e-ISSN: 0975-1556, p-ISSN:2820-2643

Available online on www.ijpcr.com

International Journal of Pharmaceutical and Clinical Research 2023; 15(2); 1371-1380

Original Research Article

To Evaluate the difference in Amplitude and Latency of ERP Waveform of N400 between Semantically Coherent, Incoherent and Recoherent Sentences Processing

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Received: 30-01-2023 / Revised: 18-02-2023 / Accepted: 28-02-2023
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Conflict of interest: Nil

Abstract

A prospective comparative study was conducted to evaluate the architectonics and mechanistic profile of semantic information processing as represented by ERP waveform of N400 along different virtual phase-time zones of human mind using set regimes of 45 paired sentences with three conditions namely Coherent, Incoherent and Recoherent. The evaluation exhibited significant violations across diffuse EEG electrodes (F3,F4,FCz FC4,C3,CZ,C4,CP3,CPz) depicting the bilateral activation of Frontal, Fronto-Central, Central And Centro-Parietal regions of brain proposing the phenomenal processing of semantics, not only confined to word knowledge, but also considering the other modalities i.e colors, textures, sounds, shapes, emotions associated with the formation of a particular letter or word segregated in neuronal pixels entangled with reasoning, planning, problem solving cubicles of human mind.

Keywords: EEG, ERP, N400, Semantically Coherent, Incoherent, Recoherent, Sentence Processing.

Introduction

Event-related potentials (ERPs) are voltage changes in EEG, that are time locked to some specific sensory, motor or cognitive events/stimuli. ERPs provide safe and non-invasive approach to study psychophysiological correlates of mental processes[1]. ERPs waves/components have been categorized into: Sensory/exogenous: Early components representing analysis of physical parameters of the stimulus. Cognitive/endogenous: Later components reflecting the manner in which the subject evaluates the stimulus.

N400 component: Peaking around 400 ms reflects semantic processing at the level of single words and sentence level [2]. Therefore, we propose to evaluate the mechanistic profile of semantic information processing as represented by the ERP wave

form N400 during the processing of legible, meaningful, comprehensive and semantically coherent sentence.

Material and Methods

The present study was a comparative prospective research protocol which was conducted in the Department of Physiology at S.M.S. Medical College and Attached Hospitals, Jaipur after obtaining desired clearance from Institutional Research Review Board (IRRB) and Ethics Committee of the Institution. The data was collected through the standard Electroencephalographic (EEG) protocol [inclusive of Event-Related Potential (ERP) design] carried out on healthy right-handed Undergraduate College Students whose age was 18-25 years. A sample size of approximately 72 subjects was required at 80% study power keeping the α error at 0.05 assuming F ratio of 6.33 as was documented for ERP wave form amplitude (Kelvin Xu *et al*., 2015) [3]. using G power software. It was further enhanced and rounded off to 80 subjects as final sample size expecting 10% attrition. The subjects were seated approximately 75 cm from a computer screen in sound attenuated dimly lit EEG room. EEG Electrodes areas to be used were: F3, FC3, C3, CP3, FZ, FCZ, Cz, CPZ, F4, FC4, C4, CP4 and reference elect electrode at left ear lobule. Subjects were asked to focus on screen and the N400 component was determined as the most prominent negative peak in the range of 300-500 ms relative to word onset. Once the EEG waves stabilized, the stimulus protocol was loaded and the data acquisition was started. The EEG using the predefined stimulus protocol which consisted of the presentation of 45 pairs of sentences. Each pair consisted four different conditions namely correct, incoherent, re-coherent. The phenomenon of correct sentence gave a correct world knowledge, incoherent sentence violates world knowledge, and a re-coherent sentence violates world knowledge in the beginning but added new information to make the violation more acceptable finally.

The Stimulus Protocol

Stimulus Protocols		
S. No.	**Sentence**	**Remarks**
1	Correct	Gives Correct World Knowledge
2	Incoherent	Violates World Knowledge
3	Re-coherent	Violates World Knowledge in Beginning but Adds New Information to make Violation More Acceptable

The ERP data was obtained in the form of latency and amplitude was then tabulated separately for each electrode site i.e., F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 for all 72 subjects for three different types of sentences i.e., correct, incoherent and re-coherent.

