Syntactic Language Processing among Women - An EEG/ERP Study of Visual Pictorial Stimuli

Nurul Nazihah Zaidil
Department of Neurosciences
Universiti Sains Malaysia
Kota Bharu, Malaysia
nazihahzaidil@gmail.com

Tahamina Begum
Department of Neurosciences
Universiti Sains Malaysia
Kota Bharu, Malaysia
tahamina@usm.my

Rozaida Abdul Rauf
Malay Linguistics Section, School of Humanities, Universiti Sains Malaysia
Pulau Pinang, Malaysia
rozaida@usm.my

Jong Hui Ying
Malay Linguistics Section, School of Humanities, Universiti Sains Malaysia
Pulau Pinang, Malaysia
ivy_jhy@hotmail.com

Faraj Al-Marri
Department of Neuroscience
King Faisal University
Al-Ahsa, Saudi Arabia
dr.almarri_777@hotmail.com

Faruque Reza
Department of Neurosciences
Universiti Sains Malaysia
Kota Bharu, Malaysia
faruquereza@gmail.com

***Abstract*— Language is one of the intelligent categories of cognitive function comprised grammar, syntax, formation, composition of phrases and sentences. Syntactic language processing with Wh-related questions are more complicated sentence pattern where difficulties might appear in specific groups to comprehend. However, we have investigated the neural correlates of syntactic Malay language processing among a group of women where the subjects would respond by pressing buttons in order to match the several binary visual pictorial stimuli with Wh-questions. There were simply two types of Wh-questions in this study, w*ho subjects questions* and w*hich object questions*. A high dense EEG sensor net was used to record the Event Related Potentials (ERP). N400 ERP component was extracted and analysed. Higher amplitude of N400 component was found significantly in the right hemisphere of the temporal - parietal region during *which object question* response indicating lateralized integrated semantic information and memory processing in the brain. To extend and compare this outcome, further work in the specific language impairment group and in the pregnancy group is our future plan.**

Keywords—Wh-questions, N400, Language processing, pictorial visual stimuli

I. Introduction

Pictorial pictures are used widely in Psychology to assess the central processing of language, attention and memory by manipulating pictures [1]. Studies regarding emotional experience aspects usually focus on one stimulus modality such as verbal or pictorial, shown the activation of the limbic and paralimbic areas (hippocampus, visual cortex, insula, anterior cingulate, amygdala and medial prefrontal cortex), proven that pictorial stimulus could elevate emotional responses [2]. Among cognitive and stimulus-response (S-R) theories of learning, according to Klinger et al. (2000) [3] and Damian (2001) [4], S-R learning can be used to explain response activation based on a direct association between the prime and the response [3, 4]. In a few studies, priming was found more robust for familiar primes than unfamiliar primes [3, 5, and 6]. On the other hand, Electroencephalography (EEG) /Event Related Potentials (ERP) are the changes in the ongoing electrical activity of the brain caused by certain occurrence of a cognitive, perceptual or motor event. Any changes in EEG due to the demands of the task are amplified, averaged, and extracted as ERP waveforms. These changes, determine which parts of the brain are being stimulated at a given time and which parts involved in a given process. ERPs can help in defining the time course of the activation during a given mental task involving perception, memory and selective attention; proceed over time ranges in the order of tens of milliseconds which make it a suitable methodology for studying the aspects of cognitive processes of both normal and abnormal nature of neurological or psychiatric disorders [7]. ERP components cannot be recognized from the raw EEG trace since the amplitudes are much smaller than spontaneous EEG components, thus they need to be extracted from a set of single recordings from digital averaging of epochs or recording periods of EEG time-locked to repeated occurrences of sensory, motor or cognitive events [8]. The ERP thus reflects the patterns of neuronal activity evoked by stimuli. One of the ERP components, N400, was found related to semantic processing of linguistic material [9]. N400 has been widely used in psycholinguistic research to prove the instantaneous effects of semantic manipulations into the processing of a critical word. Thus, in this study, N400 component was chosen as a marker to investigate the syntactic language processing during visual semantic task using high dense EEG recording among a group of healthy women.

II. Methods

A. Ethics and recruitment of participants

After receiving human ethical approval from the ethical committee of Universiti Sains Malaysia (USM), 10 Malay participants (31.06 ± 4.32 years old) were recruited through notice board advertisement, internet and personal communication. All participants gave their written informed consent before starting ERP experiments and the experiment was conducted in the Laboratory for MEG/ERP laboratory at Hospital Universiti Sains Malaysia (HUSM).

B. Experimental paradigm

This study used visual pictorial stimuli to test the syntactic processing by recording the amplitude and latency of N400 within the group with the application of E-Prime software along with EEG/ERP. A total number of 40 sentences were used in this study, consisting of simplex and complex Wh- questions. Simplex questions consist of 20 *who* subject questions (SS) while complex questions consist

of 20 *which* object questions (OM, Object Marker) and were presented to the subjects as shown in Fig. 1.

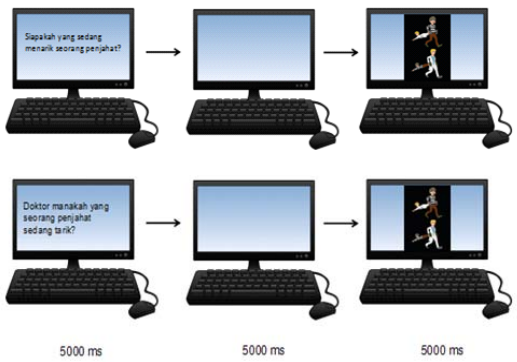

Fig. 1. Block diagram of algorithm shows the visual pictorial stimuli during SS and OM. The sentence in a form of who question, "Siapakah yang sedang menarik seorang penjahat?", (Upper panel, SS) and the sentence in a form of which question, "Doktor manakah yang seorang penjahat sedang tarik?" (Lower panel, OM) appeared on the computer screen for 5000 ms, then inter-stimulus interval (ISI) for 5000 ms before the next stimuli, the subjects were required to push button '1' for upper picture or '2' for lower picture within 5000 ms in order to match the questions.

