

Common Introduction

History of the Method

Electroencephalography (EEG) has come a long way since its discovery approximately 140 years ago by the English physician Richard Caton. In 1875, he obtained the first brainwave recordings from monkeys and rabbits. Nearly 50 years later, in 1924, Hans Berger, using simple radio equipment to amplify brain electrical activity, conducted the first human EEG recording on the scalp and produced a written output on paper. He claimed that brain activity observed through EEG could change in a consistent, reliable, and recognizable way as the state of the patient changed, such as transitioning from relaxation to alertness, sleep, or oxygen deficiency. This advancement led to subsequent research and the diverse applications of EEG that are in use today (Müller-Putz, 2020).

Structure and function of the brain in relation to EEG data

The human brain contains approximately 86 billion neurons on average, and the communication between them is the key and primary activity of the brain. Neurons are excitable cells with inherent electrical properties, and their activity generates both magnetic and electrical fields, which can then be recorded using specialized electrodes (Kramarenko and Tan, 2003). There are two main types of neural activity: action potentials and postsynaptic potentials. Action potentials are the result of a very rapid depolarization of a neuron, primarily caused by changes in membrane permeability to sodium and potassium ions. This occurs when the cell depolarizes by a certain amount from its resting negative potential. Once this threshold is reached, a rapid action potential (approximately 1 millisecond) propagates from the beginning of the axon in the neuron's cell body to the axon terminals (Chen and Lui, 2023).

On the other hand, postsynaptic potentials represent changes in electrical charge outside the membrane, and this change in the extracellular space lasts up to 200 milliseconds. The extracellular charge, whether positive or negative, is what is measured by electrodes placed on the scalp. Pyramid-shaped cells act like small batteries with polarity – if one end of the dendrite is positive, the other end is negative (Grider et al., 2023). Postsynaptic potentials are mediated by several neurotransmitter systems and, as a result of synaptic activation, they generally cause slower changes in membrane potentials. These are voltages produced when neurotransmitters bind to receptors on the postsynaptic cell membrane, causing ion channels to open or close. It can be reliably claimed that EEG can only record postsynaptic potentials. Since action potentials are very fast and brief, and must travel along the axon at a constant speed, it seems that electrodes placed on the scalp cannot easily detect them.

The positivity or negativity of the extracellular charge on the dendrite's surface of the pyramidal cell depends on two factors: first, whether an inhibitory or excitatory stimulus has arrived at the synaptic junction from the axon of another cell, and second, whether the synapse is located proximally or distally to the cell body. For example, if an excitatory stimulus arrives near the distal end of the dendrite (closer to the cortical surface), a change in membrane permeability will lead to the entry of Na^+ into the cell, making the extracellular space negative (since the pyramidal cell acts like a battery, the extracellular space at the proximal end of the dendrite will be positive). Thus, if a similar event occurs at the dendrites of many pyramidal cells, the EEG electrode will record a negative extracellular potential. Therefore, EEG represents the algebraic sum of excitatory and inhibitory postsynaptic potentials (Kress and Mennerick, 2009).

Event-related brain potentials (ERPs)

For several decades, EEG recordings have been widely used in research and clinical settings (Figure 1). However, studying specific cognitive processes using this method is challenging. This is because using continuous, raw recordings to examine specific neural activity as a function of specific cognitive processes is, if not impossible, extremely difficult. Event-related potentials (ERPs) are small sections of continuous EEG

recordings that are elicited in response to stimuli (such as viewing images or words on a computer screen, or in this study, interaction with the Faradarmani Consciousness Field) (Ogrim and Kropotov, 2020).

