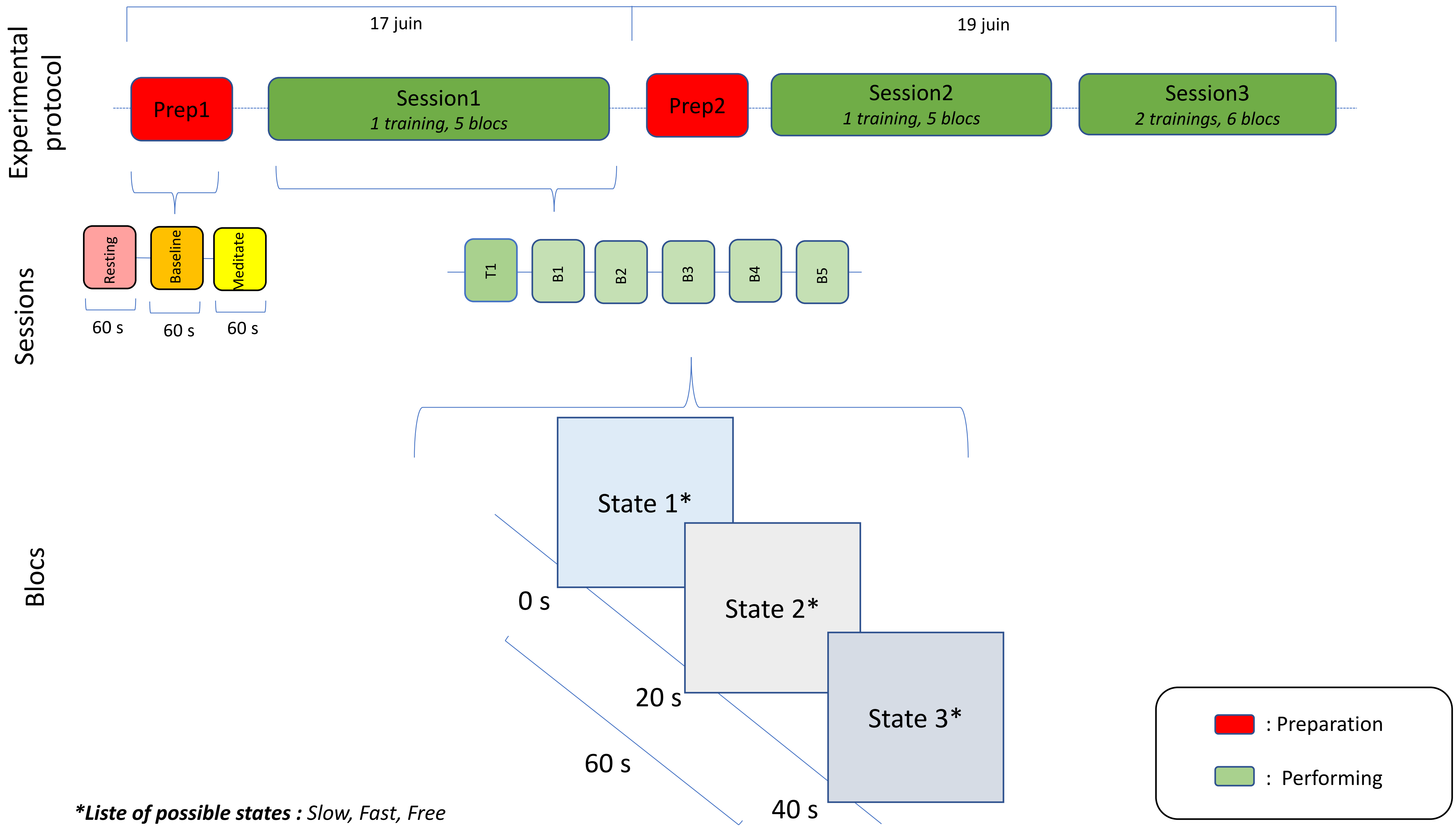


***Liste of possible states :** *Slow, Fast, Free*

Literature review

- Flow and improvisation [1]

Flow is described as a state of total absorption, concentration, distortion of time and intrinsic enjoyment during an activity. Csikszentmihalyi states that there is a close relationship between the state of flow and music experience.

- Creativity and frequency analysis[2] :

-> Several studies suggest a strong correlation between alpha-band activity and creative tasks. Generally, it has been observed that tasks requiring greater creativity resulted in higher alpha power [3] . Alpha wave activity appears to be sensitive to different creativity related tasks, musical improvisation in particular seems to be characterized higher alpha in central and posterior regions of the brain and a deactivation in prefrontal regions during flow experience[4].
Overall, the majority of the studies investigating creativity and musical improvisation report changes in alpha power, some studies even report clearer changes specifically in upper alpha.

