Original article:

Auditory Cognitive Function Assessment during Pregnancy: An Event-Related Potential and Neuropsychological Study

Tahamina Begum[1], Faruque Reza[2]

Abstract:

Objectives: We investigated the auditory cognitive and behavioral functions during 2nd and 3rd trimesters of pregnancy using event-related potentials (ERPs) and different neuropsychology tests, respectively. ***Methods:*** The ERPs were studied by using a 128-sensor net, and PAS/COWA, WCST, ZCT, RAVLTIM/RAVLTDR/RAVLTTS, and BDI were tested for neuropsychology assessment. Total 39 subjects were recruited for control group (G1, n=15, non-pregnant), 2nd trimester group (G2, n=12, 13-26 weeks gestation), and 3rd trimester group (G3, n=12, 26-40 weeks gestation). Auditory oddball paradigm was used during ERP study. Subjects silently counted only the target stimuli with attention by ignoring standard stimuli. Value of the mean differences of the target and standard stimuli were measured across groups in 10-20 electrode systems. ***Results:*** The P50, N100, and P300 ERP components were analyzed. The G3 (at F7 and C3) and G2 (at T4) groups evoked the highest significant amplitudes in P50, and G3 (at Cz and Pz) and G1 (at F8 and T4) evoked the highest significant amplitudes of N100 with significantly prolonged latencies at Cz and O1 (in G1) and F8 (in G2). However, significantly higher amplitudes of P300 were found at Fz (in G3) and FP1 (G2) (G2>G3). On the other hand, neuropsychology tests revealed that G2 possessed the highest significant score in WCST and G1 in ZCT. The G3 performed poorly in all tests. ***Conclusion:*** We concluded that pregnant groups performed better in auditory (attention/memory) and executive function assessment. Moreover, the 2nd trimester group has better auditory cognitive function compared to the 3rd trimester group due to the effect of hormonal changes during pregnancy, which might be a positive influence during the pregnancy period.

Keywords: Pregnancy; Event Related Potential; Neuropsychology tests; Standard and target stimuli.

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Introduction:

Pregnancy:

Pregnancy is a normal physiological condition among women with three stages of fetal development, known as trimester stages, namely first (1st-12th weeks), second (13th-26th weeks) and third trimesters (27th-40th weeks)[1]. Executive functions and neuronal activities change due to fluctuations of gonadal steroid hormones, like estrogen, progesterone, and testosterone, throughout the pregnancy period[2,3]. Poor memory[4], less attention[5], extreme anxiety and depression[6,7] was observed during pregnancy. Basically, auditory attention is the key factor to develop an executive function that can control mental processing[8]. Therefore, we studied the auditory cognitive function during pregnancy, both subjectively and objectively, as it is less studied and to exclude the effects of anxiety and depression on their cognitive function.

Event-Related Potential:

Event-related potential (ERP) is a non-invasive and safe procedure to record brain signal during

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auditory and visual stimulation/task[9]. Oddball paradigm can catch more neuronal activation during both tasks because participants usually pay more attention during target (odd) stimuli rather than the standard one, and ERP time-locked the responses[10]. The responses of early wave (first 100 ms after stimulation) and late wave (after 100 ms after stimulation) can be recorded during ERP study. The P25, N20, P50, and N100 ERP components are the early components, and P200, N200, P300, N400, and P600 are the late components. 'P' indicates positive peak and 'N' is negative peak for amplitudes. On the other hand, the number after 'P' and 'N' indicates the latencies after stimulation[11]. In this study, we analyzed two early ERP components of P50, N100, and one late component of P300 by using auditory oddball paradigm.

