terms of behavioral accuracy, the two MCI participants showed higher initial recall accuracy than the AD participants during the R1 stage, whereas the AD participants demonstrated a greater improvement in accuracy after cue presentation (Cue stage), suggesting that AD participants relied more heavily on structured cues. Table 3 presents the average accuracy of MCI and AD participants across the five question banks when having their first attempt at each question. Overall, the average accuracy did not reveal consistent group-level differences between MCI and AD participants across the five question banks.

Table 3. The accuracy of all participants during the R1 stage.

	Average accuracy	Average accuracy

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	MCI (%)	AD (%)
Question bank 1	33.33± 57.74	62.50±51.75
Question bank 2	100.00±0.00	50.00±53.45
Question bank 3	100.00±0.00	87.50±35.36
Question bank 4	66.67±57.74	87.50±35.36
Question bank 5	75.00±50.00	75.00±46.29
Overall	75.00 ± 27.64	72.5 ± 16.30

Note: Data are shown as mean ± SD, calculated from 5-10 questions per question bank.

4. Discussion

This study proposed and tested a new approach: combining AI-generated personalized autobiographical memory cues with simultaneous EEG recording. **This approach potentially creates a more realistic and objective assessment tool for ADS.** Through structured interviews, AI-based story generation, and a five-stage interactive test synchronized with EEG, **the study addressed the question of whether AI-generated personal stories can serve as a practical memory test and if it can reveal different EEG responses between participants with MCI and those with AD.**

The results showed that the method can be implemented smoothly at this assessment setting. Admittedly, the small sample size cannot draw a conclusion for the between-group comparisons. Nonetheless, EEG patterns differed between MCI and AD participants. Overall, MCI participants showed more pronounced ERP changes during task stages such as R1 and R2, and stronger functional connectivity between the central region and bilateral parietal regions. These preliminary results suggest that combining personalized autobiographical memory assessment with EEG recording may be a useful approach to examine cognitive and neural changes in ADS progression.

4.1. Personalized Narrative-Memory Test

In the present study, the LLM was used to convert participants' real-life experiences into personalized memory content. The core advantage of this approach is that AI helps to tailor specific content for each participant while keeping the overall test structure unchanged. This study **developed an interactive cognitive testing program. It can present personalized**

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stimuli while simultaneously recording EEG signals and behavioral responses. This interactive design follows the sequence of "memory retrieval — cue assistance — second retrieval — overall recall" that **mimics the natural way people recall events in real life.** In addition, an overall review session was included at the end of the test. After each set of questions, the LLM summarizes the participant's answers and guides them to review the entire event again. This makes the test not only a measurement tool but also a way to organize and consolidate memory. Compared with unstructured questioning, this approach better matches the cognitive path of everyday recall.

From the perspective of experimental design, the question bank, the LLM, and the five task stages (QP, R1, Cue, R2, NR) each serve different functions. The question bank provides a structured framework for LLM content generation. The LLM generates personalized memory content and guides participants through memory recall. The five task stages define the different stages of the test and the corresponding EEG analysis periods. Together, these elements allow the test to combine personalized memory assessment, a standardized task procedure, and EEG analysis.

4.2. EEG Results Analysis

During R1, PSD power was higher in the left temporal region and prefrontal cortex, with notable anterior temporal activity. In the Cue and NR stages, power distribution expanded to prefrontal, temporal, and occipital regions, while central areas showed lower activity. The beta band (13–30 Hz) showed the greatest variation. These patterns may reflect phase-specific cognitive demands. MCI participants showed more significant changes. AD participants had less varied waveforms over the whole time. This may suggest MCI participants still had some brain resources left. Left-right temporal differences in amplitude and polarity were observed, though the eight-channel setup precludes firm conclusions on hemispheric lateralization. MCI participants showed strong negative correlations between Oz–P8 and Cz–P8, while AD participants showed negative correlations between Oz–Fz and F7–P7. This result may point to connectivity reorganization as cognitive impairment progresses.

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Admittedly, the sample size was too small for meaningful group comparisons, so this study also examined significant individual-level changes. Participant 2 (AD) showed strong Cz–Pz correlations across all four stages (R1, Cue, R2, NR). The Cz–Pz connection is in the central-parietal midline area, which may reflect preserved or abnormally synchronized default network activity. Significantly, this participant achieved 70% accuracy on the question bank, higher than the other AD participant, suggesting that this connectivity pattern might be related to the higher accuracy.