The obtained data was subjected to appropriate statistical analysis using *student's paired 't'* test and ANOVA test. A p value <0.05 was taken as statistically significant.

Results

The mean age of 72 subjects was 22.75±1.65 years. Female preponderance 41(56.9%) was more than males 31(43.1%). The Mean and standard deviation of amplitudes (in μV) of N400 component of ERP among all three conditions (correct, incoherent and re-coherent) at F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 electrode sites were obtained. On comparative evaluation among these three conditions had conferred significant difference ($p<0.05$), at F3($p=0.004$) ($F=5.679$), at FCz ($p= 0.018$) ($F=4.132$), at C3 ($p=0.004$) ($F= 5.694$), at Cz($p=0.017$) ($F=4.189$), at C4 ($p<0.001$) ($F=8.626$), at CP3 ($p=0.002$) ($F=6.573$), at CPz ($p <0.001$) ($F=11.633$) could be appreciated while

making use of multivariate evaluator of *ANOVA test*.

In a similar manner, mean and standard deviation of amplitudes (in μV) of N400 component of ERP between said two conditions (correct and incoherent) at F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 electrode sites. On comparison between these two conditions significant difference ($p<0.05$) at F3 ($p=0.001$) ($t=3.478$), at F4 ($p=0.010$) ($t=2.658$), at FCz ($p= 0.012$) ($t=2.588$), at FC4 ($p= 0.020$) ($t=2.372$), at C3 ($p=0.001$) ($t=3.359$), at Cz ($p=0.001$) ($t=3.409$), at C4 ($p<0.001$) ($t=4.813$), at CP3 ($p=0.002$) ($t=3.187$), at CPz ($p <0.001$) ($t=4.063$) could be appreciated making use of *student's paired 't' test*.

The Mean and standard deviation of amplitudes (in μV) of N400 component of ERP between these two test conditions (correct and re-coherent) at F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 electrode sites. On comparison between these two conditions significant difference ($p<0.05$) at CP3 ($p=0.004$) ($t=3.005$), at CPz ($p <0.001$) ($t=3.887$) could be observed using *student's paired't' test*.

The mean and standard deviation of amplitudes (in μV) of N400 component of ERP between two conditions (incoherent and re-coherent) at F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 electrode sites. Significant difference ($p<0.05$) at F3 ($p=0.018$) ($t=-2.426$), at FCz ($p= 0.015$) ($t=2.5$), at C3 ($p=0.004$) ($t=-2.974$)), at C4 ($p=0.012$) ($t=-2.591$) using *student's paired 't' test* could be appreciated on comparative evaluation of amplitude (in μV) changes in these two conditions.

The mean and standard deviation of latencies (in ms) of N400 component of ERP among all three conditions (correct, incoherent and re-coherent) at F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 electrode sites. On comparative evaluation through *ANOVA* among these three conditions showed significant difference ($p<0.05$), at F3 ($p=0.001$) ($F=7.579$), at F4 ($p=0.001$) ($F=7.007$), at FC3 ($p=0.008$) ($F= 4.972$), at FCz ($p= 0.003$) ($F=6.247$), at FC4 ($p= 0.023$) ($F=3.862$), at Cz ($p=0.013$) ($F=4.443$), at C4 ($p<0.001$) ($F= 11.043$), at CP3 ($p=0.003$) ($F=6.023$), at CPz ($p =0.002$) ($F=6.662$) at CP4 ($p<0.001$) ($F=21.697$) could be appreciated.

The mean and standard deviation of latencies (in ms) of N400 component of ERP between two conditions (correct and incoherent) at F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 electrode sites. Significant difference ($p<0.05$) at F3 ($p=0.001$) ($t=-3.644$), at Fz ($p= 0.023$) ($t=-2.321$), at F4 ($p=0.001$) ($t=- 3.432$)), at FC3 ($p=0.012$) ($t=-2.588$), FCz ($p=0.008$) ($t=-2.716$), at Cz ($p=0.015$) ($t=2.49$), at C4 ($p<0.001$) ($t= -4.502$), at CP3 ($p=0.007$) ($t= -2.79$), at CPz ($p=0.002$) ($t= -3.16$) at CP4 ($p<0.001$) ($t=-6.589$) could be observed while making use of *student's paired 't' test*.