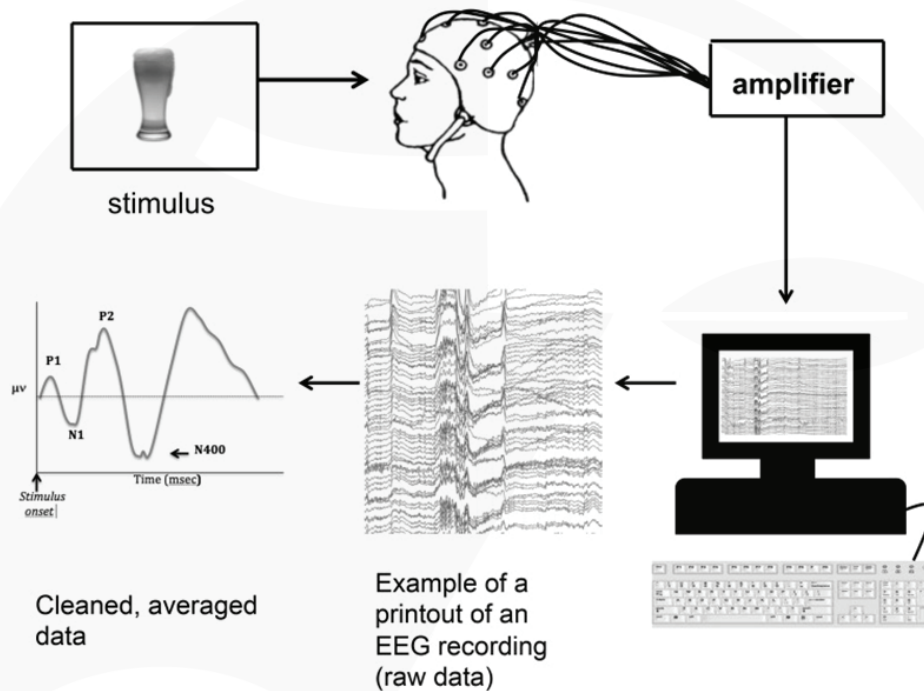


Figure 1. In an experimental setup, a number of electrodes, typically 32, 64, or 128, are placed on the participant's scalp, allowing for the measurement of brain electrical activity.

ERPs are used in a wide range of psychological experiments aimed at investigating various aspects of cognitive processes, such as language comprehension and production, memory, attention, and many others. Due to their very small amplitude, ERPs are typically not visible in raw EEG recordings. Therefore, they need to be separated from continuous recordings by averaging epochs of the recordings (Al-Ezzi et al., 2020).

After the stimulus is presented, a response is elicited by the brain, which is continuously recorded on a computer. The recording is then averaged, and individual ERPs are extracted. The EEG signal is obtained by recording the

electrical activity produced by the brain using electrodes placed at different locations on the scalp (Figure 2). In fact, the electrical potential difference between two sites (the active site and the reference site) is measured over time (Light et al., 2010).

An important point in extracting and analyzing ERP components from continuous data in research is obtaining the average activity in repeated tests with fixed conditions. Only the activity that is repeated and time-locked is not canceled out, and therefore it carries meaning and is visible in the output. The resulting output resembles a wave with a series of positive and negative peaks. These peaks are referred to as

"components" and are labeled according to their polarity, with "P" representing positive and "N" for negative, along with their approximate latency in milliseconds. Negative waves are associated with activation, while positive waves are related to inhibition. In each field of study, components are derived based on existing studies and tests

(Woodman, 2010). The names and numbers of the electrodes used in the studies of this issue are presented in Table 1. Figure 3 shows an EEG data acquisition setup in the studies presented in this issue.

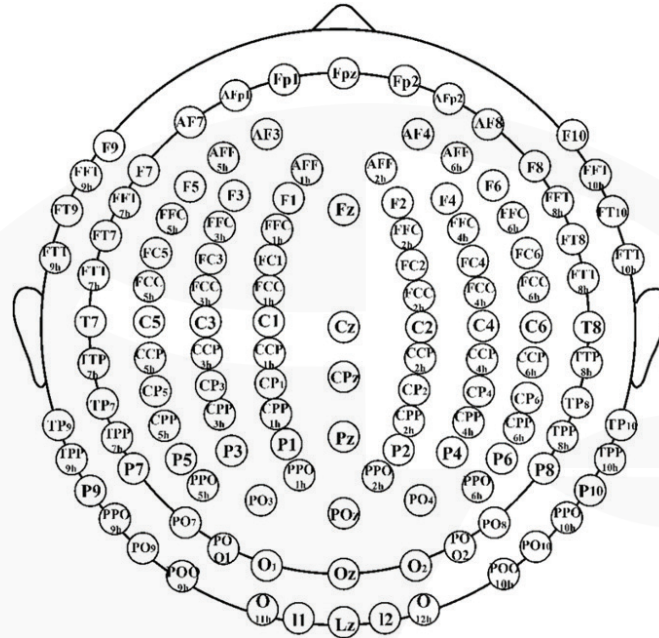


Figure 2. The names and locations of the 126 electrodes used in this study.

