Cable evaluation

**Objective:**  
Evaluate whether a thicker or thinner cable provides better EEG signal quality, comparing electrodes FP1 (thick cable) and FP2 (thin cable) across two conditions: eyes open (EO) and eyes closed (EC).

**Protocol:**

* Two spiky dry electrodes were positioned simultaneously at FP1 and FP2.
* FP1 used a regular 26 AWG cable, while FP2 used a thinner 28 AWG cable.
* Reference electrodes were connected using 26 AWG cables and spiky electrodes.
* Three recordings were taken for each condition (eyes closed and eyes open), each lasting 40 seconds.

**Procedure:**

1. **Impedance Check:**  
   Using OpenBCI, impedances for both FP1 and FP2 electrodes were monitored and found to oscillate around 300 kΩ.

A table with numbers and symbols

AI-generated content may be incorrect.

1. **Recordings:**  
   Three recordings were made for each condition (eyes closed and eyes open), each lasting 30 seconds. The first 3 seconds of each recording were excluded to avoid artifacts caused by the delay in closing the eyes (as the recording was self-administered).
2. **Data Analysis:**  
   Visual inspection of the recorded signals was performed.

Eyes open

|  |  |  |
| --- | --- | --- |
|  | EO1 | |
|  | FP1 | Fp2 |
| PSD | A graph with a blue line  AI-generated content may be incorrect. | A graph with a blue line  AI-generated content may be incorrect. |
| ALPHA POWER | 86.961 uV^2 | 109.841 uV^2 |
| BETA POWER |  |  |
| NOISE | A graph with blue and orange lines  AI-generated content may be incorrect. | |
| RELATIVE alpha POWER | 0.072 | 0.067 |
| NOISE RATIO | {'delta': 1.2328245966276967, 'theta': 0.8598885517348224, 'alpha': 0.6612346807533896, 'beta': 1.8216936997841868} | {'delta': 2.622152774538213, 'theta': 1.3529088958245938, 'alpha': 0.8798675944354596, 'beta': 2.3634700889876408} |
| METRICS QUALITY | {'alpha\_power\_uV2': 86.96074239242836,  'beta\_power\_uV2': 251.4803766878843,  'delta\_power\_uV2': 159.03375002743027,  'line\_noise\_power\_uV2': 98.41613038730944,  'zero\_crossings\_per\_sec': 57.304038004750595,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 186.6911782781535,  'symmetry\_corr\_LR': 0.8600784682619796} | {'alpha\_power\_uV2': 109.84094286713527,  'beta\_power\_uV2': 313.1901092077789,  'delta\_power\_uV2': 325.909877668459,  'line\_noise\_power\_uV2': 125.59475691781392,  'zero\_crossings\_per\_sec': 55.819477434679335,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 221.74598134864314,  'symmetry\_corr\_LR': 0.8600784682619798} |

A group of blue lines

AI-generated content may be incorrect.

Eyes closed

A group of blue lines

AI-generated content may be incorrect.

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| --- | --- | --- |
|  | EO2 | |
|  | FP1 | Fp2 |
| PSD | A graph of a person's period  AI-generated content may be incorrect. |  |
| ALPHA POWER |  |  |
| BETA POWER |  |  |
| NOISE | A graph of a sound wave  AI-generated content may be incorrect. | |
| RELATIVE alpha POWER |  |  |
| NOISE RATIO | {'delta': 0.9755229093069282, 'theta': 1.0445293255230315, 'alpha': 0.7225529847411846, 'beta': 2.2546642631652194} | {'delta': 2.1323337702862752, 'theta': 1.4433429983197053, 'alpha': 0.9078763268222189, 'beta': 2.6826973965254663} |
| METRICS QUALITY | {'alpha\_power\_uV2': 76.20300845598565,  'beta\_power\_uV2': 255.4812725692296,  'delta\_power\_uV2': 95.20698560466417,  'line\_noise\_power\_uV2': 63.21071861820434,  'zero\_crossings\_per\_sec': 57.2700296735905,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 173.91972086546912,  'symmetry\_corr\_LR': 0.8775689615018331} | {'alpha\_power\_uV2': 97.38177457590787,  'beta\_power\_uV2': 308.5681574593464,  'delta\_power\_uV2': 219.20671502094166,  'line\_noise\_power\_uV2': 100.91696708374562,  'zero\_crossings\_per\_sec': 55.97181008902077,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 222.1873004822329,  'symmetry\_corr\_LR': 0.8775689615018331} |