Thus, one idea could be that different improvisation state (low, fast and free) are characterized by different alpha power, we could differentiate upper and lower alpha to see if there are significant changes?

[1] Alice Chirico et al., 'When Music "Flows". State and Trait in Musical Performance, Composition and Listening: A Systematic Review', *Frontiers in Psychology* 6 (2015), Carl E Stevens and Darya L Zabelina,
[2] 'Creativity Comes in Waves: An EEG-Focused Exploration of the Creative Brain', *Current Opinion in Behavioral Sciences*, Creativity, 27 (1 June 2019): 154–62, https://doi.org/10.1016/j.cobeha.2019.02.003.
[3] Andreas Fink and Mathias Benedek, 'EEG Alpha Power and Creative Ideation', *Neuroscience and Biobehavioral Reviews* 44, no. 100 (July 2014): 111–23, https://doi.org/10.1016/j.neubiorev.2012.12.002.
[4] Arne Dietrich and Riam Kanso, 'A Review of EEG, ERP, and Neuroimaging Studies of Creativity and Insight', *Psychological Bulletin* 136, no. 5 (September 2010): 822–48.

Literature review

- Mental fatigue :

Another aspect we could study is whether one state causes more mental fatigue than the others. Indeed, EEG is considered to be a reliable indicator of mental fatigue .

-> [1,2]Studies show that mental fatigue can be characterized by a power shift towards the low frequency bands (alpha, theta, delta). Several ratios and frequency bands have been used in fatigue studies.

- Alpha/Beta and Theta/Beta increased as fatigue increased.
- theta increase In parietal and prefrontal cortex as fatigue increase

- Engagement in the task:

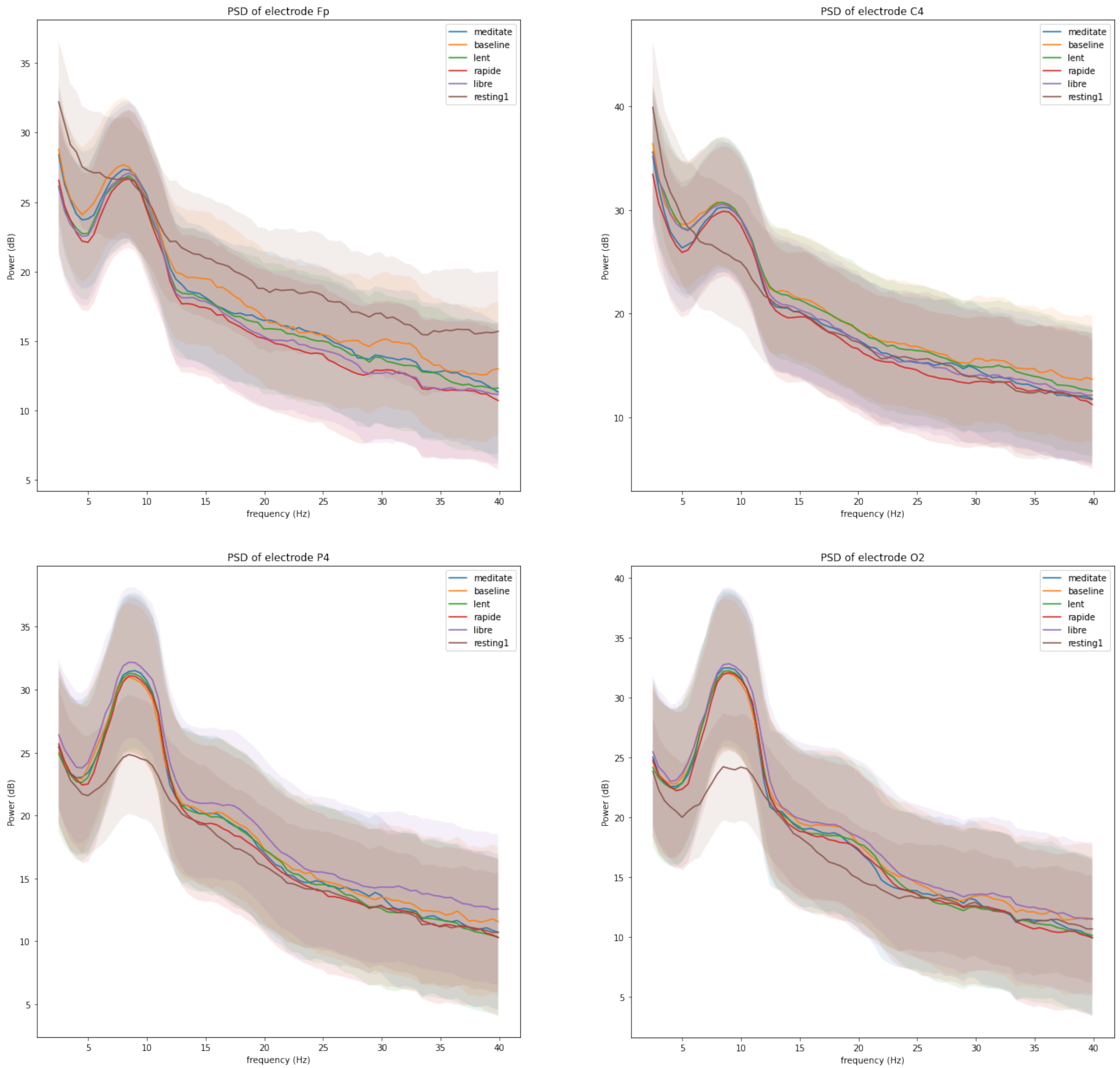
Another hypothesis is that each state require different levels of engagement in the task. Coelli et al [3], calculate an engagement index based on the Beta/Alpha ratio, using a highly engaging task and a low engaging task to get metric for high engagement and low engagement. In order to derive the index Coelli et al [3] used a combination of the power values from different channels and found that the most significant changes were found in the frontal and prefrontal cortex.