Table 1. The names and numbers of the electrodes used in the studies of this issue.

Number	Labels	theta	radius	X	Y	Z	sph_theta	sph_phi	sph_radius
1	FP1	-18.1	0.5	0.95	0.31	0	18.1	0	0.999
2	FPz	0	0.5	1	0	0	0	0	1
3	FP2	18.1	0.5	0.95	-0.31	0	-18.1	0	0.999
4	AF7	-36.1	0.5	0.81	0.59	0	36.1	0	1
5	AF3	-28.1	0.426	0.86	0.46	0.23	28.1	13.3	1
6	AF4	28.1	0.426	0.86	-0.46	0.23	-28.1	13.3	1
7	AF8	36.1	0.5	0.81	-0.59	0	-36.1	0	1
8	F9	-59.7	0.577	0.49	0.84	-0.24	59.7	-13.9	1
9	F7	-53.9	0.5	0.59	0.81	0	53.9	0	1
10	F5	-46.7	0.426	0.67	0.71	0.23	46.7	13.3	1
11	F3	-39.2	0.356	0.7	0.57	0.44	39.2	26	1
12	F1	-22.1	0.295	0.74	0.3	0.6	22.1	36.9	0.999
13	Fz	0	0.25	0.71	0	0.71	0	45	1
14	F2	22.1	0.295	0.74	-0.3	0.6	-22.1	36.9	0.999
15	F4	39.2	0.356	0.7	-0.57	0.44	-39.2	26	1
16	F6	46.7	0.426	0.67	-0.71	0.23	-46.7	13.3	1
17	F8	53.9	0.5	0.59	-0.81	0	-53.9	0	1
18	F10	59.7	0.577	0.49	-0.84	-0.24	-59.7	-13.9	1
19	FT7	-71.9	0.5	0.31	0.95	0	71.9	0	0.999
20	FC5	-67.8	0.394	0.36	0.88	0.33	67.8	19.1	1.01
21	FC3	-61.2	0.288	0.38	0.69	0.62	61.2	38.2	1