|  |  |  |
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|  | EO3 | |
|  | FP1 | Fp2 |
| PSD | A graph with lines and numbers  AI-generated content may be incorrect. | A graph of a graph showing the number of frequency  AI-generated content may be incorrect. |
| NOISE | A graph of a sound wave  AI-generated content may be incorrect. | |
| NOISE RATIO | {'delta': 0.9022061179241994, 'theta': 0.9891695769814548, 'alpha': 0.7071475076064468, 'beta': 2.5052144308651427} | {'delta': 1.6172750650401952, 'theta': 1.3114675087579606, 'alpha': 0.8696980148178305, 'beta': 3.096810385456438} |
| METRICS QUALITY | {'alpha\_power\_uV2': 80.47412008808158,  'beta\_power\_uV2': 303.0582715669054,  'delta\_power\_uV2': 97.69934887542202,  'line\_noise\_power\_uV2': 42.983107951834,  'zero\_crossings\_per\_sec': 58.25783454626467,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 157.16706163822448,  'symmetry\_corr\_LR': 0.9169353976670045} | {'alpha\_power\_uV2': 98.66242641578874,  'beta\_power\_uV2': 374.5609506291501,  'delta\_power\_uV2': 178.23782231494306,  'line\_noise\_power\_uV2': 66.07208486328332,  'zero\_crossings\_per\_sec': 55.80721817911778,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 196.14216869813603,  'symmetry\_corr\_LR': 0.9169353976670046} |

|  |  |  |
| --- | --- | --- |
|  | EC1 | |
|  | FP1 | Fp2 |
| PSD | A graph showing a number of frequency  AI-generated content may be incorrect. | A graph with a blue line  AI-generated content may be incorrect. |
| NOISE | A graph with blue and red lines  AI-generated content may be incorrect. | |
| NOISE RATIO | {'delta': 1.2005789726772027, 'theta': 1.2655556744778524, 'alpha': 1.063702792496175, 'beta': 2.9267036803099953} | {'delta': 1.9571361684365198, 'theta': 1.527146209811782, 'alpha': 1.2000139533678886, 'beta': 3.3332595993399283} |
| METRICS QUALITY | {'alpha\_power\_uV2': 107.5961831206613,  'beta\_power\_uV2': 295.40228378702375,  'delta\_power\_uV2': 112.41682300389607,  'line\_noise\_power\_uV2': 14.97341099017701,  'zero\_crossings\_per\_sec': 51.135520261243876,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 141.0115860049683,  'symmetry\_corr\_LR': 0.9589090100175088} | {'alpha\_power\_uV2': 128.41681024660696,  'beta\_power\_uV2': 358.7383074737281,  'delta\_power\_uV2': 193.3645013202345,  'line\_noise\_power\_uV2': 21.062401874174537,  'zero\_crossings\_per\_sec': 51.469496808668545,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 175.04940411149335,  'symmetry\_corr\_LR': 0.9589090100175087} |

