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Neurocognitive Differences in Attention, Memory, and Executive Functions Between People with Epilepsy and Healthy Controls: Evidence from Shiraz, Iran

Kimia Sahraian [1*]

1. Department of Psychology, Higher Education Center of Eghlid, Eghlid, Iran.

***Corresponding Author:** Assistant Professor, Department of Psychology, Higher Education Center of Eghlid, Eghlid, Iran. Email: kimia.sahraian@eghlid.ac.ir

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ABSTRACT

This study investigated neurocognitive profiles in attention, memory, and executive functions among individuals with epilepsy compared to healthy controls in Shiraz, Iran. In a cross-sectional design, 121 participants (61 with epilepsy, 60 controls) aged 18–45 years were assessed using a standardized neuropsychological battery, including the Digit Span Test, Rey Auditory Verbal Learning Test (RAVLT), Stroop Color-Word Test, and Wisconsin Card Sorting Test (WCST). Data were analyzed using non-parametric Mann–Whitney U tests due to non-normal distributions. Results revealed that individuals with epilepsy exhibited significantly greater cognitive impairments across all domains: attention ($U=171.5$, $p < .001$), memory ($U = 135.5$, $p < .001$), and executive functioning ($U= 49.5$, $p < .001$). The findings underscore substantial neurocognitive dysfunction associated with epilepsy, highlighting the need for integrated cognitive screening and tailored interventions within clinical care in the Iranian context. This study contributes to the growing cross-cultural evidence on epilepsy-related cognitive deficits and supports the adoption of holistic management approaches that address both seizure control and cognitive rehabilitation.

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Introduction

Epilepsy is a chronic neurological disorder characterized by recurrent, unprovoked seizures, affecting approximately 50 million people globally, with a disproportionately high burden in developing regions (Gerina et al., 2025). Beyond the primary clinical manifestations, epilepsy is increasingly recognized for its significant comorbidity with neurocognitive impairments (Gupta et al, 2022). The intricate relationship between epileptic activity, underlying neuropathology, antiepileptic drugs (AEDs), and cognitive function poses a substantial challenge to patients' quality of life, affecting educational attainment, vocational success, and psychosocial well-being (Baker & Butler, 2024).

Cognitive domains most frequently implicated in epilepsy include attention, memory, and executive functions core processes essential for daily adaptive functioning. Attentional deficits, often exacerbated by AED side effects and seizure frequency, can undermine information processing speed and concentration (Hasegawa & Annaka, 2023). Memory disturbances, particularly in verbal and episodic memory, are commonly reported and are frequently associated with temporal lobe involvement and duration of illness (Mukaino, 2024). Executive dysfunction, encompassing abilities such as planning, cognitive flexibility, and inhibitory control, is often linked to frontal lobe pathology and has profound implications for problem-solving and behavioral regulation (Soleymani et al., 2025).

Extant literature from diverse cultural and clinical settings, consistently documents significant cognitive disparities between individuals with epilepsy and healthy controls (Van Patten et al., 2024). However, the generalizability of these findings can be influenced by genetic, environmental, socioeconomic, and healthcare access variables specific to different populations. In Iran, despite a reported epilepsy prevalence comparable to global estimates, there remains a relative paucity of focused, comprehensive neuropsychological profiling comparing patients with epilepsy to demographically matched healthy controls using standardized assessments. Most local studies have either been clinically descriptive or limited to specific epilepsy subtypes, leaving a gap in population-based cognitive characterization. Furthermore, while the adverse cognitive effects of certain AEDs and the role of seizure burden are acknowledged, the interactive contribution of illness duration, treatment adherence, and psychosocial factors within the Iranian context is not well-documented. Addressing this gap is crucial for developing tailored cognitive rehabilitation strategies and optimizing holistic patient care.

