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Data Article

Brain electrophysiological recording during olfactory stimulation in mild cognitive impairment and Alzheimer disease patients: An EEG dataset

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ABSTRACT

The dataset presented in this article contains preprocessed cleaned electroencephalography (EEG) recording from 35 participants including 13 Alzheimer's disease (AD) patients, 7 amnestic mild cognitive impairment (aMCI) patients, and 15 healthy elderly. All participants performed the same olfactory task which consisted of 120 trials of 2 s olfactory stimulation and 8 s rest (no odorant). The olfactory stimulation consisted of rose and lemon odorants. Odor trials were presented randomly with a probability of 0.75 presenting lemon and 0.25 presenting rose. The impedance of the electrodes was kept under 15 KΩ during the experiment. The data was filtered from 0.5 to 40 Hz using a bandpass filter and epoched from 1 s pre-stimulus to 2 s post-stimulus. Artifacts related to eye blinks were removed by running independent component analysis (ICA) and the remaining noisy trials were identified by eye and removed from further analysis. Mini Mental State Examination (MMSE) test scores for all participants are also provided in the dataset.

Olfactory dysfunction has been shown to be associated with neurodegenerative diseases such as dementia and Alzheimer's disease. Therefore, studying the response of the

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olfactory system may lead to identifying early biomarkers for related brain disorders.

Specifications Table

Subject	Neuroscience: Sensory Systems
Specific subject area	Analysis of olfactory system dysfunction caused by neurodegenerative diseases such as Alzheimer's disease
Type of data	EEG data
How the data were acquired	The data were acquired from the Fp1, Fz, Cz, and Pz EEG channels while the participants received a sequence of lemon and rose olfactory stimulation in a random order.
Data format	Raw format Cleaned (preprocessed)
Description of data collection	A total of 44 individuals, including healthy elderly individuals and those with mild cognitive impairment (MCI) or Alzheimer's disease (AD), participated in this experiment. Of these participants, 9 were excluded from further analysis due to issues with EEG data recording, a history of stroke, traumatic brain injury, a history of olfactory dysfunction, or diagnosis of neurodegenerative diseases other than AD such as Parkinson's disease or multi-system atrophy. The remaining 35 participants (age = 70.97 ± 8.58, female = 57.14%) included 15 healthy individuals (age = 69.27 ± 6.65, female = 53.33%), 7 MCI patients (age = 66.57 ± 6.85, female = 51.14%), and 13 AD patients (age = 75.31 ± 9.90, female = 61.54%). An olfactory oddball perception task was performed on the participants. During this task, each participant was presented with a random sequence of two different odors. The sequence of odors was the same for all participants. One odor (lemon) was presented frequently (standard) with a probability of 0.75 and the other odor (rose) was presented non-frequently (deviant) with a probability of 0.25.
Data source location	• Institution: Ziaeian Hospital • City/Town/Region: Tehran • Country: Iran • Latitude & longitude: 35.65749976121071, 51.35925206137421
Data accessibility	• Repository name: Mendeley • DOI: 10.17632/sgzbgwjfkr.5 • Direct URL to the data: https://data.mendeley.com/datasets/sgzbgwjfkr
Related research article	Sedghizadeh, M.J., Aghajan, H., Vahabi, Z., Fatemi, S.N., Afzal, A., Network synchronization deficits caused by dementia and Alzheimer's disease serve as topographical biomarkers: a pilot study. Brain Structure & Function 227, 2957–2969 (2022). https://doi.org/10.1007/s00429-022-02554-2

Value of the Data

- The neurodegenerative processes associated with the deposition of amyloid plaques in AD patients are more prominent in the early stage of the disease in the medial temporal lobe where olfactory perception occurs. Therefore, any dysfunction in the perception of smells can be considered as a potential biomarker for early diagnosis of AD.
- Studying the brain's oscillatory activity in response to olfactory stimulation and conducting a comparative study between MCI and AD patients and healthy participants is possible with this dataset and may explain new methods for diagnosis or treatment of AD patients.