P50, N100, and P300 of ERP components:

The sequences of ERP components vary in latencies, amplitudes, and scalp distributions[12]. The P50 and N100 are exogenous attributes as they are influenced by the physical characteristics of stimuli, independent of cognitive factors, while P300 is an endogenous attribute. The endogenous attributes do not depend on physical stimuli and get influenced by cognitive factors, like attention[13]. Based on the human and animal studies, the P50 ERP component is largely generated by the hippocampus area by providing pre-attention gating to repeated stimulation[14]. Sensory gating protects the brain by preventing overflow of redundant repetitive stimulus[15], thus, explaining the mean difference in peak values between target stimuli and deviant stimuli in oddball paradigm task. Abnormalities of sensory gating are hypothesized as one of the indicators in cognitive impairment[14], like schizophrenia[16]. The auditory N100 is an exogenous component, and it depends on the pitch of the auditory stimulus[17,18]. The N100 is also known as the 'vertex potential' as it has maximum amplitude over Cz compared to other sites[15]. The P300 ERP component has two sub-components, P3a and P3b, that differ by the peak latency. P3a has more frontocentral distribution compared to P3b[12]. However, the polarity, scalp distribution, and latency did not solely reflect the origin of a component; instead, it depends on the difficulty of the discrimination task[18].

Relationship of amplitudes and latencies of ERP components with cognitive function:

Based on previous reports, the interpretation of the amplitudes and latencies of P50 and N100 are variable. The increase in amplitude of N100 and longer latencies were found in low cognitive function in bipolar disorder patients[19]. Schizophrenia patients displayed poor attention, with a smaller amplitude of the N100 component. It is because the small amplitude is related to the low attention to the stimuli. However, a few studies followed different methods in interpreting the amplitude and latencies of these early components. There is a common misinterpretation about early exogenous ERP components, as some researchers did not consider the refractory short inter-stimulus interval duration. Thus, the early ERP components, such as P50 and N100, tend to have small amplitude when the elicited auditory stimulus follows soon after another stimulus[20].This means that the early ERP component was expected to have small amplitude when there was low sensory and perceptual function. Thus, we adapted these studies in our P50 and N100 data interpretation.

Lower amplitudes and longer latencies of P300 ERP component are considered as lack of attention, which is also called mild cognitive impairment. The generators of P300 components are from the frontal, temporal and parietal areas, and these areas are easily evoked by auditory oddball task, where participants can focus more during odd stimuli. On the other hand, difficult task can diminish these areas[21].

Neuropsychology tests and pregnancy:

Few studies were conducted to assess memory and attention during pregnancy, mainly in the 3rd trimester, with different neuropsychology tests. Memory testing during pregnancy was done previously[22], especially to determine memory impairment during last trimester[23]. Some researchers investigated attention during pregnancy, where the results were controversial with attention deficit[24] and no changes of attention[25]. Some general memory and attention tasks were performed in the previous studies to assess attention. Digit span tests (digit span forward: DSF and digit span backward: DSB), resulting during high-risk pregnancy, showed a significant decline in this group compared to the normal uncomplicated pregnancies during DSF condition but not in DSB condition[26].

The different trimesters of pregnancy can make different impacts on cognitive functions[23,27]. Some researchers found no difference in the cognitive changes across all trimesters of pregnancy[28]. Therefore, a new study is needed to investigate the changes in cognitive function not only at mid

trimester but also in the third trimester so that the changes can be further studied and compared.

Neuropsychological tests for assessing cognitive function

The results of neuropsychological tests among pregnant women are different. The Wisconsin Card Sorting Test **(**WCST) was widely used to assess cognitive disorder. Lower WCST score was found in schizophrenic patients who have frontal lobe dysfunction[29]. Studies reported that WCST can assess abstract thinking[29], abstract reasoning and concept formation[30], and also the function of the frontal lobe[29,30]. Pregnant women may have lapse of memory due to cognitive concerns during pregnancy[31], and they are prone to fatigue and sleep disturbances[6]. They also tend to have depression and negative effect. Depression or psychological stress has an impact on the memory of pregnant women[6]. The Zazzo's Cancellation Test (ZCT) is able to measure mild cognitive impairment[32]. In order to assess and measure the cognitive abilities, it was suggested to combine multiple types of neuropsychological tests in the study because different tests have different capabilities of clinical diagnosis. Therefore, seven different types of neuropsychological tests were used to assess cognitive dysfunction in the preclinical phase of dementia. The tests were Mini Mental Status Examination, ZCT, Digit symbol Substitution Test, Benton Visual Retention Test, Wechsler Paired Associates Test, Isaacs Set Test, and Weschler Similarities Test[33].