The mean and standard deviation of latencies (in ms) of N400 component of ERP between two conditions (incoherent and re-coherent) at F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 electrode sites. On comparative evaluation between these two conditions significant difference ($p<0.05$) at F3 ($p=0.021$) ($t=-2.365$), at F4 ($p= 0.030$) ($t=-2.208$), at FC3 ($p=0.018$) ($t=-2.431$)), at FCz ($p=0.004$) ($t=-3.011$), FC4 ($p=0.007$) ($t=-2.792$), at Cz ($p=0.016$) ($t=-2.467$), at C4 ($p=0.001$) ($t= -3.582$), at CP3($p=0.003$) ($t= -3.057$), at CPz ($p=0.004$) ($t= -2.967$) at CP4 ($p<0.001$) ($t=-3.818$) could be appreciated while making use of *student's paired 't' test*.

Mean and standard deviation of latencies (in ms) of N400 component of ERP between two conditions (incoherent and re-coherent) at F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 electrode sites. Significant difference ($p<0.05$) was found only at CP4 ($p<0.010$) ($t=2.659$) could be observed through *student's paired 't' test*.

Table 1: Demographic information of patients

Age group (19-25) years	Patients (n=72)	Frequency (n%)	Mean age of patients in years
22	18	25%	22.75±1.65
24	15	20.8%	
25	14	19.4%	
21	1	13.9%	
23	9	12.5%	
20	4	5.6%	
19	2	2.8%	
Gender	Female	Male	
	41(56.9%)	31(43.1%)	

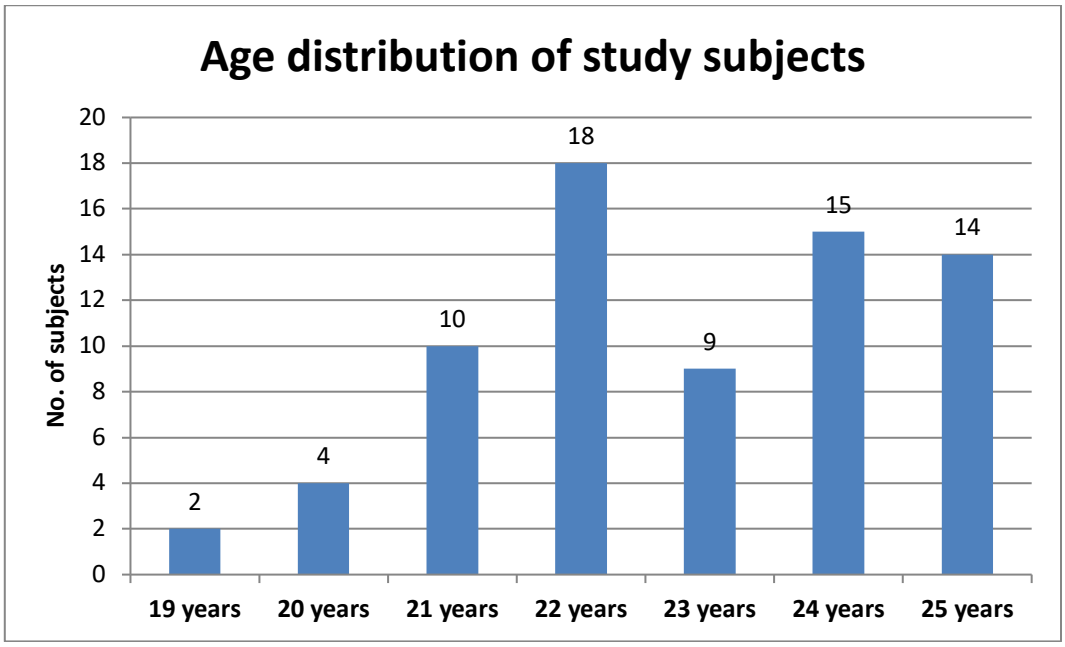

Figure 1: Bar Diagram Representing Age Distribution of Participant Population

Figure 1 Bar diagrams shows age distribution of the participants where the X-axis depicts age (years) of participants and Y-axis represents number of participants enrolled in the study.