- Researchers, neuroscientists and clinicians working on AD can employ the dataset to investigate the EEG responses that reveal brain activity during different stimulation cycles and study characteristics related to the disease.
- Researchers, neuroscientists and clinicians studying the olfactory system can employ the dataset to investigate the olfactory response mechanisms in each group of participants.
- The dataset can be used for applying different EEG processing algorithms and analyses such as: brain connectivity, event-related potentials (ERP), event-related spectral potentials (ERSP), phase coherence, or time series analysis.

1. Objective

Two research articles published based on the presented data can be viewed at [1,2]. Alzheimer's disease (AD) is the leading cause of dementia and the sixth leading cause of death in the United States [3]. The staging of the AD is associated with the accumulation of Amyloid-beta ($A\beta$) proteins in the brain [4]. These depositions cause synaptic and neuronal loss, which leads to major cognitive dysfunction in the advanced levels of the disease. In the early stages of AD, the medial temporal lobe has been reported to undergo more prominent neuronal atrophy [5], which affects the performance of the olfactory system. Therefore, detecting any dysfunction of the olfactory system in the early stages of the disease could lead to early diagnosis and prevention. This dataset is published in order to enable broad examination of the functionality of the olfactory system in AD and amnestic mild cognitive impairment (aMCI) patients based on EEG data, which may lead to better understanding the mechanisms of the disease progress for early diagnosis and better management of Alzheimer's disease.

2. Data Description

2.1. Data Shared with this Article

The dataset consists of four files as follows:

(1) "AD.mat" / "AD.txt": Contains data for Alzheimer's disease patients.
(2) "normal.mat" / "normal.txt": Contains data for healthy elderly participants.
(3) "MCI.mat" / "MCI.txt": Contains data for amnestic mild cognitive impairment patients.
(4) "MMSE_Data.txt": Contains demographic and MMSE data of all participants.

The structure of the first three files is the same. Each file is organized as a structure array, in which each row contains information of one participant and the three columns correspond to the "epoch", "odor" and "noisy" fields as described in Table 1. The files can be used with programming languages like MATLAB and python (using the scipy package). Text versions of the data files are also included in the dataset.

The fourth file includes demographic data of each participant as age in a range, gender, their diagnosed mental state, and the details of their MMSE score. The columns indicate abbreviated MMSE test components as follows: O Place: Orientation to Place, O Time: Orientation to time, Reg: Registration, Att & Calc: Attention and Calculation, Rep: Repetition, DR: Delayed Recall, VS: Visuospatial, Comm: Commands. The detailed information is also presented in Table 2.

Table 1
Description of each structure array (.mat file) in the dataset.

Fields	Description
epoch	This is a 3D array structured as 4 × 600 × Num_trial. The first dimension indicates EEG channels respectively from the first column as Fp1, Fz, Cz, and Pz. The second dimension contains EEG samples from 1 s pre stimulus to 2 s post stimulus, which at a 200 Hz sampling rate amounts to 600 samples. The last dimension shows the number of trials. This could be different for each participant as some trials were deleted during preprocessing.
odor	This is a 2D binary array shaped as Num_trial × 1. This array shows the odorant type (lemon/rose) the participant was exposed to in each trial. The value = 1 indicates the rose odor and the value = 0 indicates the lemon odor.
noisy	This is a 2D array with the size 1 × Num_noisy. This array indicates noisy trials identified based on comparing the instantaneous and average trial amplitudes. These noisy trials can be ignored in processing and were included for the dataset completeness.

Table 2
MMSE score of the participants with details.