Significance of this study:

There were mixed and inconsistent findings in the cognitive functions among pregnant women, in which the neuropsychological tests and self-report were not related significantly. Women frequently self-report worse memory during pregnancy and are more likely to have memory complaints than non-pregnant women[31]. However, the self-report is not reliable in clinical diagnosis and identification. Therefore, a combination method of investigation is needed to investigate the cognitive functions among pregnant women. This recent study was done to identify the functions through a combination of objective test (ERP) and subjective tests (neuropsychological tests). On the other hand, the cognitive functions of auditory attention and memory between each trimester can be investigated. As mentioned in the previous literature, late stages of pregnancy tend to have hormonal fluctuations. The progesterone level is higher in pregnant women for the maintenance of the endometrium during early pregnancy, which later grows into a fetus. Besides, the regulation of the hormones allowed for the preparation for child labor in the third trimester stage[34]. Mild deficits of late pregnancy (i.e., third trimester) in attention, verbal, and spatial memory were associated with the fluctuations of estrogen[35]. Hence, through this study, it was worthwhile to know the exact neuronal network processing for therapeutic/rehabilitation purpose to improve the auditory cognition among pregnant women.

The aim of this study is to investigate the amplitudes and the latencies of P50, N100, and P300 ERP components and different neuropsychology tests among subjects with 2nd and 3rd trimesters of pregnancy compared to the normal healthy subjects by using the auditory oddball task.

Materials and Methods:

Study design:

We received human ethical approval from the Ethical Committee of USM (USM/JEPeM/15090294) before starting the experiment. All subjects were recruited through personal communication, internet, and notice board advertisement. This study was conducted in the MEG/ERP laboratory at Hospital UniversitiSains Malaysia (HUSM) by using a 128-electrode sensor net. Written informed consent was obtained from all subjects prior to the experiment. The subjects underwent ERP experiment and neuropsychological tests and were assessed by a clinical neuropsychologist.

Study populations and groups:

The study population was calculated by a statistician using Power and Sample Size software. There were three groups: control healthy subjects (non-pregnant, G1), 2nd trimester pregnant group (G2), and 3rd trimester pregnant group (G3). The numbers of subjects were, G1=15, G2=12 and G3=12. We did not add the 1st trimester of pregnancy due to vulnerability.

We excluded the subjects suffering from major diseases like hypertension, diabetes, and kidney diseases[36,37] and who had a history of drug and alcohol abuse[38] as these factors can affect the cognitive functions. All women in these three groups were age-matched (20-40 years)[39] and education-matched (higher than SijilPelajaranTinggi Malaysia; Malaysian education system) as lower education

reflected lower cognitive function like attention[40].

Event-Related Potential:

ERP Recording

The electrolyte solution was made using 11 mg potassium chloride (KCI), 5 ml Johnson Baby shampoo, and 1 L of distilled water. The 128 ERP sensor net/cap was soaked in this solution for 10 min. The sponge of the electrode in the net absorbed the electrolyte solution and helped to reduce impedance during recording. Impedance was set at <50 KΩ.

ERP procedure (Experimental paradigm)

E-Prime v 2.0 software (Psychology Software Tools, Inc, Sharpsburg, Pennsylvania, USA) was used for the presentation of stimuli, timing operations, and data collection. Each subject sat in a dimly lit room with headphone placed on both ears, wearing the 128-electrode sensor net. In the auditory oddball paradigm, all participants counted target tones (60 dB sound pressure level (SPL), which was low frequency (20%) and high pitched (2000 Hz)) silently while ignoring standard tones (60 dB SPL, high frequency (80%) and low pitched (1000 Hz)). Tone duration was 100 ms with a rise/fall time of 10 ms. All data were recorded on Net-Station software 5.2 (Eletrical Geodesics, Inc, Eugene, OR, USA). The ERP component of latencies and amplitudes of P50, N100, and P300 were analyzed.

Neuropsychological tests

Subjects were assessed based on different types of neuropsychological tests, such as Controlled Oral Word Association (COWA or PAS), WCST, ZCT, Rey Auditory Verbal and Learning Test (RAVLT), and Beck Depression Inventory (BDI).