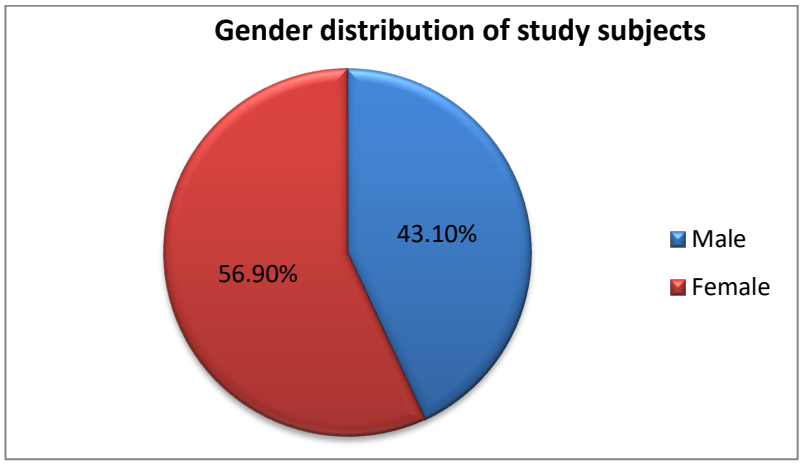

Figure 2: Pie chart Representing Gender Distribution of Sample Population

Table 2: Clinical information of patients

Comparison of N400 amplitudes of ERP		Correct sentence	Incoherent sentence	Recoherent sentence	p-value
ROI	**Electrodes**				
Frontal	**F3**	0.46 ± 5.32	-2.48 ± 5.06	-0.23 ± 6.63	0.004 (S)
Fronto Central	**FC_z**	-0.36 ± 4.79	-2.21 ± 5.19	0.69 ± 8.21	0.018 (S)
Central	**C_3**	-0.72 ± 4.8	-3.03±3.91	-0.36 ± 7.2	0.004 (S)
	C_Z	0.66 ± 5.56	-2.17±5.02	-0.89±7.52	0.017 (S)
	C_4	0.56 ± 5.58	-3.15±4.19	-0.94±6.39	<0.001(S)
Centroparietal	**CPz**	0.83 ± 5.33	-2 ± 4.92	-2.05±6.06	0.002 (S)
	CP4	0.99 ± 6.27	-2.7 ± 4.76	-2.61±5.71	<0.001(S)
		Correct sentence	**Incoherent sentence**		**p-value**
Frontal	**F_3**	0.46± 5.32	-2.48 ± 5.06		0.001 (S)
	F_4	0.08± 5.88	-2.19 ± 4.79		0.010 (S)
Fronto Central	**FCz**	0.36±4.79	-2.21 ± 5.19		0.012 (S)
	FC4	-0.6 ± 3.73	-2.13 ± 4.29		0.020 (S)
Central	**C3**	-0.72 ± 4.8	-3.03 ± 3.91		0.001 (S)
	Cz	0.66 ± 5.56	-2.17 ± 5.02		0.001 (S)
	C4	0.56 ± 5.58	-3.15 ± 4.19		<0.001(S)
Centro-parietal	**CP3**	0.83±5.33	-2 ± 4.92		0.002 (S)
	CPz	0.99 ± 6.27	-2.7 ± 4.76		<0.001(S)
Centro-parietal		**Correct sentence**		**Re-coherent sentence**	**p-value**
	CP3	0.83± 5.33		-2.05±6.06	0.004 (S)
	CPz	0.99± 6.27		-2.61±5.71	<0.001(S)
			Incoherent sentence	**Re-coherent sentence**	**p-value**
Frontal	**F_3**		2.48±5.06	-0.23±6.63	0.018 (S)
Fronto Central	**FCz**		2.21±5.19	0.69± 8.21	0.015 (S)
Central	**C_3**		3.03± 3.91	-0.36 ± 7.2	0.004 (S)
	C_4		3.15±4.19	-0.94±6.39	0.012 (S)