Mental State	Age	Gender	O place	O time	Reg	Att & Calc	Name	Rep	Read	Write	DR	VS	Comm	Total MMSE
Normal	75–80	M	5	5	3	4	2	2	1	1	0	1	3	27
Normal	70–75	M	5	5	3	5	3	2	1	1	1	1	3	30
Normal	65–70	F	5	5	3	4	2	2	0	1	0	1	3	26
Normal	60–65	F	5	5	3	5	3	2	1	1	1	1	3	30
Normal	70–75	M	5	5	3	1	2	2	1	0	0	0	3	21
Normal	60–65	M	5	5	3	5	2	2	1	1	1	1	3	29
Normal	65–70	F	5	5	3	1	1	2	1	0	0	0	3	21
Normal	55–60	F	5	5	3	2	3	2	1	1	1	1	3	27
Normal	70–75	F	4	5	3	4	2	2	1	0	0	0	3	23
Normal	70–75	M	5	5	3	5	1	2	1	1	0	0	3	26
Normal	70–75	M	5	4	3	2	3	2	1	1	1	1	3	26
Normal	65–70	F	5	4	3	1	3	2	0	0	0	0	3	21
Normal	60–65	M	5	5	3	3	3	2	1	1	1	1	3	28
Normal	70–75	F	4	5	3	4	2	2	1	0	0	0	3	23
Normal	75–80	F	4	5	3	3	2	2	1	1	1	0	3	26
aMCI	55–60	M	4	4	3	4	2	0	0	0	2	0	3	22
aMCI	70–75	F	4	4	3	3	2	0	0	1	2	0	3	22
aMCI	60–65	M	5	4	3	1	1	0	1	1	2	0	3	21
aMCI	70–75	M	5	3	3	3	2	0	0	3	1	0	3	21
aMCI	70–75	F	5	5	3	3	2	1	1	1	1	0	3	25
aMCI	60–65	F	5	5	3	4	2	1	1	1	2	0	3	27
aMCI	70–75	F	5	5	3	4	2	1	1	1	2	1	3	28
AD	75–80	M	4	4	3	0	0	2	1	1	1	1	2	19
AD	75–80	F	2	5	3	0	2	2	1	0	0	0	1	16
AD	80–85	M	4	5	3	1	0	2	0	0	0	0	3	18
AD	85–90	F	2	3	3	0	0	2	1	0	0	0	2	12
AD	70–75	F	2	5	3	0	0	2	0	0	0	0	3	15
AD	85–90	M	3	4	3	0	0	2	1	0	0	0	3	16
AD	65–70	F	3	2	3	0	0	2	0	0	0	0	2	12
AD	65–70	F	2	3	3	0	3	2	1	0	0	0	3	18
AD	70–75	F	5	3	3	3	0	2	0	1	1	0	1	19
AD	80–85	M	2	5	3	0	0	2	0	1	1	0	3	17
AD	55–60	F	3	2	3	0	0	2	0	0	0	0	3	11
AD	55–60	F	5	2	3	2	2	1	0	0	2	0	3	20
AD	75–80	M	2	4	3	3	0	2	1	1	1	1	3	21

3. Experimental Design, Materials and Methods

3.1. Participants

Participants were recruited from individuals who sought treatment for memory complaints at the memory clinic of Ziaeian Hospital in Tehran. Two neuropsychologists recorded information on the participants' age, smoking history, preferred hand, level of education, and history of olfactory problems. Following the neuropsychological assessment, a neurologist conducted a physical examination of the participants and diagnosed probable Alzheimer's disease in accordance with the latest guideline of the National Institute on Aging-Alzheimer's Association (NIA-AA) [6]. Results of the Mini-Mental State Examination (MMSE) and inquiry about the onset and progressions of the symptoms from the patients and their companions were used by the neurologist to diagnose cognitive impairment. In addition to criteria for dementia, diagnosis of AD was also based on meeting the criteria for probable AD dementia. Structural MRI images (1.5 Tesla MR Scanner and a 16-channel HR head coil) were analyzed, and the Medial Temporal Atrophy Scale, White Matter Lesions, and Global Atrophy Scale were used by the neurologist to perform AD diagnosis [6]. Exclusion criteria were a history of stroke, schizophrenia, major depressive disorders and electroconvulsive therapy (ECT) over the past six months, traumatic brain injury, non-AD neurodegenerative diseases (Parkinson's disease, progressive supranuclear palsy, multi-system atrophy, cortico-basal degeneration), and any history of olfactory pathway disorders. Given the selection and exclusion criteria, data of 35 participants were included in the dataset (age = 70.97±8.58, female = 57.14%), consisting of 15 healthy (normal) individuals (age = 69.27±6.65, female = 53.33%), 7 aMCI (age = 66.57±6.85, female = 51.14%), and 13 AD (age = 75.31±9.90, female = 61.54%) patients.