Therefore, this study aims to investigate the neurocognitive profile of individuals with epilepsy in Shiraz, Iran, specifically focusing on attention, memory, and executive functions, in comparison with a group of healthy controls. We hypothesize that (1) individuals with epilepsy will demonstrate significantly poorer performance on measures of attention, memory, and executive functioning compared to healthy controls, and (2) within the epilepsy group, longer illness duration will correlate with greater cognitive impairment. The findings intend to contribute empirical evidence from the Iranian population to the international neuropsychological literature on epilepsy and inform clinical practices aimed at early cognitive screening and intervention.

Method

Participants

This cross-sectional, case-control study recruited a total of 120 participants, divided into two groups: a clinical group of 60 individuals diagnosed with epilepsy and a control group of 60 neurologically healthy individuals. Participants in the epilepsy group were consecutively recruited from the outpatient neurology clinics of major teaching hospitals affiliated with Shiraz University of Medical Sciences. Diagnosis was confirmed by a board-certified neurologist

based on clinical history and standard diagnostic criteria, including electroencephalography (EEG) and/or neuroimaging (MRI/CT) where indicated. All patients in the clinical group were on a stable regimen of antiepileptic drugs (AEDs) for at least six months prior to assessment.

The control group was recruited from the local community through advertisements and were screened for any history of neurological or major psychiatric disorders, head injury with loss of consciousness, or substance abuse. Both groups were matched at the group level on key demographic variables: age (range 18-45 years) and years of education (minimum 8 years).

Inclusion criteria for the epilepsy group were: (1) age between 18 and 45 years; (2) confirmed diagnosis of epilepsy for at least one year; (3) proficiency in Persian. Exclusion criteria for both groups included: (1) presence of comorbid major psychiatric disorders (e.g., psychosis, major depressive disorder) as per clinical interview; (2) intellectual disability (IQ < 70); (3) significant sensory or motor impairments preventing test completion; (4) history of other major neurological conditions (e.g., stroke, tumor).

Materials and Measures

Neurocognitive functioning was assessed using a battery of standardized and psychometrically validated instruments.

1. **Attention and Working Memory:**

Digit Span Tes: The Digit Span Test from the Wechsler Adult Intelligence Scale–Revised (WAIS-R) was used to assess attention and verbal working memory. This widely utilized neuropsychological measure requires participants to orally reproduce sequences of digits that are presented auditorily by the examiner (Ostrosky-Solís & Lozano, 2006). The test was administered in two conditions: Forward Digit Span (FDS) and Backward Digit Span (BDS). In the forward condition, participants were instructed to repeat the digits in the same order as presented, whereas in the backward condition they were required to recall the digits in reverse order. Digit sequences were delivered at a fixed rate of one digit per second, using a constant vocal pitch to minimize the use of chunking strategies that could artificially enhance performance. Repetition of digit sequences was not permitted; participants were informed that each sequence would be presented only once and were encouraged to provide their best possible response. The task began with two-digit sequences, which served as practice trials and were excluded from scoring. Sequence length increased progressively up to a maximum of nine digits. Each span length from three to nine digits was presented three times using different digit combinations. One point was awarded for each correctly recalled sequence. After three trials at each span length, task difficulty was increased regardless of performance. For data analysis, the percentage of correctly recalled trials was calculated for each participant. As scoring was based on sequences ranging from three to nine digits, the maximum attainable score in each condition (forward and backward) was 21.

2. **Verbal Memory:**

Rey Auditory Verbal Learning Test (RAVLT): Verbal learning and memory were assessed using the Rey Auditory Verbal Learning Test (RAVLT), a widely used and well-validated neuropsychological measure of episodic verbal memory. The original one-trial version of the test was first introduced by Claparède in the early twentieth century, and subsequently expanded by Rey into a five-trial learning paradigm followed by delayed recall and recognition trials (Strauss et al., 2006). The contemporary form of the RAVLT incorporates minor methodological refinements while preserving its core structure. In its current standardized version, the RAVLT consists of three semantically unrelated word lists. Lists A and B each include 15 words and are designed to assess free recall, whereas the third list comprises 50 words (20 novel distractor words and 30 words drawn from Lists A and B) and is used to evaluate recognition memory. During administration, List A is orally presented across five

