

# What is the N-back Test?

The **N-back Test** is a **working memory task** widely used in cognitive neuroscience to measure **mental workload (MW)**. It requires participants to **remember a sequence of items** and respond if the current item matches the one presented **N steps earlier**.

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## Purpose in This Dataset

To induce and measure three distinct levels of mental workload:

- **1-back (Low Load)**: Easy memory recall.
  - **1-back Arithmetic (Medium Load)**: Basic math + memory.
  - **2-back Dual Task (High Load)**: Combines memory + spatial + math tasks.
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## How It Was Used in the Experiment


### Participants:

- 16 male participants
- Aged 20 to 60
- Scientists or researchers from universities (students, PhDs, professors)

### Session Timeline:

Each subject completed:

- **Baseline phase (10 min)**: Watched relaxing video (no task)
- **Task phase (20 min)**: Played the N-back game
- **Recovery phase (10 min)**: Resting state

 Each subject performed all 3 N-back test variants. The order was randomized to avoid sequence bias.

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## Data Files and Structure

Located in: `data_n_back_test/`

### 1. `eeg.parquet`

Contains the **raw EEG signals**, plus:

- **139 columns**, including:
  - `datetime, timestamp`
  - **14 EEG channel values** (e.g., AF3, AF4, T7, T8, etc.)
  - **5 power band values** (theta, alpha, beta low, beta high, gamma)
  - **Quality metrics** (signal quality scores per channel)
- Plus 3 metadata columns:
  - `subject`: e.g., `subject_01`
  - `test`: 1 (low), 2 (medium), 3 (high)
  - `phase`: 1 (baseline), 2 (task), 3 (recovery)

### 2. `game_scores.parquet`

Contains:

- **Game performance scores** for each subject and test
- Since each test runs for 20 minutes with multiple trials, scores are stored as a **list of correct responses** per trial
- Metadata:

- `subject`
- `test`

### 3. `tlx_answers.parquet`

Contains:

- **NASA-TLX questionnaire results** for each test and subject
    - Measures perceived **mental demand, effort, frustration**, etc.
  - Metadata:
    - `subject`
    - `test`
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## Types of N-back Tasks Used

### ◆ 1-Back Position Test (Low Workload)

- A square appears in one of 9 grid positions.
- The subject presses a key if the current square **matches the previous one**.
- Emphasizes **visual-spatial memory**.

### ◆ 1-Back Arithmetic Test (Medium Workload)

- A number appears on the screen (0–9).
- An **arithmetic operation** (e.g., +, −, ×, ÷) is heard.
- The subject computes: `current op previous` and types the result.

## ◆ 2-Back Dual Task (High Workload)

- Number appears **in a position** on a 3×3 grid.
- The subject must:
  - Press a key if the **position matches** that from 2 steps before.
  - Solve an **arithmetic operation** using the number from 2 steps ago.

This test imposes high **cognitive load**, combining **working memory, attention, math, and spatial reasoning**.