3.2. Electroencephalogram

EEG signals were recorded using a 32-channel Mitsar amplifier. To shorten the EEG electrode installation time and minimize fatigue effect on participants, a limited number of channels were used in this study due to the age and mental condition of participants. Data were recorded from the Fz, Cz, Pz, and Fp1 electrodes. The Fp1 electrode data was used to identify blinks. The channel impedance was kept under 15 kΩ for each electrode. The EEG sampling rate was 2000 Hz, and electrodes were referenced to the A1 earlobe.

3.3. Olfactory Task

The same sequence of stimuli was presented to all participants. The stimulation sequence was composed of two different odors, one occurring frequently (standard) with a probability of 0.75 and the other presented rarely (deviant) with a probability of 0.25. Each trial consisted of a 2 s stimulus presentation followed by 8 s of rest (pure water vapor). The odors were delivered to the participants using a laboratory olfactometer [7]. The experiment involved 120 trials in which 90 frequent and 30 rare stimulation cycles were presented in a predetermined, randomized order. Lemon essence was used as the frequent odorant and rose essence was used as the rare odorant. These odors were selected to avoid trigeminal system activation as the olfactory and trigeminal systems are interconnected and may interact with each other during exposure to certain stimuli [8]. The duration of odor presentation was set at 2 s to enable regular breathing cycles for the participants.

3.4. Preprocessing

The steps involved in preprocessing the data and extracting epochs for further processing consisted of filtering, eye blink removal, partitioning to epochs, and noisy epoch removal. Signals were filtered to 0.5 to 40 Hz and down-sampled to 200 Hz. Independent Component Analysis (ICA) was used for eye blink removal. One component corresponding to eye blinks was removed, and the rest were projected back to the electrode space. The resulting signals were segmented into epochs with one second of pre- and two seconds of post-stimulus onset (resulting in 600 samples based on a sampling frequency of 200 Hz). Noisy epochs were then visually identified by the lead author and deleted. Moreover, a semi-automated method was used for labeling epochs with high peak-to-average ratios. These trials were left in the dataset and their labels are available in the dataset as described in the data description section. All preprocessing steps were conducted using MATLAB 2018b and EEGLab v2021.0.

Ethics Statements

Approval for this study was granted by the Review Board of Tehran University of Medical Sciences (Approval ID: IR.TUMS.MEDICINE.REC.1398.524), and all participants provided written consent to participate in the experiment. The participants were selected from individuals who had memory performance complaints and were seeking treatment at the memory clinic of Ziaeian Hospital in Tehran. All the tests were conducted at the Department of Geriatric Medicine of Ziaeian Hospital. The research was carried out in accordance with the Declaration of Helsinki. The confidentiality of the participants' private information, including their name and date of birth, was maintained and this information was not used in any of the analyses.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Olfactory EEG Dataset (Original data) (Mendeley Data).

CRediT Author Statement

Mohammad Javad Sedghizadeh: Methodology, Software, Formal analysis, Data curation, Writing – original draft; **Hamid Aghajan:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition; **Zahra Vahabi:** Data curation, Supervision.

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