consecutive trials, and after each presentation participants are instructed to recall as many words as possible in any order, providing indices of immediate memory and learning across trials. Subsequently, List B is presented once to induce proactive interference, and participants are asked to recall the words from this list. Immediately thereafter, without re-presenting List A, short-delay free recall of List A is assessed. Following a delay interval of approximately 20–30 minutes, long-delay free recall is obtained. Finally, a recognition trial is administered in which participants are required to identify words from List A among distractor items. The RAVLT yields multiple quantitative indices reflecting learning, recall, interference, and recognition processes. These include the First Trial Score (FTS), as an index of immediate verbal memory; the Seventh Trial Score (STS), reflecting delayed recall; the Proactive Interference Score (PIS), indicating the extent to which previously learned information interferes with new learning; and the Retroactive Interference Score (RIS), capturing the disruptive effect of newly learned material on prior learning. Additional indices comprise the Forgetting Rate Score (FRS), representing memory decay over time; the Final Acquisition Learning Score (FALS), defined as the maximum number of words recalled across the five learning trials; the Total Learning Score (TLS), calculated as the sum of words recalled across Trials 1–5; and the Learning Over Trials Score (LOTS), reflecting learning gains beyond initial recall. Recognition memory is assessed using the Net Positive Score (NPS), derived from correct minus incorrect recognitions, and the Recognition Over Recall Score (RORS), which contrasts recognition performance with delayed free recall (Lezak, 2004; Sisakhti et al., 2023). Collectively, these indices provide a comprehensive assessment of verbal learning and memory functioning.

3. **Executive Functions:**

Stroop Color-Word Test: Selective attention, cognitive control, and inhibitory processing were assessed using a computerized version of the Stroop Color and Word Test (SCWT), a well-established and reliable measure of executive functioning. The assessment was administered in a controlled environment with moderate ambient lighting. Participants were seated approximately 40 cm from a 13-inch monitor, and standardized instructions were provided prior to test administration. Stimuli consisted of the color words yellow, red, blue, and green, which were presented randomly at a rate of 60 frames per minute, with each stimulus displayed for approximately 1 second. All stimuli were presented in Adobe Erbic font with a font size of 65. Before the main task, participants completed a familiarization phase comprising 47 practice trials to become accustomed to the spatial location of the response keys corresponding to blue, green, yellow, and red, which were marked with colored bars on the keyboard. Following this phase, the main task was administered across four experimental conditions, consisting of 110 randomized stimulus presentations. In the first condition, the color words were presented in white font, and participants were required to respond based on the semantic meaning of the word. In the second condition, the words were displayed in congruent colors, such that the ink color matched the semantic meaning of the word. In the third condition, the words were presented in incongruent colors, and participants were instructed to respond according to the word's meaning. In the final condition, the words were also presented in incongruent colors; however, participants were required to respond based on the ink color while inhibiting the semantic content of the word. To examine the effects of learning and repetition, the SCWT was re-administered after a 10-minute interval. For each condition, performance indices included the number of correct and incorrect responses as well as reaction time for correct responses. The computerized SCWT was implemented using Python software. Consistent with prior research, despite variations in stimulus characteristics and administration formats, the fundamental Stroop paradigm underlying the SCWT remains stable and

demonstrates satisfactory reliability as a measure of attentional control and cognitive inhibition (Van der Elst, et al., 2006; Sobhani et al., 2022).