[1] Xiaoli Fan et al., 'Electroencephalogram Assessment of Mental Fatigue in Visual Search', ed. Feng Liu et al., *Bio-Medical Materials and Engineering* 26, no. s1 (17 August 2015): S1455–63

[2] Gianluca Borghini et al., 'Measuring Neurophysiological Signals in Aircraft Pilots and Car Drivers for the Assessment of Mental Workload, Fatigue and Drowsiness', *Neuroscience & Biobehavioral Reviews*, Applied Neuroscience: Models, methods, theories, reviews. A Society of Applied Neuroscience (SAN) special issue., 44 (1 July 2014): 58–75

[3]S. Coelli, R. Sclocco, R. Barbieri, G. Reni, C. Zucca and A. M. Bianchi, "EEG-based index for engagement level monitoring during sustained attention," *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Milan, 2015, pp. 1512-1515, doi: 10.1109/EMBC.2015.7318658.

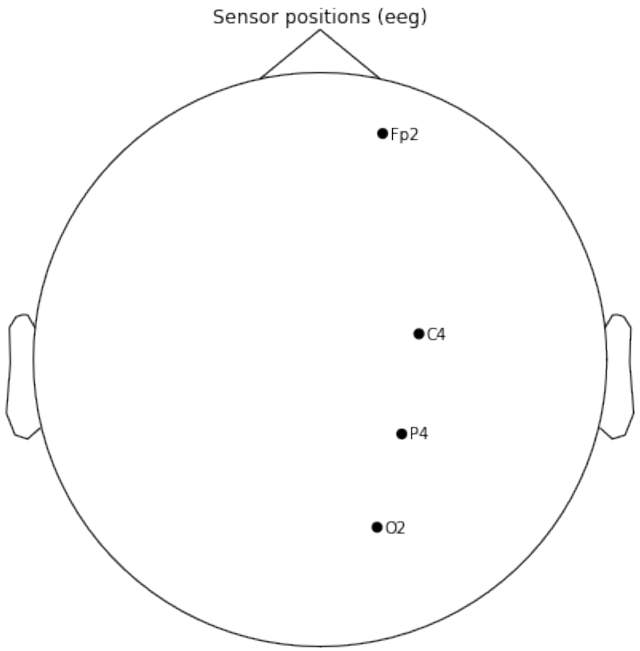
Frequency analysis for each channel

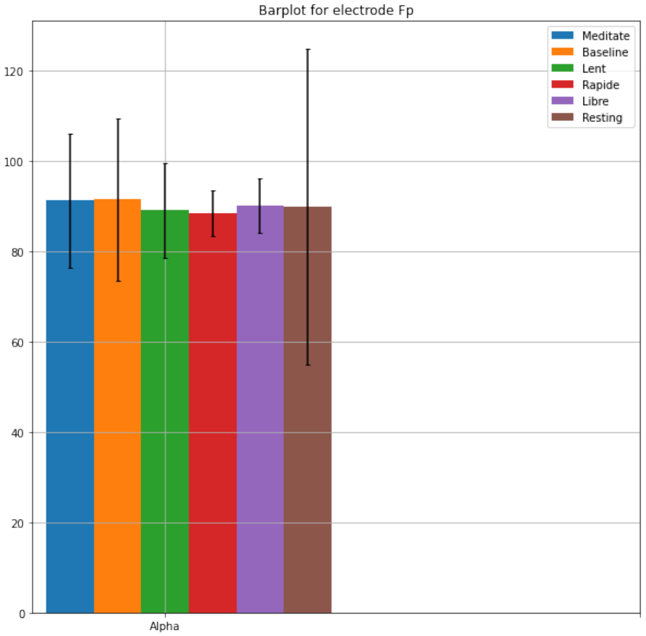


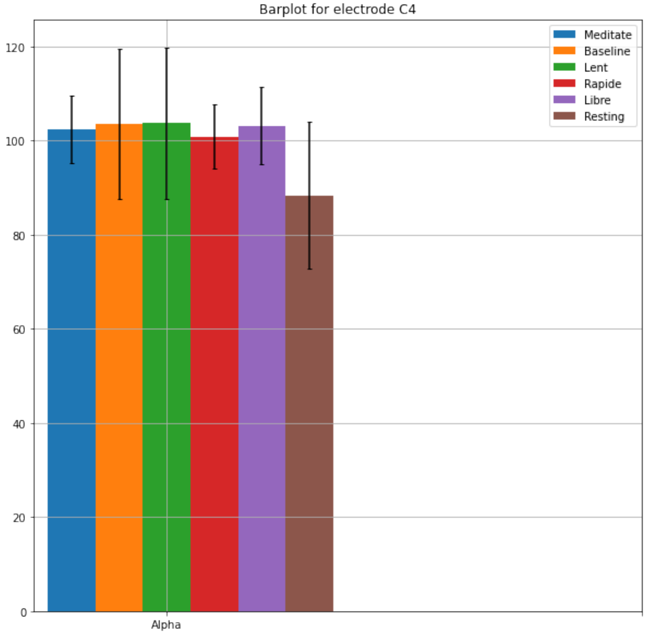
State	Alpha	Beta	Theta	Beta/Alpha
Meditate	102.89	434.89	88.0	4.25
C4	102.52	452.79	95.95	4.42
P4	107.27	434.52	85.7	4.08
O2	110.56	420.42	84.32	3.82
Fp	91.23	431.83	86.02	4.68
Baseline	102.36	456.18	90.72	4.44
C4	103.56	490.51	102.17	4.65
P4	105.35	444.76	86.53	4.24
O2	109.07	439.17	86.07	4.03
Fp	91.47	450.28	88.11	4.86
Lent	102.34	438.42	88.64	4.3
C4	103.73	479.97	101.73	4.57
P4	106.61	430.74	84.96	4.06
O2	109.89	420.22	84.47	3.84
Fp	89.12	422.75	83.41	4.72
Rapide	101.13	417.72	85.67	4.16
C4	100.89	434.84	94.65	4.32
P4	105.84	421.25	83.94	3.99
O2	109.34	415.19	82.68	3.8
Fp	88.44	399.61	81.42	4.53
Libre	103.79	445.52	89.98	4.28
C4	103.17	454.62	101.04	4.41
P4	109.88	470.79	89.17	4.22
O2	112.06	449.89	86.79	3.95
Fp	90.03	406.78	82.91	4.53
resting	86.7	443.69	87.06	5.14
C4	88.43	446.48	102.13	5.11
P4	85.12	412.94	77.57	4.95
O2	83.41	402.07	72.55	4.91
Fp	89.85	513.28	95.97	5.6