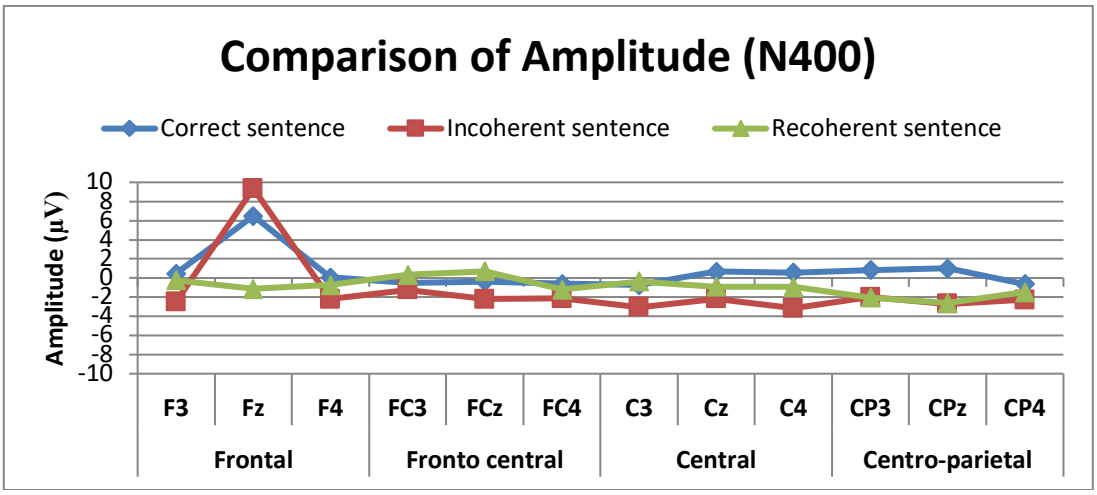

Figure 3: Comparison of Amplitude of N400 (μV) across different EEG channels among Correct, Incoherent and Re-coherent Sentence

Figure 3 exhibits *Mean Amplitudes (in μV) of N400 component of ERP* among *all three conditions correct (blue), incoherent (red) and re-coherent (green)* at F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 electrode sites. X-axis depicts varied EEG electrodes F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4, and Y- axis represents amplitude in (μV).

Table 3: Clinical information of patients

Comparison of N400 latencies of ERP		**Correct sentence**	**Incoherent sentence**	**Recoherent sentence**	**p-value**
ROI	**Electrodes**				
Frontal	**F_3**	388.7± 39.9	411 ± 31.3	402.1 ± 31.7	0.001(S)
	F_4	393.2 ± 40.3	415.2 ± 32	406.8 ± 33.2	0.001(S)
Fronto Central	**FC3**	389.4 ± 39.4	406.4 ± 35.5	403.2 ± 27	0.008 (S)
	FCz	392.2 ± 40.8	409.4 ± 33.3	407.8 ± 30.4	0.003 (S)
	FC4	398.3 ± 39.6	407 ± 36.8	414.5 ± 27.1	0.023 (S)
Central	**C_Z**	394.4 ± 38.6	409.2 ± 33.9	408.1 ± 32.1	0.013 (S)
	C_4	385.1 ± 37.6	409.5 ± 37.1	405.1 ± 31.1	<0.001(S)
Centroparietal	**CP3**	394.7 ± 41.5	411 ± 32.3	411.1 ± 29.9	0.003 (S)
	CPz	395.8 ± 37.5	414.4 ± 32.3	409.8 ± 30.3	0.002 (S)
	CP4	383.6 ± 39	418.5 ± 29.8	404.8 ± 30.8	<0.001(S)
		Correct sentence	**Incoherent sentence**		**p-value**
Frontal	**F_3**	388.7± 39.9	411 ± 31.3		0.001(S)
	F_Z	398.7± 41.5	411.7±30.5		0.023 (S)
	F_4	393.2± 40.3	415.2 ± 32		0.001 (S)
Fronto Central	**FC3**	389.4± 39.4	406.4±35.5		0.012 (S)
	FCz	392.2± 40.8	409.4±33.3		0.008 (S)
Central	**Cz**	394.4± 38.6	409.2±33.9		0.015 (S)
	C4	385.1± 37.6	409.5±37.1		<0.001(S)
Centro-parietal	**CP3**	394.7± 41.5	411 ± 32.3		0.007 (S)
	CPz	395.8± 37.5	414.4±32.3		0.002 (S)
	CP4	383.6 ± 39	418.5±29.8		<0.001(S)
		Correct sentence		**Recoherent sentence**	**p-value**
Frontal	**F3**	388.7± 39.9		402.1 ± 31.7	0.021(S)
	F4	393.2± 40.3		406.8 ± 33.2	0.030(S)
Fronto Central	**FC3**	389.4± 39.4		403.2 ± 27	0.018 (S)
	FCz	391.3± 40.4		407.8 ± 30.4	0.004 (S)
	FC4	398.3± 39.6		414.5 ± 27.1	0.007 (S)
Central	**Cz**	394.4± 38.6		408.1 ± 32.1	0.016 (S)
	C4	385.1± 37.6		405.1 ± 31.1	0.001 (S)
Centro-parietal	**CP3**	394.7± 41.5		411.1 ± 29.9	0.003 (S)
	CPz	395.8 ± 37.5		409.8 ± 30.3	0.004 (S)
	CP4	383.6 ± 39		404.8 ± 30.8	<0.001(S
Centro-parietal			**Incoherent sentence**	**Re-coherent sentence**	**p-value**
	CP4		418.5±29.8	404.8 ± 30.8	0.010(S)