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['timestamp', 'EEG.Counter', 'EEG.Interpolated', 'EEG.AF3', 'EEG.F7',  
'EEG.F3', 'EEG.FC5', 'EEG.T7', 'EEG.P7', 'EEG.O1', 'EEG.O2', 'EEG.P8',  
'EEG.T8', 'EEG.FC6', 'EEG.F4', 'EEG.F8', 'EEG.AF4', 'EEG.RawCq',  
'EEG.Battery', 'MarkerIndex', 'MarkerType', 'MarkerValueInt',  
'EEG.MarkerHardware', 'CQ.AF3', 'CQ.F7', 'CQ.F3', 'CQ.FC5', 'CQ.T7',  
'CQ.P7', 'CQ.O1', 'CQ.O2', 'CQ.P8', 'CQ.T8', 'CQ.FC6', 'CQ.F4', 'CQ.F8',  
'CQ.AF4', 'PM.Engagement.IsActive', 'PM.Engagement.Scaled',  
'PM.Engagement.Raw', 'PM.Engagement.Min', 'PM.Engagement.Max',  
'PM.Excitement.IsActive', 'PM.Excitement.Scaled', 'PM.Excitement.Raw',  
'PM.Excitement.Min', 'PM.Excitement.Max', 'PM.LongTermExcitement',  
'PM.Stress.IsActive', 'PM.Stress.Scaled', 'PM.Stress.Raw',  
'PM.Stress.Min', 'PM.Stress.Max', 'PM.Relaxation.IsActive',  
'PM.Relaxation.Scaled', 'PM.Relaxation.Raw', 'PM.Relaxation.Min',  
'PM.Relaxation.Max', 'PM.Interest.IsActive', 'PM.Interest.Scaled',  
'PM.Interest.Raw', 'PM.Interest.Min', 'PM.Interest.Max',  
'PM.Focus.IsActive', 'PM.Focus.Scaled', 'PM.Focus.Raw', 'PM.Focus.Min',  
'PM.Focus.Max', 'POW.AF3.Theta', 'POW.AF3.Alpha', 'POW.AF3.BetaL',  
'POW.AF3.BetaH', 'POW.AF3.Gamma', 'POW.F7.Theta', 'POW.F7.Alpha',  
'POW.F7.BetaL', 'POW.F7.BetaH', 'POW.F7.Gamma', 'POW.F3.Theta',  
'POW.F3.Alpha', 'POW.F3.BetaL', 'POW.F3.BetaH', 'POW.F3.Gamma',  
'POW.FC5.Theta', 'POW.FC5.Alpha', 'POW.FC5.BetaL', 'POW.FC5.BetaH',  
'POW.FC5.Gamma', 'POW.T7.Theta', 'POW.T7.Alpha', 'POW.T7.BetaL',  
'POW.T7.BetaH', 'POW.T7.Gamma', 'POW.P7.Theta', 'POW.P7.Alpha',  
'POW.P7.BetaL', 'POW.P7.BetaH', 'POW.P7.Gamma', 'POW.O1.Theta',  
'POW.O1.Alpha', 'POW.O1.BetaL', 'POW.O1.BetaH', 'POW.O1.Gamma',  
'POW.O2.Theta', 'POW.O2.Alpha', 'POW.O2.BetaL', 'POW.O2.BetaH',
```