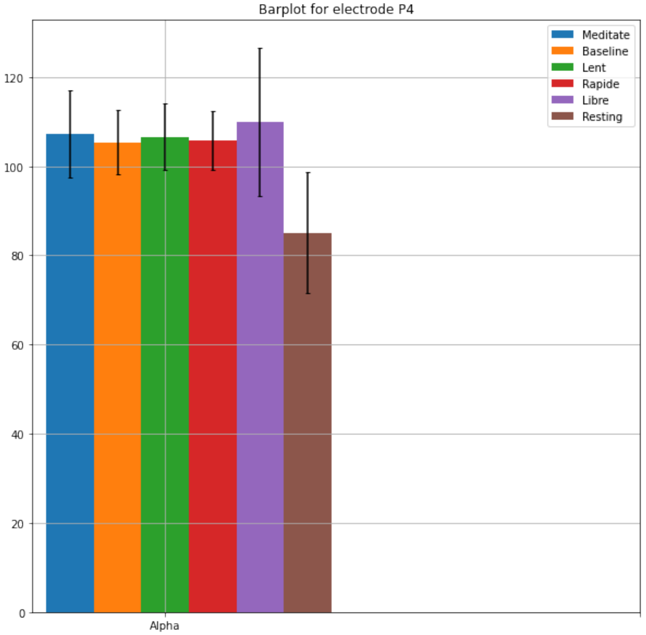
Focus on Alpha frequency band

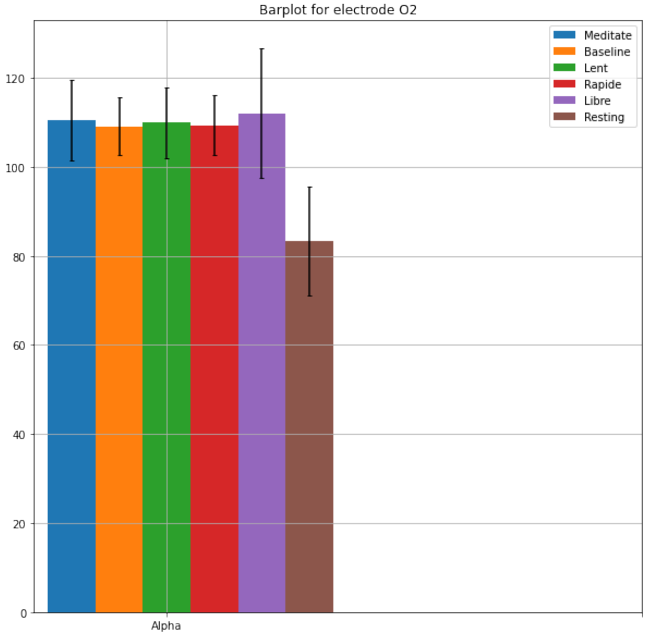
- Alpha











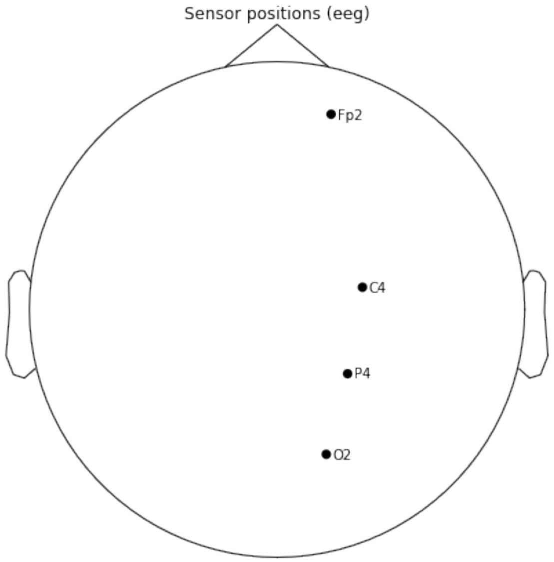
Most Significant Statistical test

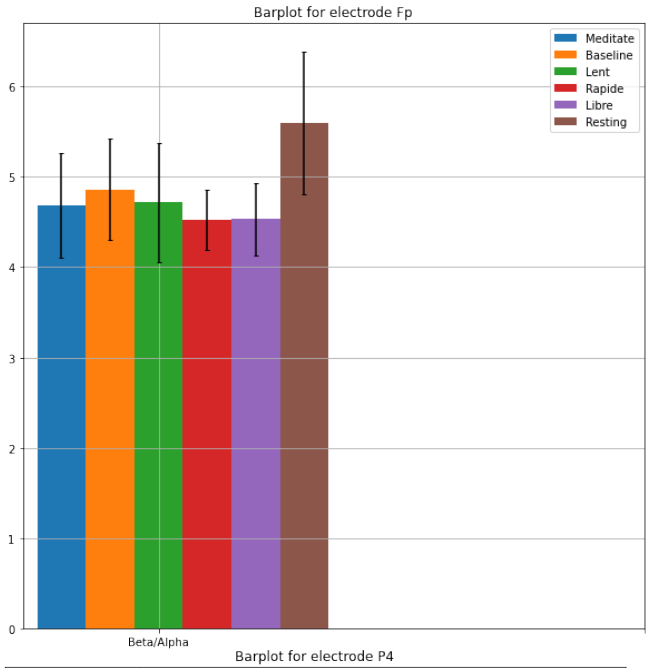
- Electrode P4

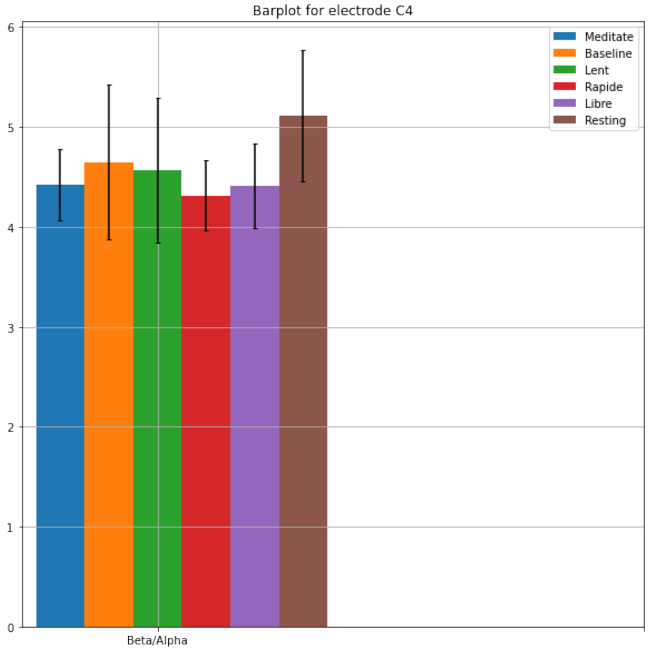
	sum_sq	df	F	PR(>F)
State	667.453076	2.0	2.573691	0.078635
Residual	27489.713815	212.0	NaN	NaN