Controlled Oral Word Association

The COWA or PAS test is also known as the "Verbal Fluency Test". It consists of the task of naming a word for the alphabets P, A, and S. The three set of letters made it known as the PAS test[41]. This test requires subjects to mention verbally as many words as possible starting with letters P, A, and S in one minute based on the category of the words, such as animals, fruits, and furniture and excluding proper names and numbers[42]. The sum of correct words was scored and adjusted based on age, sex, and education. Any word errors or repetitions were also calculated for the scoring.

Wisconsin Card Sorting Test

The WCST can assess the executive function[43], and it is a specific test for frontal lobe dysfunctions[29,43]. Four different cards are placed before the subjects. The cards have different features of color (i.e., red, green, blue, or yellow), form (i.e., circles, stars, squares, or crosses), and number (i.e., 1, 2, 3, 4). The subjects need to sort and match the cards according to the specific features and goals, as instructed by the researcher during the test. Throughout the test, the matching rules are changed after 10 successive matchings. Meanwhile, the researcher gives out scores for each error and correct matching in the test. In this test, the error rate is the main score for the subjects/patients.

Zazzo's Cancellation Test

This is a visuospatial perception test, including selective attention and response speed to particular tasks[44,45]. The subjects are required to cross out particular target sign on the sheet of white paper containing a number of signs. Then, the scores are calculated based on the number of signs that were correctly crossed out (ZCTtot) and the time taken to complete the task (ZCTtime). Impaired performance signifies lower scores.

Rey Auditory Verbal and Learning Test

The RAVLT is a well-known test to evaluate the ability of encoding, combining, storing, and recovering verbal information at different stages of immediate memory[46]. During this test, the researcher will read out 15 noun words from list A to the subjects at the timing rate of one word per second. Then, the subjects are required to recall as many words as possible. The procedure is repeated for 5 trials and the scores are averaged into one score based on the 5 trials. Then, 15 new noun words from list B are presented to the subjects, which acts as interference. Then, the subjects need to recall the maximum possible nouns from list A. This step is carried out to evaluate the delayed recall, immediate recall, and long recall of memory[46,47].

Beck Depression Inventory

The BDI intended to determine the severity and intensity of depression symptoms[48]. The evaluation is based on the rating scale of 21 specific items, and the scale ranges from 0 to 3. Individuals with a clinical diagnosis of depression will be assessed and scored differently than the general population. For the general population, a score of 21 and above is associated with depression while for those clinically diagnosed with depression have 3 stages of scores. Those with 0 to 9 represent minimal depressive

symptoms, 10 to 16 is mild depression, scores of 17 to 29 indicate moderate depression, and severe depression scores range from 30 to 63. The benefit of this test is that majority of people can finish it in five to ten minutes as long as the environment is suitable for the subjects to concentrate[48].

Data analysis:

The ERP data were analyzed using EGI Net Station 5.3 Software. Filtering was 0.3-50 Hz with 0.5 as the stimulus rate. Segmentation was 100 ms before the stimulation and 1000 ms after the stimulation. Artifacts, such as eye blink, eye movements, and movement artifacts were removed using the artifact detection tools in Net-Station Software. The artifacts were removed by notch filter setting that filtered out eye blink (> 200 μV), eye movement (70 μV), and bad channels (>400 μV). Baseline was corrected to 100 ms before the stimulation[49,50].

The amplitudes and latencies of P50, N100, and P300 ERP components on 19 channels of electrodes were extracted from Net Software Station. To know the significant value among groups, data from ERP and neuropsychology tests were analyzed using Statistical Package for the Social Sciences 22 (SPSS22) software, using one-way ANOVA analysis. The significance level, *p*-value, was set as $p \leq 0.05$. Further, ANOVA post hoc Bonferroni test was conducted to identify the mean differences between groups[49,50].

Ethical clearance: This research study was approved by ethics committee of School of Medical Sciences, Universiti Sains Malaysia, Kubang Kerian 16150, Kota Bharu, Kelantan, Malaysia.

Results:

Socio-demographic profile:

Age- and education-matched married women were recruited for G1 (n=15), G2 (n=12), and G3 (n=12) groups. Their mean ages (mean± SD) were 32.59±3.75 years, 27.19±2.92 years, and 27.89±4.57 years, respectively. Mean (SD) years of education were 16.57 (1.74) years, 15 (2.13) years, and 16.92 (3.68) years, respectively.