22	FC1	-42.1	0.187	0.41	0.37	0.83	42.1	56.4	0.997
23	FCz	0	0.125	0.38	0	0.92	0	67.6	0.995
24	FC2	42.1	0.187	0.41	-0.37	0.83	-42.1	56.4	0.997
25	FC4	61.2	0.288	0.38	-0.69	0.62	-61.2	38.2	1
26	FC6	67.8	0.394	0.36	-0.88	0.33	-67.8	19.1	1.01
27	FT8	71.9	0.5	0.31	-0.95	0	-71.9	0	0.999
28	T7	-90	0.5	6.12E-17	1	0	90	0	1
29	C5	-90	0.375	5.63E-17	0.92	0.38	90	22.4	0.995
30	C3	-90	0.25	4.35E-17	0.71	0.71	90	45	1
31	C1	-90	0.125	2.33E-17	0.38	0.92	90	67.6	0.995
32	Cz	0	0	6.12E-17	0	1	0	90	1
33	C2	90	0.125	2.33E-17	-0.38	0.92	-90	67.6	0.995
34	C4	90	0.25	4.35E-17	-0.71	0.71	-90	45	1
35	C6	90	0.375	5.63E-17	-0.92	0.38	-90	22.4	0.995
36	T8	90	0.5	6.12E-17	-1	0	-90	0	1
37	TP7	-108	0.5	-0.31	0.95	0	108	0	0.999
38	CP5	-112	0.394	-0.36	0.88	0.33	112	19.1	1.01
39	CP3	-119	0.288	-0.38	0.69	0.62	119	38.2	1
40	CP1	-138	0.187	-0.41	0.37	0.83	138	56.4	0.997
41	CPz	180	0.125	-0.38	-4.65E-17	0.92	-180	67.6	0.995
42	CP2	138	0.187	-0.41	-0.37	0.83	-138	56.4	0.997
43	CP4	119	0.288	-0.38	-0.69	0.62	-119	38.2	1
44	CP6	112	0.394	-0.36	-0.88	0.33	-112	19.1	1.01
45	TP8	108	0.5	-0.31	-0.95	0	-108	0	0.999
46	P7	-126	0.5	-0.59	0.81	0	126	0	1
47	P5	-133	0.426	-0.67	0.71	0.23	133	13.3	1
48	P3	-141	0.356	-0.7	0.57	0.44	141	26	1
49	P1	-158	0.295	-0.74	0.3	0.6	158	36.9	0.999
50	Pz	180	0.25	-0.71	-8.69E-17	0.71	-180	45	1
51	P2	158	0.295	-0.74	-0.3	0.6	-158	36.9	0.999
52	P4	141	0.356	-0.7	-0.57	0.44	-141	26	1
53	P6	133	0.426	-0.67	-0.71	0.23	-133	13.3	1
54	P8	126	0.5	-0.59	-0.81	0	-126	0	1
55	PO7	-144	0.5	-0.81	0.59	0	144	0	1
56	PO3	-152	0.426	-0.86	0.46	0.23	152	13.3	1
57	POz	180	0.375	-0.92	-1.13E-16	0.38	-180	22.4	0.995
58	PO4	152	0.426	-0.86	-0.46	0.23	-152	13.3	1
59	PO8	144	0.5	-0.81	-0.59	0	-144	0	1
60	O1	-162	0.5	-0.95	0.31	0	162	0	0.999
61	Oz	180	0.5	-1	-1.22E-16	0	-180	0	1
62	O2	162	0.5	-0.95	-0.31	0	-162	0	0.999
63	AFp5	-27.3	0.475	0.89	0.46	0.08	27.3	4.57	1.01
64	AFp1	-11.7	0.449	0.97	0.2	0.16	11.7	9.18	1
65	AFp2	11.7	0.449	0.97	-0.2	0.16	-11.7	9.18	1
66	AFp6	27.3	0.475	0.89	-0.46	0.08	-27.3	4.57	1.01
67	AFF7h	-41.3	0.462	0.75	0.66	0.12	41.3	6.85	1.01
68	AFF5h	-37.5	0.426	0.77	0.59	0.23	37.5	13.3	0.997
69	AFF3h	-25.4	0.362	0.82	0.39	0.42	25.4	24.8	1
70	AFF1h	-13.4	0.333	0.84	0.2	0.5	13.4	30.1	0.998
71	AFF2h	13.4	0.333	0.84	-0.2	0.5	-13.4	30.1	0.998