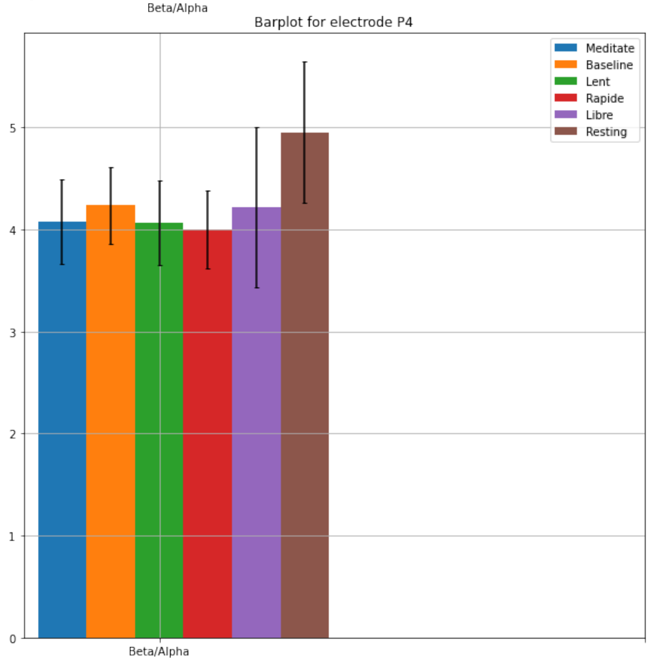
	coef	std err	t	P>|t|	Conf. Int. Low	Conf. Int. Upp.	pvalue-hs	reject-hs
Libre-Lent	3.273924	1.885001	1.736829	0.083870	-0.441821	6.989669	0.160706	False
Rapide-Lent	-0.768942	1.918386	-0.400828	0.688951	-4.550497	3.012612	0.688951	False
Rapide-Libre	-4.042866	1.905657	-2.121508	0.035040	-7.799330	-0.286402	0.101480	False