|  |  |  |
| --- | --- | --- |
|  | EC2 | |
|  | FP1 | Fp2 |
| PSD | A graph of a graph showing a number of frequency  AI-generated content may be incorrect. | A graph of a graph  AI-generated content may be incorrect. |
| NOISE | A graph of a sound wave  AI-generated content may be incorrect. | |
| NOISE RATIO | {'delta': 0.6887075424031442, 'theta': 1.290931850800313, 'alpha': 0.785285466242677, 'beta': 2.5315296293589356} | {'delta': 1.0717842707778336, 'theta': 1.8926680257658834, 'alpha': 1.0035650609417404, 'beta': 3.2614230732044276} |
| METRICS QUALITY | {'alpha\_power\_uV2': 84.68336771389123,  'beta\_power\_uV2': 285.14334810525963,  'delta\_power\_uV2': 71.38482561400555,  'line\_noise\_power\_uV2': 50.404782850827644,  'zero\_crossings\_per\_sec': 58.04631828978623,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 147.6947726823022,  'symmetry\_corr\_LR': 0.9597943922023056} | {'alpha\_power\_uV2': 110.82971963415841,  'beta\_power\_uV2': 372.7359040748207,  'delta\_power\_uV2': 116.89535059987544,  'line\_noise\_power\_uV2': 87.66690944792379,  'zero\_crossings\_per\_sec': 55.59679334916865,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 159.21557383163275,  'symmetry\_corr\_LR': 0.9597943922023056} |

|  |  |  |
| --- | --- | --- |
|  | EC3 | |
|  | FP1 | Fp2 |
| PSD | A graph of a graph showing a number of frequency  AI-generated content may be incorrect. | A graph of a graph showing a number of frequency  AI-generated content may be incorrect. |
| NOISE | A graph with blue and orange lines  AI-generated content may be incorrect. | |
| NOISE RATIO | {'delta': 1.2667547209045036, 'theta': 1.3094507247993203, 'alpha': 0.9788340338825489, 'beta': 2.5567444014971006} | {'delta': 2.4685051995057354, 'theta': 1.7867484076253184, 'alpha': 1.1083464895242112, 'beta': 2.8366288539545965} |
| METRICS QUALITY | {'alpha\_power\_uV2': 93.95787424018539,  'beta\_power\_uV2': 268.51191181603065,  'delta\_power\_uV2': 115.13993315571156,  'line\_noise\_power\_uV2': 6.671694106134741,  'zero\_crossings\_per\_sec': 51.58199643493761,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 182.96795673437083,  'symmetry\_corr\_LR': 0.9085901904927783} | {'alpha\_power\_uV2': 117.5123943474753,  'beta\_power\_uV2': 325.19855664707524,  'delta\_power\_uV2': 245.5173174857619,  'line\_noise\_power\_uV2': 14.276031671816423,  'zero\_crossings\_per\_sec': 47.27421271538918,  'percentage\_flatline': 0.0,  'large\_jumps': 0,  'range\_uV': 191.35716972592047,  'symmetry\_corr\_LR': 0.9085901904927784} |

**MEAN and IQR of 3 recordings, ratio band noise**

RATIO Eyes open

FP1- thick wire

delta 1.0369 ± 0.1653

theta 0.9645 ± 0.0923

alpha 0.6970 ± 0.0307

beta 2.1939 ± 0.3418

FP2-thin wire

delta 2.1239 ± 0.5024

theta 1.3692 ± 0.0659

alpha 0.8858 ± 0.0191

beta 2.7143 ± 0.3667

Ratio eyes closed

Fp1

delta 1.0520 ± 0.2890

theta 1.2886 ± 0.0219

alpha 0.9426 ± 0.1392

beta 2.6717 ± 0.1976

Fp2

delta 1.8325 ± 0.6984

theta 1.7355 ± 0.1828

alpha 1.1040 ± 0.0982

beta 3.1438 ± 0.2483

Here the ratios show that the relation band/noise is better for the thin cable, which could mean higher attenuation of the noise or best resistance to it. The IQR shows that the recordings are consistent, with a low variability among them an a good reproducibility among the 3 recordings.