On the other hand, Participant 3 (MCI) showed strong Oz–F7 correlations across all four stages. The Oz–F7 connection is between the occipital midline and left frontal area, possibly reflecting preserved or abnormally synchronized occipito-frontal network activity. Question bank results also showed that Participant 3 (MCI) achieved the highest accuracy among all participants,

However, with only two cases, these observations remain descriptive and cannot be generalized.

4.3. Clinical Implications

This study has several potential practical applications. First, this study uses personalized interviews and AI-generated narratives to design test content based on participants' real-life experiences. **This helps overcome the "one-size-fits-all" limitation of traditional memory tests.** Second, simultaneous EEG recording provides neural activity information beyond behavioral accuracy, which **helps describe cognitive changes in ADS progression.** Third, cueing and the second recall stage **may help memory retrieval**. AD participants showed higher response accuracy after receiving cues. This suggests that the method may be useful for memory training in the future. However, the current results are still preliminary. Larger studies are needed to further validate the clinical value of this method in ADS assessment and intervention.

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5. Limitations and Outlooks

This study has several limitations. First, the sample size was small, and no healthy participants as a control group were included. Second, only eight EEG channels were used, which limited the analysis to basic ERP comparisons and simple channel correlations. This setup could not locate where the signals came from in the brain, nor could it capture more detailed interactions between brain regions. For these reasons, all findings should be seen as early and exploratory, not as conclusions.

Future research could move beyond feasibility and examine whether this method reliably reflects ADS progression. Large multicenter studies with longitudinal follow-up should include healthy older adults, MCI, and AD participants. Such studies can determine whether behavioral and EEG patterns distinguish cognitive stages and track individual changes. Also, multi-channel EEG combined with advanced analysis may reveal brain network reorganization during personalized autobiographical memory retrieval. It can clarify how brain activity relates to clinical presentation and help identify more sensitive neural markers. Finally, this interactive test could develop from a cognitive assessment into a platform that combines memory assessment with personalized cognitive training in the future.

6. Conclusion

Overall, this study developed an interactive memory assessment paradigm. **It combines a unified testing structure with AI-generated personalized autobiographical memory**. All participants completed the test successfully, and their accuracy improved after cueing. This improvement was especially obvious in the AD participants. This suggests that personalized structured cues may help with autobiographical memory retrieval. The EEG results also provide early evidence of brain responses at different task stages. They show differences in functional connections between EEG channels in MCI and AD participants. However, considering the small sample size, these results remain exploratory. They should not be interpreted as proof that the paradigm can diagnose disease or determine disease stage. **This paradigm provides a feasible foundation for further research on personalized**

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autobiographical memory assessment. It also suggests potential directions for its future use in ADS personalized interventions.

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Acknowledgement

The original motivation for this study came from my personal experience with my grandmother, who suffered from Alzheimer's disease. Years ago, because the hospital's early recognition mechanisms for the disease were still inadequate, she did not receive timely diagnosis or effective intervention. By the time she was diagnosed, she was already in the middle to late stage of Alzheimer’s disease and had lost her language, motor abilities, and most of her memories. This family experience made me deeply aware of the importance of early assessment and intervention, and it inspired me to introduce cutting-edge technologies into Alzheimer's disease research and clinical practice. With the rapid development of artificial intelligence, especially large language models, I gradually developed the research topic “EEG Responses Evoked by AI-Generated Personalized Autobiographical Memory Cues Across the ADS.

In the course of this project, I would first like to express my sincere gratitude to my primary supervisors, President Tan Minghua of Guangdong Pharmaceutical University Guangzhou Fosun Chancheng Hospital and Associate Chief Physician Li Zhigang of the Department of Neurology. The two teachers provided systematic, meticulous, and participant guidance throughout the entire process, from topic selection and research design, neuroscience know-how, participant recruitment assistance, to the final revision of the manuscript, and offered me extensive teaching and inspiration in the field of neuroscience. The successful completion of this project would not have been possible without their continuous encouragement and support.