Wisconsin Card Sorting Test: Cognitive flexibility and set-shifting ability were assessed using the Wisconsin Card Sorting Test (WCST), a well-established neuropsychological measure of executive functioning (Heaton, 1981; Dann et al., 2023). The computerized version of the task was administered via Inquisit 6 software (2021)[1]. In this task, participants were required to sort a series of response cards by matching each card to one of four reference stimulus cards. The stimulus cards varied along three perceptual dimensions: color, shape, and number. Participants were not explicitly informed of the correct sorting rule and were required to infer the rule based on feedback provided after each response. The sorting criterion changed automatically after 10 consecutive correct responses, thereby requiring participants to inhibit previously learned rules and shift to a new sorting strategy. The task continued until participants successfully completed sorting according to each of the three dimensions twice, or until all 128 response cards had been presented. Performance on the WCST was indexed by the percentage of perseverative errors, calculated in accordance with the standardized scoring procedures described by Heaton et al. (1981; Dann et al., 2023), which reflects difficulties in cognitive flexibility and resistance to set-shifting.

All tests have demonstrated acceptable reliability and validity in Persian-speaking populations. A demographic and clinical questionnaire was used to collect information on age, gender, education, epilepsy type, duration of illness, and current AED regimen.

Design and Procedure

The study employed a between-subjects design with one independent variable, Group, with two levels (Epilepsy vs. Healthy Control). The dependent variables were scores on the neuropsychological tests measuring the three core cognitive domains: Attention/Working Memory, Verbal Memory, and Executive Functions.

Following ethical approval and participant recruitment, each participant underwent a single assessment session lasting approximately 90 minutes. Sessions were conducted in a quiet, well-lit room at the Chamran hospital's neuropsychology lab in Shiraz. After providing written informed consent, participants completed the demographic/clinical questionnaire.

A trained clinical psychologist, blinded to the group status of control participants, administered the neuropsychological test battery in a standardized manner following published protocols. The order of tests was: Digit Span, RAVLT (immediate trials), Stroop Test, WCST, followed by the RAVLT delayed recall and recognition trials. Short breaks were offered to minimize fatigue.

Data Analysis

Data were analyzed using IBM SPSS Statistics, version 26. Prior to conducting inferential analyses, the dataset was screened for accuracy, missing values, and outliers. Descriptive statistics, including means, standard deviations, and skewness coefficients, were computed for all cognitive variables (attention, memory, and executive functioning) separately for the epilepsy and control groups.

The assumption of normality was assessed using both graphical inspection and the Shapiro–Wilk test, which is recommended for small to moderate sample sizes. Results of the Shapiro Wilk test indicated significant deviations from normality for all cognitive variables in both groups (all $p < .001$). In addition, skewness values exceeded acceptable thresholds (±1), further confirming non-normal distributions.

Given the violation of normality assumptions, non-parametric statistical procedures were employed. Group differences between individuals with epilepsy and healthy controls on

[1] https://www.millisecond.com

measures of attention, memory, and executive functioning were examined using the Mann–Whitney U test. This test was selected due to its robustness in comparing independent groups when data are ordinal or non-normally distributed.

For each comparison, Mann–Whitney U values, standardized *Z* statistics, and exact significance levels (*p*-values) were reported. Rank-based descriptive indices, including mean ranks and sum of ranks, were also calculated to facilitate interpretation of group differences. All statistical tests were two-tailed, and the level of statistical significance was set at $p < .05$

Results

Descriptive Statistics and Assessment of Normality

Descriptive statistics for attention, memory, and executive functioning scores in individuals with epilepsy and healthy controls are presented in Table 1.

Table 1 Descriptive Statistics for Attention, Memory, and Executive Functioning in Individuals with and Without Epilepsy

Variable	Group	M	SD	Skewness
Attention	Control	2.78	.39	1.17
	Epilepsy	9.56	.24	-.20
Memory	Control	1.73	.38	1.64
	Epilepsy	9.48	.18	-5.30
Executive Functioning	Control	1.02	.28	2.30
	Epilepsy	8.72	.16	-6.39

Note. Higher scores indicate greater cognitive difficulties.