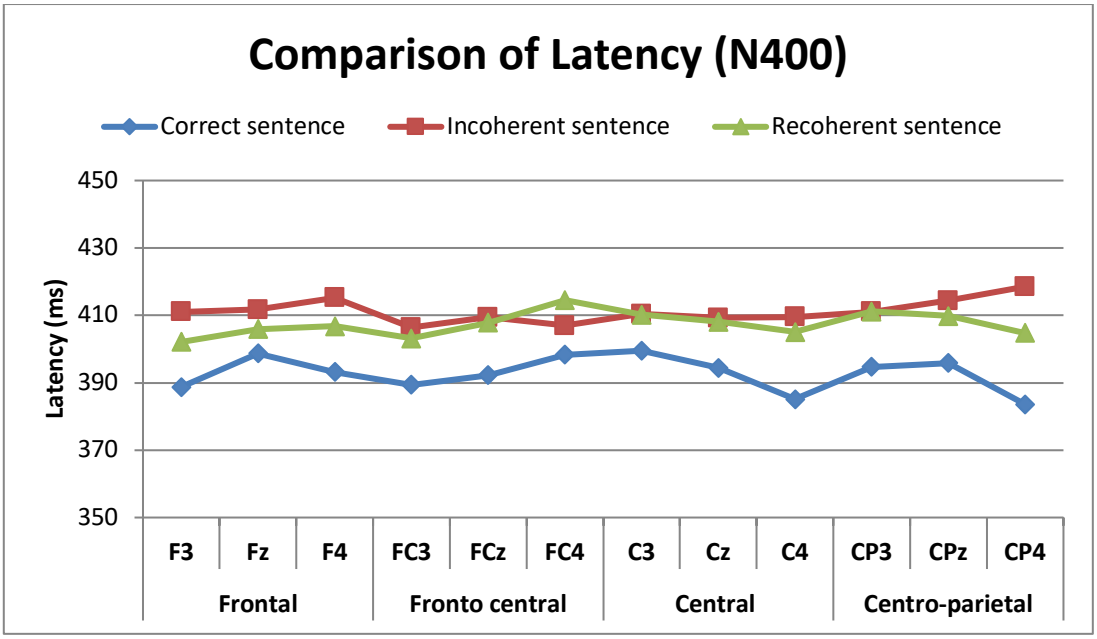

Figure 4: Comparison of Latencies of N400 (ms) across different EEG channels among Correct, Incoherent and Re-coherent Sentence

Figure 4 exhibits *Mean Latencies (in ms) of N400 component* of ERP among *all three conditions correct (blue), incoherent (red) and recoherent (green)* at F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 electrode sites.X- axis represents varied EEG electrodes, F3, Fz, F4, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4 and Y- axis depicts Latencies in (ms).

Discussion

The present study was a prospective comparative one, which was conducted to assess the human capacity to produce and comprehend language (means of structured valid, reliable and reproducible communication) which is one of the most distinctive characteristics of our species. Seventy-two (72) undergraduate students of colleges of Jaipur city were allowed in the study and their amplitude response of N400 for Correct, Incoherent and Re-coherent Sentences.