III. Data analysis

The data were recorded using the Geodesic EEG System (EGI) software and were analyzed using the EEG tools in the software. Fig.2 shows the steps of data analysis. The statistic extracted from the EEG was then analyzed using IBM SPSS Statistics 24. Since the sample size is small, non-parametric Wilcoxon signed-rank test or non-parametric paired t-test was used to compare the amplitude and latency of N400 during OM and SS tasks.

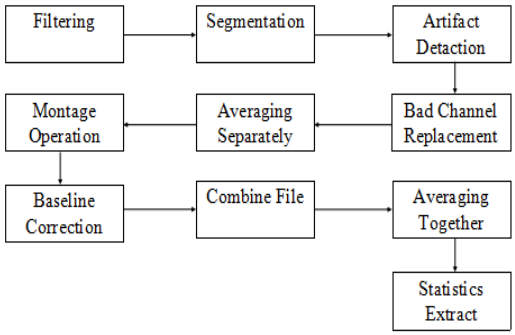

Fig.2. Data Analysis algorithm for extraction of N400 ERP component.

IV. Results

A. *N400 Amplitude during OM and SS*

Table I below shows the mean of N400 amplitude during OM and SS in the group (n = 10). The significantly higher N400 amplitude was found at the T4 channel site (p = 0.017).

TABLE I. N400 amplitude during SS and OM tasks

Site	OM		SS		*p*-value
	Mean	SD	Mean	SD	
Fp1	0.56	0.45	0.71	0.32	.333
F3	0.28	0.47	0.23	0.64	.799
F7	0.21	0.73	0.43	0.55	.169
Fp2	0.44	0.44	0.36	0.64	.878
F4	0.23	0.51	0.24	0.50	.646
F8	0.15	0.66	0.37	0.46	.646
C3	0.48	0.43	0.30	0.49	.386
C4	0.45	0.38	0.31	0.37	.169
T3	0.41	0.24	0.33	0.42	.646
T4	0.35	0.39	0.21	0.42	*.017**
P3	0.57	0.43	0.46	0.39	.575
T5	0.47	0.38	0.09	0.63	.333
P4	0.54	0.41	0.33	0.57	.285
T6	0.45	0.44	0.37	0.43	.575
O1	0.51	0.62	0.53	0.57	.799
O2	0.48	0.59	0.40	1.07	.721
Fz	0.46	0.40	0.38	0.47	.799
Cz	0.32	0.43	0.41	0.62	.799
Pz	0.49	0.53	0.46	0.83	.799

**significant*

B. *N400 Latency during OM and SS*

Table II below shows the mean of N400 latency during OM and SS in the group (n = 10). No significant difference of N400 latency was found at any channel sites.

TABLE II. N400 latency during SS and OM tasks

Site	OM		SS		*p*-value
	Mean	SD	Mean	SD	
Fp1	446.0	96.45	464.8	85.95	.878
F3	440.8	90.31	400.4	66.22	.262
F7	417.6	71.66	401.6	64.94	.508
Fp2	412.8	93.42	426.4	99.92	.878
F4	400.4	76.35	434.8	97.36	.508
F8	388.4	90.16	402.0	95.48	.721
C3	428.4	87.26	453.6	61.69	.284
C4	427.6	90.46	482.0	97.82	.475
T3	468.0	88.42	458.4	79.98	.760
T4	491.6	123.57	436.4	108.75	.285
P3	467.2	107.31	495.2	104.37	.594
T5	469.2	92.65	495.2	115.74	.508
P4	501.6	102.96	561.6	85.61	.173
T6	469.6	111.29	518.8	104.05	.263
O1	455.6	103.13	486.0	132.32	.333
O2	474.0	116.96	524.8	107.18	.508
Fz	450.4	96.19	421.2	93.81	.109
Cz	451.6	88.61	458.4	109.27	.799
Pz	490.8	107.83	508.4	116.61	.721

V. Discussion

We proposed to measure the amplitudes and latencies of the N400 ERP components using pictorial stimuli in syntactic Malay language processing using simplex (SS session: subject-subject) and complex sentences (OM session: object marker) in a group of normal healthy women. Our results revealed that a tendency of higher N400 amplitudes was observed at right hemisphere of temporal and parietal region during *which* object question stimuli. The determination is nearly consistent with the previous study that N400 ERP component is the stimulus-related brain activity between 200 ms to 600 ms, a negativity peaking around 400 ms, bias at the right hemisphere over Centro-parietal sites, for written words [10]. According to Kutas & Federmeier (2000) [10], N400 ERP component is specifically sensitive to semantic or association of meanings. Other researchers also used N400 component as a marker in studies involving attention, language (auditory and visual language), semantic memory (words, pictures and meaningful stimuli) and recognition memory [10, 11, 12 13]. Luck & Kappenman (2012) [11] as well stated that the N400 is a component that response to words and other meaningful stimuli, including auditory words and visual, sign language, faces, environmental, pictures and smells. However, the information about this study may guide us in finding the exact neuronal network processing which could be beneficial for the therapeutic/rehabilitation purpose to improve the cognition among impaired groups especially in syntactic processing.

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