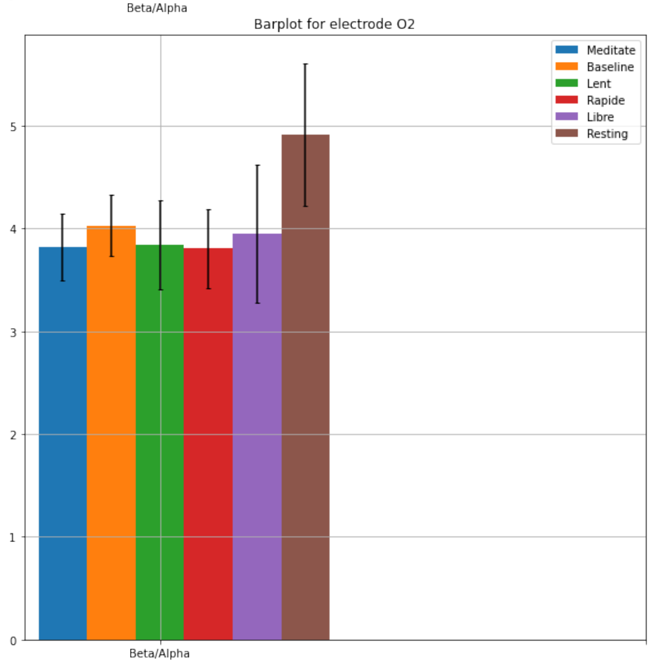
Beta/Alpha ratio engagement index











Most Significant Statistical test

- Electrode C4

	sum_sq	df	F	PR(>F)
State	2.284864	2.0	4.076147	0.018321
Residual	59.417761	212.0	NaN	NaN

	coef	std err	t	P>|t|	Conf. Int. Low	Conf. Int. Upp.	pvalue-hs	reject-hs
Libre-Lent	-0.156262	0.087636	-1.783067	0.076006	-0.329012	0.016489	0.146235	False
Rapide-Lent	-0.251672	0.089189	-2.821800	0.005230	-0.427482	-0.075862	0.015607	True
Rapide-Libre	-0.095411	0.088597	-1.076908	0.282745	-0.270054	0.079233	0.282745	False

- Electrode P4

	sum_sq	df	F	PR(>F)
State	1.915349	2.0	2.98262	0.05279
Residual	68.070007	212.0	NaN	NaN

	coef	std err	t	P>|t|	Conf. Int. Low	Conf. Int. Upp.	pvalue-hs	reject-hs
Libre-Lent	0.157547	0.093800	1.679598	0.094509	-0.027354	0.342448	0.180085	False
Rapide-Lent	-0.066933	0.095462	-0.701150	0.483979	-0.255108	0.121243	0.483979	False
Rapide-Libre	-0.224480	0.094828	-2.367224	0.018822	-0.411407	-0.037553	0.055410	False