The basic operational architectonics of Human Mind, functional correlate of Human Brain is primarily centered on the premise of neurophysiological precept of memory, the neurodynamical aspect of which is manifested through changes in amplitude and/or Power Spectral Density (PSD) reflective of respective dedicated distributed neuronal network pool on digital quantitation of Electroencephalographic (EEG) time-series wave form. Moreover, stimulus and/or event-specific changes in potentials of EEG time-series wave form manifested in terms of changes in amplitude and latency in real-time highlight the underlying neural dynamical modification of amplitude and/or PSD that essentially is mesoscopic representation of process of memory [4]. The Human Mind is also working on the principles of Chaos (akin to Dynamical Features of Universe) [5] that represents an order within seeming disorder, etching a stochastic trajectory through operational architectonics of distributed neuronal networks dedicated and adequate and specific to the stimulus. In other words, operational architectonics of neurophysiological of memory manifests in terms of either an increase in PSD (Eventrelated Synchrony, ERS) and a decrease in PSD (Event-related Desynchrony, ERD) [6-7]. The phenomena of ERS and ERD represents distributed neuronal network oscillating in synchrony

and out of synchrony (asynchronous) in response to the specific stimulus, respectively [8-12]. ERS is a phenomenon reflective of acquisition of new facts converted into neural language of consolidation of memory and ERD represents the select feature of Human Mind to retrieve and recall past experience represented neurally in form of memory evolving a portal and/or window for such a selective and specific neurophysiological responsive correlate with out of phase reverberations of distributed neuronal networks represented as ERD ensuring easy, quick and efficient flow of information so needed for the specific task[13].

It has been proposed that a novel concept and/or stimulus recruits a dedicated neuronal circuitry neurophysiologically and elicits an ERS, a phenomenon that represents an ongoing process of learning and with conditioning and/or memory formation ERS transmogrifies into ERD [6-7].

Event-related Potentials (ERPs) are very small voltages generated in underlying brain structures in response to specific events or stimuli [1]. They are EEG changes that are time locked to sensory, motor or cognitive events and provide safe and non-invasive approach to study psychophysiological correlates of mental processes. Event-related Potentials (ERPs) can be elicited by a wide variety of sensory, cognitive or motor events and are thought to reflect the summed activity of postsynaptic potentials produced when a large number of similarly oriented cortical pyramidal neurons (in the order of thousands or millions) fire in synchrony while processing information [8]. ERPs in humans have been categorized into 2 distinct components. The early waves, or components peaking roughly within the first 100 milliseconds or so post-stimulus represent 'Sensory' or 'Exogenous' Component, as qualia and quanta of such a component is largely dependent on physical parameters of the stimulus. In contrast, ERP Component generated in later half reflects the manner in which the subject evaluates the stimulus and subsequently define the 'Cognitive' or 'Endogenous Component' of ERP as the latter component is a reflection of underlying innate dynamical neural information processing. The ERP waveforms have further been identified through their elemental variates of latency and amplitude. In this context, the present study was designed to get an insight into underlying neural processes of language and subsequently the self-iterating fractal network of language and subsequently the self-iterating fractal network of language was assessed through select domains of ERPs inclusive of N400 [9-10] specific fractal neural response that mirror semantic incongruity and syntactic violation and/or non-preferential syntactic structure, respectively.

The N400, a negative wave occurring at around 300 – 500 ms post – stimulus [11-12] is typically seen in response to violations of semantic expectancies. In this study a significant peaking, an increase in amplitude, so observed in N400 ERP wave form during the test condition is the characteristic response of distributed neuronal networks of frontal, fronto-central, central and centro-parietal cortical regions underlying the said EEG electrodes that detect a change and different stimulus, not learnt and is out of pattern, a violation of coherence of learnt facts. The phenomenon of incoherence, a submission does not match with known laid down learnt and memorized facts, again elicited peaking or odd-man out response of N400 by select distributed neuronal networks of frontal, fronto-central, central and centro-parietal cortical regions underlying the said EEG electrodes. The essence of correct and re-coherent sentences lies in the fact that a nominal violation of semantics seems to exist between the two set of sentences and the same was exemplified by restricted and localized significant changes in N400 amplitude at EEG electrodes of CP3 and

CPz, a stark contrast that was observed in comparative assessment of correct and incoherent sentences, a phenomenon depicting gross violation as exhibited by in N400 amplitude across diffuse EEG electrodes F3, F4, FCz, FC4, C3, Cz, C4, CP3, and CPz.