METRICS

AVERAGE OF 3 recordings

|  |  |
| --- | --- |
| EOFP1 | EOFP2 |
| alpha\_power\_uV2 81.21  beta\_power\_uV2 270.01  delta\_power\_uV2 117.31  line\_noise\_power\_uV2 68.20  zero\_crossings\_per\_sec 57.61  percentage\_flatline 0.00  large\_jumps 0.00  range\_uV 172.59  symmetry\_corr\_LR 0.88  dtype: float64 | alpha\_power\_uV2 101.96  beta\_power\_uV2 332.11  delta\_power\_uV2 241.12  line\_noise\_power\_uV2 97.53  zero\_crossings\_per\_sec 55.87  percentage\_flatline 0.00  large\_jumps 0.00  range\_uV 213.36  symmetry\_corr\_LR 0.88  dtype: float64 |
| ECFP1 | ECFP2 |
| alpha\_power\_uV2 95.41  beta\_power\_uV2 283.02  delta\_power\_uV2 99.65  line\_noise\_power\_uV2 24.02  zero\_crossings\_per\_sec 53.59  percentage\_flatline 0.00  large\_jumps 0.00  range\_uV 157.22  symmetry\_corr\_LR 0.94 | alpha\_power\_uV2 118.92  beta\_power\_uV2 352.22  delta\_power\_uV2 185.26  line\_noise\_power\_uV2 41.00  zero\_crossings\_per\_sec 51.45  percentage\_flatline 0.00  large\_jumps 0.00  range\_uV 175.21  symmetry\_corr\_LR 0.94 |

These results suggest that the captured signal is better for the thin cable, which align with the signal to noise ratio computations.

The noise power is higher for both conditions, which could suggest that the captured noise is higher. However, together with the computed noise ratios, the util signal band also grows, being favourable for the thin cable.

Zero crossing are quite similar for both cables

Symmetry correlation shows that the registered signal is consistent for both sides

STATS

EYES CLOSEDA screenshot of a graph

AI-generated content may be incorrect.

With eyes closed, alpha and beta have significant differences, with higher values in FP2. WE only work with 3 recordings so we can only expect a trend

EYES OPEN

A table of numbers and symbols

AI-generated content may be incorrect.

With eyes open, we also observe a trend with higher values for fp1 than fp2

STAT DESCRIPTIVE

EYES CLOSED

A group of blue and white diagrams

AI-generated content may be incorrect.

EYES OPEN

A group of blue and white graphs

AI-generated content may be incorrect.

**Key Findings:**

1. **Signal-to-Noise Ratios (Ratio of Band Power to Noise > 55 Hz):**
   * Across all frequency bands (delta, theta, alpha, beta) and conditions, the thin cable (FP2) consistently showed **higher signal-to-noise ratios** than the thick cable (FP1).
   * This suggests that the thin cable transmits EEG signals with better relative quality compared to the thick cable.
2. **Data Variability (IQR):**
   * The interquartile range (IQR) values were generally small to moderate, indicating **consistent and reproducible results across the 3 recordings**.
   * Some variability exists but is not enough to undermine the observed trend favoring the thin cable.
3. **Power Metrics (Average µV²):**
   * The thin cable yielded **higher absolute power** in alpha, beta, and delta bands across both EO and EC conditions, indicating a stronger EEG signal.
   * Although line noise power was also higher with the thin cable, the increase in signal power was proportionally greater, resulting in an overall improved signal-to-noise scenario.
4. **Signal Quality Indicators:**
   * Metrics like zero crossings per second, percentage of flatlines, and large jumps showed **no significant difference** between cables, and very low artifact presence, supporting the reliability of both setups.
5. **Amplitude Range:**
   * The thin cable recordings had a wider amplitude range, further supporting a stronger EEG signal capture.
6. **Symmetry Correlation Between Hemispheres:**
   * High correlation values (~0.88-0.94) between FP1 and FP2 electrodes suggest **highly consistent and symmetric brain activity measurements**.
   * This confirms the reliability of recordings from both cables with no apparent degradation in signal coherence on either side.

**Other tests that could be perfomed: Improvements**

* Coherence: computing coherence with nearby electrodes, however we don’t have enough electrodes to perform this analysis
* Phase lag: to check if cable introduce delays
* Signal to artifact

Good practices

* Stats, more recordings, more subjects
* Cable mechanical stress, important for the design and mechanical part
* Environmental noise susceptibility ( near power lines, indoors and outdoors, checking shielding)
* Longer duration recordings