72	AFF4h	25.4	0.362	0.82	-0.39	0.42	-25.4	24.8	1
73	AFF6h	37.5	0.426	0.77	-0.59	0.23	-37.5	13.3	0.997
74	AFF8h	41.3	0.462	0.75	-0.66	0.12	-41.3	6.85	1.01
75	FFT9h	-65	0.545	0.42	0.9	-0.14	65	-8.02	1
76	FFT7h	-60.3	0.455	0.49	0.86	0.14	60.3	8.05	1
77	FFC5h	-53.5	0.362	0.54	0.73	0.42	53.5	24.8	1
78	FFC3h	-40.8	0.278	0.58	0.5	0.64	40.8	39.9	0.998
79	FFC1h	-16.3	0.208	0.58	0.17	0.79	16.3	52.6	0.995
80	FFC2h	16.3	0.208	0.58	-0.17	0.79	-16.3	52.6	0.995
81	FFC4h	40.8	0.278	0.58	-0.5	0.64	-40.8	39.9	0.998
82	FFC6h	53.5	0.362	0.54	-0.73	0.42	-53.5	24.8	1
83	FFT8h	60.3	0.455	0.49	-0.86	0.14	-60.3	8.05	1
84	FFT10h	65	0.545	0.42	-0.9	-0.14	-65	-8.02	1
85	FTT7h	-80.1	0.442	0.17	0.97	0.18	80.1	10.4	1
86	FCC5h	-77.1	0.323	0.19	0.83	0.53	77.1	31.9	1
87	FCC3h	-69.4	0.204	0.21	0.56	0.8	69.4	53.2	0.999
88	FCC1h	-43.6	0.0934	0.21	0.2	0.96	43.6	73.2	1
89	FCC2h	43.6	0.0934	0.21	-0.2	0.96	-43.6	73.2	1
90	FCC4h	69.4	0.204	0.21	-0.56	0.8	-69.4	53.2	0.999
91	FCC6h	77.1	0.323	0.19	-0.83	0.53	-77.1	31.9	1
92	FTT8h	80.1	0.442	0.17	-0.97	0.18	-80.1	10.4	1
93	TTP7h	-99.9	0.442	-0.17	0.97	0.18	99.9	10.4	1
94	CCP5h	-103	0.323	-0.19	0.83	0.53	103	31.9	1
95	CCP3h	-111	0.204	-0.21	0.56	0.8	111	53.2	0.999
96	CCP1h	-136	0.0934	-0.21	0.2	0.96	136	73.2	1
97	CCP2h	136	0.0934	-0.21	-0.2	0.96	-136	73.2	1
98	CCP4h	111	0.204	-0.21	-0.56	0.8	-111	53.2	0.999
99	CCP6h	103	0.323	-0.19	-0.83	0.53	-103	31.9	1
100	TTP8h	99.9	0.442	-0.17	-0.97	0.18	-99.9	10.4	1
101	TPP7h	-120	0.455	-0.49	0.86	0.14	120	8.05	1
102	CPP5h	-126	0.362	-0.54	0.73	0.42	126	24.8	1
103	CPP3h	-139	0.278	-0.58	0.5	0.64	139	39.9	0.998
104	CPP1h	-164	0.208	-0.58	0.17	0.79	164	52.6	0.995
105	CPP2h	164	0.208	-0.58	-0.17	0.79	-164	52.6	0.995
106	CPP4h	139	0.278	-0.58	-0.5	0.64	-139	39.9	0.998
107	CPP6h	126	0.362	-0.54	-0.73	0.42	-126	24.8	1
108	TPP8h	120	0.455	-0.49	-0.86	0.14	-120	8.05	1
109	PPO9h	-133	0.554	-0.68	0.72	-0.17	133	-9.74	1
110	PPO7h	-139	0.462	-0.75	0.66	0.12	139	6.85	1.01
111	PPO5h	-143	0.426	-0.77	0.59	0.23	143	13.3	0.997
112	PPO3h	-150	0.358	-0.78	0.45	0.43	150	25.5	0.998
113	PPO1h	-167	0.333	-0.84	0.2	0.5	167	30.1	0.998
114	PPO2h	167	0.333	-0.84	-0.2	0.5	-167	30.1	0.998
115	PPO4h	150	0.358	-0.78	-0.45	0.43	-150	25.5	0.998
116	PPO6h	143	0.426	-0.77	-0.59	0.23	-143	13.3	0.997
117	PPO8h	139	0.462	-0.75	-0.66	0.12	-139	6.85	1.01
118	PPO10h	133	0.554	-0.68	-0.72	-0.17	-133	-9.74	1
119	POO5	-153	0.475	-0.89	0.46	0.08	153	4.57	1.01
120	POO1	-168	0.449	-0.97	0.2	0.16	168	9.18	1
121	POO2	168	0.449	-0.97	-0.2	0.16	-168	9.18	1

122	POO6	153	0.475	-0.89	-0.46	0.08	-153	4.57	1.01
123	POO9h	-153	0.571	-0.87	0.44	-0.22	153	-12.7	0.999
124	OI1h	-171	0.567	-0.97	0.15	-0.21	171	-12.1	1
125	OI2h	171	0.567	-0.97	-0.15	-0.21	-171	v	1
126	POO10h	153	0.571	-0.87	-0.44	-0.22	-153	-12.7	0.999



Figure 3. EEG data acquisition setup in the studies presented in this issue.

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