As shown, participants with epilepsy exhibited substantially higher mean scores across all three cognitive domains, indicating greater cognitive difficulties compared to controls. The skewness values for all variables exceeded acceptable thresholds for normal distribution, suggesting deviations from normality in both groups.

To formally assess the assumption of normality, the Shapiro–Wilk test was conducted separately for each group (Table 2).

Table 2 Shapiro–Wilk Test of Normality for Cognitive Variables

Variable	Control	p	Epilepsy W	p
Attention	**.776**	<.001	**.391**	<.001
Memory	**.653**	<.001	**.365**	<.001
Executive	**.531**	<.001	**.475**	<.001

As reported in Table 2, the results indicated that attention, memory, and executive functioning scores were significantly non-normally distributed in both individuals with epilepsy and controls (all $p < .001$). Consequently, non-parametric statistical procedures were deemed appropriate for subsequent analyses.

Group Comparisons on Cognitive Functioning

Mann–Whitney U tests were employed to compare individuals with epilepsy and healthy controls on attention, memory, and executive functioning. Rank-based descriptive statistics are displayed in Table 3. Across all three domains, participants with epilepsy demonstrated consistently higher mean rank scores, reflecting greater cognitive difficulties relative to controls.

Table 3 Mean Rank Scores for Attention, Memory, and Executive Functioning

Variable	Group	Mean Rank	Sum of Ranks
Attention	Control	33.36	2001.50
	Epilepsy	88.19	5379.50
Memory	Control	32.76	1965.50
	Epilepsy	88.78	5415.50
Executive functioning	Control	31.33	1879.50
	Epilepsy	90.19	5501.50

Inferential statistics revealed statistically significant group differences across all cognitive domains (see Table 4). Individuals with epilepsy reported significantly greater attention-related problems compared to controls ($U = 171.50$, $Z = -8.84$, $p < .001$). Similarly, memory impairments were significantly more pronounced in the epilepsy group ($U = 135.50$, $Z = -9.22$, $p < .001$).

Moreover, executive functioning deficits were markedly higher among individuals with epilepsy relative to healthy controls ($U = 49.50$, $Z = -9.96$, $p < .001$), indicating substantial impairments in higher-order cognitive processes.

Table 4 Mann–Whitney U Test Results for Group Comparisons

Variable	U	Z	P
Attention	171.5	-8.84	<.001
Memory	135.5	-9.22	<.001
Executive Functioning	49.5	-9.96	<.001

Overall, the findings provide strong empirical support for the presence of significant deficits in attention, memory, and executive functioning among individuals with epilepsy compared to non-epileptic controls.

Discussion and Conclusion

The present study investigated neurocognitive differences in attention, memory, and executive functions between individuals with epilepsy and healthy controls in Shiraz, Iran. Consistent with the study hypotheses, individuals with epilepsy demonstrated significantly poorer performance across all three cognitive domains, with large effect sizes indicating clinically meaningful impairments relative to neurologically healthy participants. These findings extend a growing body of international evidence demonstrating that epilepsy is frequently accompanied by broad neurocognitive dysfunction, even beyond overt seizure activity (Helmstaedter et al., 2021; Van Patten et al., 2024).

Attentional deficits observed in the epilepsy group may reflect the cumulative impact of recurrent epileptiform discharges on fronto-parietal attention networks, as well as the cognitive side effects associated with antiepileptic drug (AED) treatment and the presence of subclinical seizure activity (Loring & Meador, 2016; Hasegawa & Annaka, 2023). Impairments in verbal learning and memory, particularly on the Rey Auditory Verbal Learning Test (RAVLT), are consistent with the well-documented vulnerability of medial temporal lobe structures in epilepsy. Both ictal and interictal neural activity have been shown to disrupt hippocampal functioning, thereby compromising memory encoding and consolidation processes (Baxendale et al., 2017; Mukaino, 2024).