At the same time, I would like to sincerely thank Dr. Wang Xingli, President of Global R&D Center, Fosun Pharma Group, and Professor Geng Meiyu, Academic Director of the Shanghai Institute of Materia Medica, Chinese Academy of Sciences, and a renowned scientist in the field of pharmacology. Both of them helped me gain a deeper understanding of the current research status and frontier challenges of ADS, inspired me to think about the clinical significance of this project, and constantly encouraged me to refine my research ideas.

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This project involves interdisciplinary content of computer science, and other fields, some of which I had only briefly encountered or had never studied before. Therefore, during the study process, I engaged in extensive consultation with Ma Junyi, Director of AI Strategy Development of Fosun Pharma, and self-study, systematically learning Python programming skills.

I would also like to thank Teacher Tian Run, the homeroom teacher of Class G10-1 at Shanghai Starriver Bilingual School. She provided careful guidance during the project implementation and inspired me to reflect on the long-term social significance and interdisciplinary value of the research findings.

I also thank the quality content creators on online platforms such as GitHub, Bilibili, YouTube, DeepSeek, and ChatGPT. I used these platforms to supplement a large amount of professional knowledge and referred to, learned from, and adapted existing algorithms; they helped me find solutions to several key programming issues in the deep learning model. The AI models and creators from numerous platforms provided tremendous support for this project. More detailed information about AI usage is presented in the “AI Use Declaration” part.

It is particularly worth emphasizing that conducting one-on-one interviews with two MCI participants and two elderly participants with AD, as well as collecting EEG data during task execution, was one of the most central and challenging parts of this project. The entire testing procedure was time-consuming, communication with the elderly participants involved many difficulties, and the process itself was a demanding journey for the participants. Here, I would like to express my heartfelt gratitude to the four volunteers and their families for their full cooperation and unwavering support throughout the entire process. Their participation not only enabled the research to move forward but also strengthened my determination to complete the project with high quality. At the same time, I sincerely thank my mother for her valuable guidance and assistance in participant recruitment, interview coordination, and testing implementation.

From topic conception, experimental design, participant recruitment and interviews, Python system development, response flow and task design, to EEG data collection, signal filtering and analysis, and finally to manuscript writing and repeated revisions, the entire

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research cycle lasted approximately twelve months and ultimately resulted in this paper. Throughout this process, I have always upheld the belief of "empowering the diagnosis and treatment of ADS with advanced technology and artificial intelligence, so that science and technology can truly benefit participants." This belief sustained me through many difficulties during the research. I have come to deeply recognize that, compared with the final paper itself, the active exploratory awareness, project design and execution abilities, innovative and iterative thinking, multidimensional understanding of complex diseases, and real-world communication and interview experience cultivated during the project will have a far more profound impact on my future academic development.

In addition, I am clearly aware that the current EEG elicitation research based on personalized autobiographical memory cues still has many limitations and considerable room for expansion. In the future, I am willing to continue investing effort in optimizing this system, gradually making it more applicable to real-life settings, benefiting a broader population of older adults, and contributing to the early prevention and intervention of ADS, so that more elderly people can enjoy a healthy and happy later life.

All assistance received during this project was provided without compensation.

Finally, I would like to once again extend my most sincere gratitude to all the teachers, family members, friends, and participants who supported, helped, and encouraged me throughout this project.

AI Use Declaration

In this study, I used AI as an aid in the following aspects. All of the AI-generated content was manually verified. The core parts of this research, including topic selection, study design, participant recruitment, experimental implementation, data collection & analysis, conclusion derivation, and paper writing, were independently completed by me. Major using histories as follows:

AI Tool Name	Application Area	Purpose	Time and Frequency
Tingnao AI	Interview information	Records interview contents to prevent misunderstanding of the	Jan.- Mar.2026

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AI Tool Name	Application Area	Purpose	Time and Frequency
	recording	content mentioned by participants	
OpenAI GPT-4.0	Experimental material generation	Converts interview records into personalized narrative cues; generates multiple-choice questions and distractors.	Mar. 2026, intensive use
OpenAI GPT-4.0	Programming support	Assists in debugging Python experiment programs and MATLAB analysis scripts.	Mar. -May 2026, intermittent use
DeepSeek Grammarly	Language polishing	Grammar check and expression refinement of the English wording.	Aug. 2026, 3 times

This research paper is entirely written by me; all usage complies with academic integrity standards. No AI was used for the generation or manipulation of any raw data or other unethical practices.

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