```
'POW.O2.Gamma', 'POW.P8.Theta', 'POW.P8.Alpha', 'POW.P8.BetaL',  
'POW.P8.BetaH', 'POW.P8.Gamma', 'POW.T8.Theta', 'POW.T8.Alpha',  
'POW.T8.BetaL', 'POW.T8.BetaH', 'POW.T8.Gamma', 'POW.FC6.Theta',  
'POW.FC6.Alpha', 'POW.FC6.BetaL', 'POW.FC6.BetaH', 'POW.FC6.Gamma',  
'POW.F4.Theta', 'POW.F4.Alpha', 'POW.F4.BetaL', 'POW.F4.BetaH',  
'POW.F4.Gamma', 'POW.F8.Theta', 'POW.F8.Alpha', 'POW.F8.BetaL',  
'POW.F8.BetaH', 'POW.F8.Gamma', 'POW.AF4.Theta', 'POW.AF4.Alpha',  
'POW.AF4.BetaL', 'POW.AF4.BetaH', 'POW.AF4.Gamma', 'datetime', 'subject',  
'test', 'phase']
```

## ✓ EEG File Column Breakdown

### 1. Time & Metadata

Column	Description
<code>timestamp</code>	Unix time or elapsed time (in seconds or ms).
<code>mp</code>	
<code>datetime</code>	Actual date & time of recording.
<code>e</code>	
<code>subject</code>	Subject ID, e.g., <code>subject_01</code> .
<code>test</code>	N-back test type: 1 = Low, 2 = Medium, 3 = High workload.
<code>phase</code>	1 = Baseline, 2 = Task, 3 = Recovery.

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### 2. Raw EEG Signals

14 EEG electrodes as per the **10-20 system**:

Column	Electrode Location
<code>EEG.AF3</code> , <code>EEG.AF4</code>	Anterior frontal
<code>EEG.F3</code> , <code>EEG.F4</code> , <code>EEG.F7</code> , <code>EEG.F8</code>	Frontal
<code>EEG.FC5</code> , <code>EEG.FC6</code>	Fronto-central

EEG.T7, EEG.T8	Temporal
EEG.P7, EEG.P8	Parietal
EEG.O1, EEG.O2	Occipital

Other columns:

- EEG.Counter, EEG.Interpolated, EEG.RawCq, EEG.Battery → device-specific telemetry data.

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### 3. Event Markers (Optional)

Column	Description
MarkerIndex, MarkerType, MarkerValueInt, EEG.MarkerHardware	Useful if task events (stimuli) were annotated.

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### 4. Channel Quality (CQ)

These represent signal quality per electrode.

Example	Description
CQ.AF3, CQ.F3, ..., CQ.AF4	Channel quality scores (typically 0–4 or a percentage).

These help you detect **bad or noisy channels** during preprocessing.

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### 5. Performance Metrics (PM)

Category	Examples
Engagement	PM.Engagement.Raw, .Scaled, .IsActive, etc.

**Excitement, Stress, Relaxation,  
Interest, Focus**

Similar structure: each with `.IsActive`, `.Raw`,  
`.Scaled`, `.Min`, `.Max`.

These are **Emotiv's proprietary real-time affective state indicators**, inferred from EEG. They **aren't perfect**, but they can offer high-level estimates of cognitive states like **focus and stress**.

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## 6. Power Spectral Features (Frequency Bands)

These are the **core EEG workload features** you'll want to use for ML or statistical analysis.

For **each EEG channel**, power values are computed for:

- **Theta (4–8 Hz)**
- **Alpha (8–12 Hz)**
- **BetaL (12–18 Hz)**
- **BetaH (18–25 Hz)**
- **Gamma (>25 Hz)**

➡ For example:

- `POW.AF3.Theta` → Theta power at AF3.
- `POW.F7.BetaH` → Beta-high power at F7.

There are **14 electrodes × 5 frequency bands = 70 spectral features**.

**14 EEG channels:**

- Frontal: `AF3`, `AF4`, `F3`, `F4`, `F7`, `F8`
- Central: `FC5`, `FC6`
- Temporal: `T7`, `T8`

- Parietal: P7, P8
- Occipital: 01, 02

#### Metadata:

- **datetime**: Timestamp of each sample
- **subject**: Always **subject\_01** in this case
- **test**: N-back condition → 1 = low, 2 = medium, 3 = high
- **phase**: 1 = baseline, 2 = task, 3 = recovery




## Mental Workload EEG Dataset – N-back Test Focus

This dataset is part of the broader research:

**“EEG Dataset Collection for Mental Workload Predictions in Flight-Deck Environment”**

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### GENERAL DATASET OVERVIEW

Item	Description
<b>Collected by</b>	Jose Yauri & team (UAB, Spain)
<b>Recording Devices</b>	EEG: Emotiv Epoc X (14 channels, 128 Hz), ECG (Shimmer3, Suunto Ambit3)
<b>Experiments Conducted</b>	3: N-back Test  , Heat-the-Chair Game  , Flight Simulator 
<b>Subjects</b>	16 for N-back, 17 for Chair game, 2 pilots for flights



Data Type	Raw EEG signals + Power Band data + Game scores + Subjective TLX ratings
Sampling Rate	128 Hz (EEG), various physiological metrics per second (ECG, power bands)
Data Format	.parquet, .csv, .json