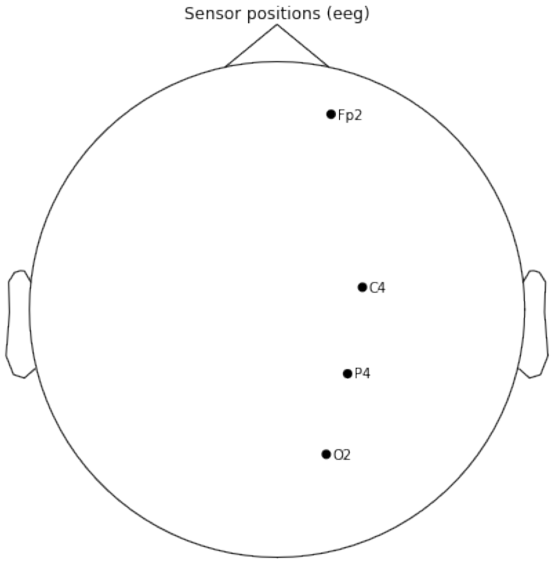
Most Significant Statistical test

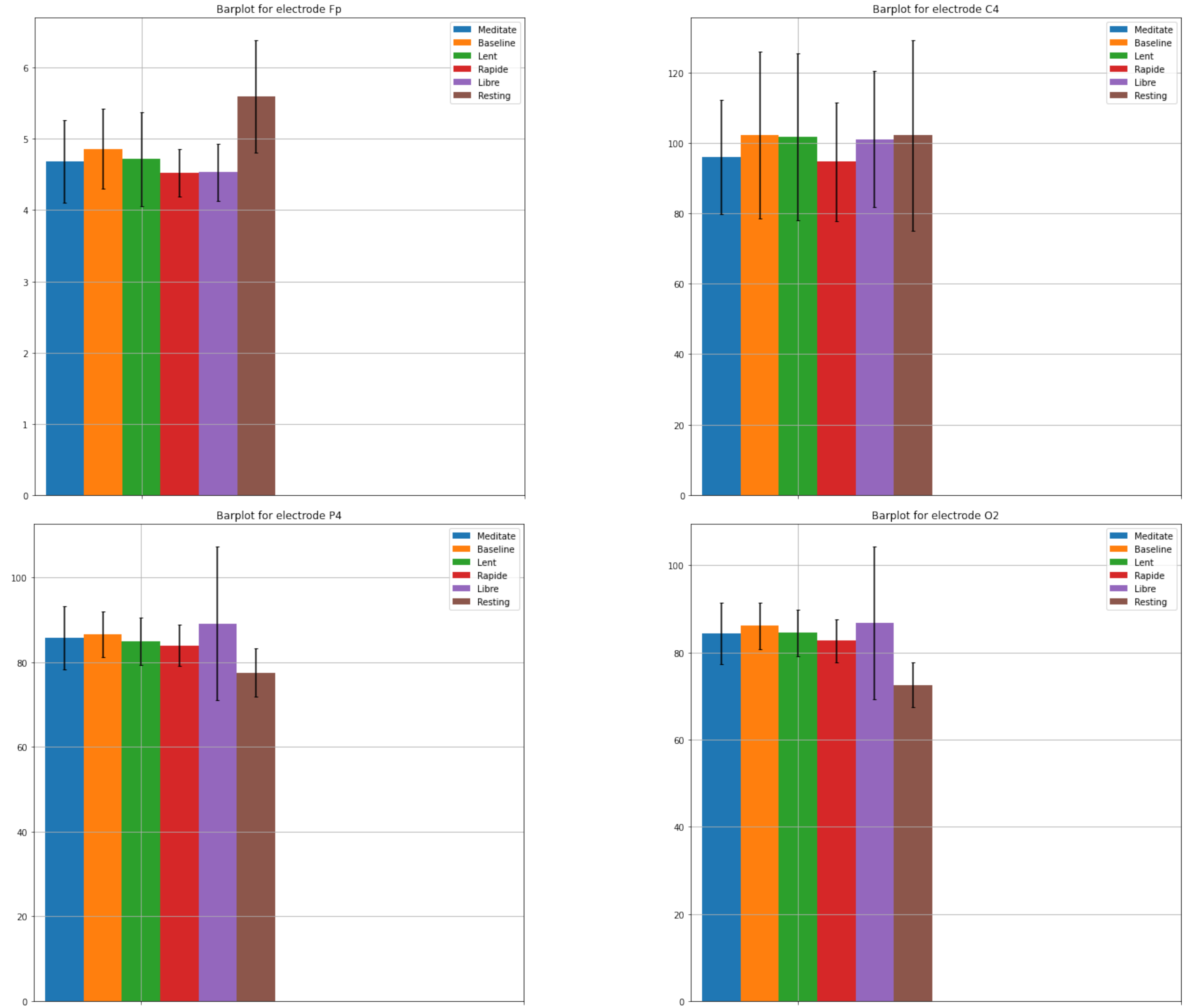
- Electrode Fp

	sum_sq	df	F	PR(>F)
State	1.700467	2.0	3.534622	0.030901
Residual	50.995415	212.0	NaN	NaN

	coef	std err	t	P>|t|	Conf. Int. Low	Conf. Int. Upp.	pvalue-hs	reject-hs
Libre-Lent	-0.186306	0.081188	-2.294745	0.022726	-0.346345	-0.026267	0.064558	False
Rapide-Lent	-0.190648	0.082626	-2.307362	0.022000	-0.353522	-0.027774	0.064558	False
Rapide-Libre	-0.004342	0.082078	-0.052902	0.957859	-0.166135	0.157451	0.957859	False

Mental fatigue/ Workload #theta





Most Significant Statistical test

- Electrode P4

	sum_sq	df	F	PR(>F)
State	1111.635786	2.0	4.174107	0.016672
Residual	28229.602631	212.0	NaN	NaN

	coef	std err	t	P>|t|	Conf. Int. Low	Conf. Int. Upp.	pvalue-hs	reject-hs
Libre-Lent	4.209897	1.910200	2.203904	0.028607	0.444479	7.975315	0.056396	False
Rapide-Lent	-1.015987	1.944031	-0.522619	0.601785	-4.848094	2.816120	0.601785	False
Rapide-Libre	-5.225884	1.931132	-2.706124	0.007362	-9.032565	-1.419203	0.021923	True

Supervised learning 2 class lent-rapide/libre

- X --> (n_samples, n_features) with n_samples = 478 and n_features = 4 (channels)*3(frequency bands)
- Y --> (n_samples,)

Pipeline :

- Oversampling : SMOTE
- Feature selection (SelectKBest with K = 5))
- Classifier : SVM

Mean_cross_val score = 0. 63
Permutation_test_score p_value = 0.05

	C4	**P4**	**O2**	**Fp**
Alpha	X	X	✓	X
Beta	X	✓	X	✓
Theta	✓	✓	X	X

Tab : Feature selection by KBest