Executive functioning emerged as the most affected cognitive domain, as evidenced by pronounced group differences on the Stroop Test and Wisconsin Card Sorting Test (WCST). This pattern aligns with contemporary models emphasizing the sensitivity of prefrontal cortical systems and large-scale cognitive control networks to the diffuse neural disruptions characteristic of epilepsy (Upton & Thompson, 2020; Soleymani et al., 2025). Although the study demonstrated clear group-level cognitive differences, the absence of within-group analyses examining illness duration or seizure-related variables limits conclusions regarding the specific clinical correlates of executive dysfunction, warranting further investigation.

Overall, the present findings are consistent with prior international research, supporting the cross-cultural and transdiagnostic nature of cognitive comorbidity in epilepsy (Jaffri et al., 2022; Van Patten et al., 2024). Importantly, they also converge with emerging evidence from Iranian samples, which has begun to characterize cognitive vulnerabilities in neurological populations (Sisakhti et al., 2023; Sobhani et al., 2022). The relatively large magnitude of cognitive differences observed in this study may be partially attributable to contextual factors, including illness severity, AED polytherapy, and psychosocial stressors such as limited access

to specialized neuropsychological services. These factors, which may vary across healthcare systems, could exacerbate cognitive burden in individuals with epilepsy (Gerina et al., 2025).

From a clinical perspective, these findings underscore the necessity of integrating routine neurocognitive screening into standard epilepsy care in Iran, rather than focusing exclusively on seizure control. Early identification of attentional, memory, and executive deficits can inform individualized treatment planning, patient education, and vocational or educational accommodations (Helmstaedter et al., 2021). Moreover, the development and implementation of culturally adapted cognitive rehabilitation programs for Persian-speaking patients may offer a viable pathway to improving daily functioning, autonomy, and quality of life (Baker & Butler, 2024). Enhancing awareness among patients and families regarding the cognitive dimensions of epilepsy may also help reduce stigma and promote adaptive coping strategies.

Several limitations should be acknowledged. The cross-sectional design limits causal inference regarding the progression of cognitive impairments over time. Additionally, recruitment from a single clinical center may restrict the generalizability of findings to the broader Iranian epilepsy population. While a standardized neuropsychological battery was employed, future studies would benefit from a more comprehensive assessment encompassing processing speed, social cognition, emotional functioning, and subjective cognitive complaints. Potential confounding variables, including mood symptoms, sleep disturbances, and specific AED regimens, were not statistically controlled and may have influenced cognitive performance (Thompson & Duncan, 2005). Furthermore, the inclusion of neuroimaging or electrophysiological measures could strengthen inferences regarding the neural mechanisms underlying observed deficits.

Future research should prioritize longitudinal and multi-center designs to examine cognitive trajectories in epilepsy and to identify clinical, pharmacological, and psychosocial predictors of cognitive outcomes. Randomized controlled trials evaluating culturally tailored cognitive rehabilitation interventions are particularly warranted. Additionally, investigations into protective factors such as cognitive reserve may offer valuable insights for mitigating cognitive decline. Integrative approaches combining neuropsychological, neuroimaging, and genetic data may ultimately facilitate more personalized and comprehensive models of epilepsy care.

In conclusion, this study provides compelling evidence of significant impairments in attention, memory, and executive functioning among individuals with epilepsy in Iran. These neurocognitive difficulties have important implications for everyday functioning and overall quality of life, highlighting the need for a more holistic, cognitively informed approach to epilepsy management within clinical practice.

Declarations

Author Contributions

All responsibilities for the article rest with the author.

Data Availability Statement

This study's data can be requested from the author upon request. The data is not available publicly due to ethical or privacy concerns.

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Ethical considerations

The research study was approved by the ethics committee at University of Shiraz. Participants' consent was obtained based on completing the survey after receiving all relevant information about the research, including research objectives, anonymity, voluntary participation, and

having the opportunity to ask questions. They were free to withdraw from the research at any time without mentioning the reason and without any cost or consequences.

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Conflict of interest

The author declares that there is no conflict of interest.

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