On examining the comparative and proportional study of significant changes in amplitude of N400 ERP wave form between correct and incoherent sentences, correct and re-coherent sentences and incoherent and re-coherent, it was observed that more numbers of EEG electrodes pairs data registered significant changes in N400 amplitude along the correct and incoherent sentences pair as compared to that observed during correct and re-coherent sentences and incoherent and re-coherent sentences.

The Latency Response of N400 for Correct, Incoherent and Re-coherent Sentences In this study the latencies of N400 were analyzed in healthy right-handed undergraduate College Students at electrode areas of frontal (F3, Fz, F4), frontocentral (FC3, FCz, FC4,) central (C3, Cz, C4), centroparietal (CP3, CPz, CP4). The result revealed significant difference among Correct, Incoherent and Re-coherent Sentences.

Conclusion

The observations and results obtained from the present study reflects that the amplitudes and latencies of N400 waveforms of ERP, which were compared, yielded a significant difference which could be appreciated in the electrodes of defined regions i.e., frontal (F3, Fz, F4), fronto-central (FC3, FCz, FC4), central (C3, Cz, C4) and centro-parietal (CP3, CPz, CP4) observed during correct and re-coherent sentences and incoherent and re-coherent sentences reveals phenomenological considerations of semantic processing induced during task or the on-going retrieval of perceptual and conceptual knowledge, which is inclusive of neuronal pools primarily operating sensory processing, motor processing, spatial attention and the neuronal treasure containing the knowledge obtained from past experiences parallelly deactivating the irrelevant channels or neuronal circuits making them inaccessible during tasks indicating the intricating and entangled multi-dimensional systems within the brain.

References

1. Blackwood D., & Muir W. Cognitive Brain Potentials and their Application. British Journal of Psychiatry. 1990; 157(S9): 96-101.
2. Kutas M, Federmeier KD. Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP). Annual review of psychology. 2011 Jan 10;62:621-47.
3. Kelvin Xu, Jimmy Ba, Ryan Kiros, Kyunghyun Cho, AaronCourville, Ruslan Salakhudinov, Rich Zemel, Yoshua Bengio. Proceedings of the 32nd International Conference on Machine Learning, PMLR. 2015; 37:2048-2057.
4. Burke JF, Zaghloul, Jacobs J, Williams RB, Sperling MR, Sharan AD and Kahana MJ. Synchronous and asynchronous theta and gamma activity during episodic memory formation. The Journal of Neuroscience, 2013;33(1): 292-304.
5. Dube A, Kumar A, Gupta K, Vyas P, Boolchandani D and Sonania R. Chaotic Neural Dynamics as evinced from scalp electroencephalography (EEG). European Journal of Neurology. 2009; 16(3): 451.
6. Crone NE, Korzeniewska A, Franaszczuk PJ. Cortical gamma responses: searching high and low. Int J Psychophysiol. 2011; 79:9 –15.
7. Pfurtscheller G, Lopes da Silva FH. Event-related EEG/MEG synchronization and desynchronization: basic principles. Clin Neurophysiol. 1999; 110:1842–1857.
8. Peterson N. N., Schroeder C. E. and Arezzo J. C. Neural generators of early cortical somatosensory evoked

potentials in the awake monkey. Electroencephalogr Clin Neurophysiol. 1995; 96(3); 248-260.
9. Kutas M, Hillyard SA. Event-related brain potentials to semantically inappropriate and surprisingly large words. Biological psychology. 1980 Sep 1;11(2):99-116.
10. Osterhout L, Holcomb PJ. Event-related brain potentials elicited by syntactic anomaly. Journal of memory and language. 1992 Dec 1;31(6):785-806.
11. Hagoort P. The fractionation of spoken language understanding by measuring electrical and magnetic brain signals. Philos Trans R Soc Lond B Biol Sci. 2008; 363(1493):1055-1069.
12. Kutas M, Van Petten C.K. Psycholinguistics electrified: event-related brain potential investigations. In: Gernsbacher M.A, editor. Handbook of psycholinguistics. Academic Press; New York, NY: 1994; 83–143.
13. Jetaji L., Patel B., Choudhary M., Tak A., Gupta K., Gupta J., Yadav K., & Dube A. Power spectral densities of electroencephalographic theta and alpha frequency waves during information processing of language comprehension. Neuropsychological Trends. 2021; 30: 53–78.