Labels	Theoretical workload level (test), self-perceived TLX rating
Use License	CC BY-SA
Link	<a href="#">Dataset DOI</a>

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## FOCUS: N-back Test (Memory Load Assessment)

### Objective




To study brain activity and mental workload under controlled memory tasks of increasing difficulty using EEG.

### Participants

- 16 male subjects (aged 20–60)
  - From 3 university labs (students, PhD researchers, professors)
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### N-back Test Structure

Each participant completed **3 test variants** (randomized order):

Test	Description	Workload Level
1	1-back Position: Match square pos.	 Low
2	1-back Arithmetic: Solve math op.	 Medium
3	2-back Dual: Math + Position (2-back)	 High

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## Session Timeline Per Test

Phase	Duration	Description
Baseline	10 min	Subject watches calming video
Task	20 min	Performs the N-back task
Recovery	10 min	Rest phase after task
<b>Total</b>	<b>40 min</b>	→ ~307,200 samples/test @ 128 Hz

→ Each subject = **3 test sessions** → ~**921,600 expected samples**

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## EEG Data Details

### EEG Channels

14 channels based on the 10–20 system:

AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, O2

### Recorded Data Includes:

- Raw EEG voltages (in  $\mu\text{V}$ )
- EEG channel quality
- Power spectral features:
  - Theta (4–8 Hz)
  - Alpha (8–12 Hz)
  - Beta Low (12–18 Hz)
  - Beta High (18–25 Hz)
  - Gamma (>25 Hz)

- Mental state metrics: focus, stress, engagement, etc.
  - Timestamps and phases
  - Game performance scores
  - NASA-TLX questionnaire scores (self-perceived workload)
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## Workload Labels & Validation

Each test is labeled:

- `test = 1` → low workload
- `test = 2` → medium workload
- `test = 3` → high workload

Validation was done using:

1. Game performance (decreases with load)
  2. TLX scores (increase with load)
  3. EEG power peaks (band-wise differences by test/phase)
  4. Deep learning classifiers (CNNs trained on data)
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## Files Involved (N-back Test Folder)

bash

CopyEdit

`data_n_back_test/`

<code> — eeg.parquet</code>	→ Raw EEG + power + metadata
<code> — game_scores.parquet</code>	→ Scores for each subject/test
<code> — tlx_answers.parquet</code>	→ Subjective workload (NASA-TLX)

◆ Full Dataset Shape (rows, columns): (15294488, 18)

🕒 Global Start Time: 2020-01-15 08:10:42.007477

🕒 Global End Time: 2020-11-19 13:48:46.993748

🕒 Total Duration: 309 days 05:38:04.986271

👤 Total Unique Subjects: 16

ID Subjects: ['subject\_01' 'subject\_02' 'subject\_03' 'subject\_04' 'subject\_05'  
'subject\_06' 'subject\_07' 'subject\_08' 'subject\_09' 'subject\_10'  
'subject\_11' 'subject\_12' 'subject\_13' 'subject\_14' 'subject\_15'  
'subject\_16']

📊 Row count per subject:

subject

subject\_01 974072

subject\_02 973157

subject\_03 959145

subject\_04 998694

subject\_05 983382

subject\_06 978269

subject\_07 950255

subject\_08 994502

subject\_09 878821

subject\_10 836755

subject\_11 1047537

subject\_12 983090

subject\_13 976636

subject\_14 964373

subject\_15 831361

subject\_16 964439

Name: count, dtype: int64

📊 Rows per phase:

phase

1 3964087

2 7694147

3 3636254

Name: count, dtype: int64

📊 Rows per test:

test

1 5006127

2 5095468

3 5192893

Name: count, dtype: int64

 Rows per (subject, test, phase):

	subject	test	phase	row_count
0	subject_01	1	1	82609
1	subject_01	1	2	168144
2	subject_01	1	3	80959
3	subject_01	2	1	80581
4	subject_01	2	2	159001
...	...	...	...	...
138	subject_16	2	2	158240
139	subject_16	2	3	80713
140	subject_16	3	1	81853
141	subject_16	3	2	165093
142	subject_16	3	3	80834

[143 rows x 4 columns]


## Subject 1

◆ Data shape (rows, columns): (974072, 18)

🕒 Start time: 2020-01-17 09:57:02.001394

🕒 End time: 2020-01-17 17:17:48.994743

🕒 Total duration: 0 days 07:20:46.993349

 Rows per phase:

phase

1 244917

2 487420

3 241735

Name: count, dtype: int64

 Rows per test:


test

1 331712

2 320163

3 322197

Name: count, dtype: int64

 Rows per (test, phase):

	test	phase	row_count
0	1	1	82609
1	1	2	168144
2	1	3	80959
3	2	1	80581
4	2	2	159001
5	2	3	80581

6	3	1	81727
7	3	2	160275
8	3	3	80195