Results of ERP components:

Nineteen electrode channels were analyzed in 10-20 systems. The values of the mean differences of standard and target stimuli for the three groups were measured for the amplitudes and latencies of the P50, N100, and P300 ERP components. Only the significant changes at some electrodes were found for all three ERP components (Table 1). Grand average waveforms of the P50, N100, and P300 ERP components for G1, G2, and G3 groups were shown in Figure 1.The waveforms were shown only at the significant electrode sites.

Figure 1: Grand average waveforms of P50, N100, and P300 ERP components of some electrode channels were shownamong groups.Standard stimuli are in blue color, and target stimuli are in red color.

Three electrodes F7, C3, and T4 showed significant differences among groups for the amplitudes of the P50 ERP component. The G3 group evoked the highest amplitudes at F7 (G3> G1 >G2) (p=0.034), C3 (G3> G1 >G2) (p=0.034) locations. On the other hand, G2 group induced the highest amplitude at T4 (G2> G3 >G1) (p=0.031) electrode site. The group effects at F7, C3, and T4 were F(*df*)= 3.660(*2,36*), F(*df*)= 3.679(*2,36*) and F(*df*)= 3.797(*2,36*), respectively. There were no significant differences for the latencies among groups for P50 component (Table 1).

Table 1: The significant amplitudes and latencies of the P50, N100 and P300 ERP components were shown among groups

Areas	FP1	F7	F8	C3	T4	Fz	Cz	Pz	O1
P50 amplitude (in μV). Mean (SD)		G1:1.11 (0.65) G2:1.05 (0.60) G3:1.71 (0.85) G3>G1>G2		G1:0.86 (0.32) G2:0.76 (0.39) G3:1.12 (0.32) G3>G1>G2	G1:0.72 (0.36) G2:1.36 (1.07) G3:0.81 (0.28) G2>G3>G1				
N100 amplitude (in μV). Mean (SD)			G1:1.28 (0.72) G2:0.53 (0.72)G3:0.73 (1.07) G1>G3>G2		G1:1.16 (0.47) G2:0.53 (0.79)G3:0.68 (0.67) G1>G3>G2		G1:0.63 (0.86) G2:1.42 (1.07) G3:1.69 (1.03) G3>G2>G1	G1:0.67 (1.07)G2:1.63 (1.42)G3:2.30 (2.52) G3>G2>G1	

Areas	FP1	F7	F8	C3	T4	Fz	Cz	Pz	O1
P300 amplitude (in µV). Mean (SD)	G1:4.25 (3.92) G2: 8.28 (4.52) G3:7.85 (3.48) G2>G3>G1					G1:3.03 (2.45) G2:5.09 (3.21) G3:5.87 (2.73) G3>G2>G1			
N100 latency (in ms). Mean (SD)			G1:89.50 (21.21) G2:114.25 (26.21) G3:107.67 (27.68) G2>G3>G1				G1:129.50 (15.45) G2:100.25 (25.94) G3:105.00 (26.32) G1>G3>G2		G1:121.75 (22.91) G2:95.75 (25.74) G3:110.33 (25.95) G1>G3>G2

Total four electrode locations (Cz, Pz, F8, and T4) showed significant differences among groups for the amplitude of N100 component. The G3 group induced the highest amplitudes at Cz (G3>G2>G1) (G3/G1, p=0.017) and Pz (G3>G2>G1) (G3/G1, p=0.048) areas. The group effects were F(*df*)= 4.542(*2,36*), F(*df*)= 3.269(*2,36*), respectively. On the other hand, G1 evoked the highest amplitudes of N100 at F8 (G1>G3>G2) (G1/G2, p=0.039) and T4 (G1>G3>G2) (G1/G2, p=0.026) areas. The group effects were F(*df*)= 3.503(*2,36*) and F(*df*)=4.005(*2,36*), respectively. In case of N100 latencies, Cz, F8, and O1 showed significant values among groups. The G1 group evoked prolonged latencies at Cz (G1>G3>G2) (G1/G2, p=0.002) and O1 (G1>G3>G2) (G1/G2, p=0.018) locations. The G2 group possessed the longest latency of the N100 component at F8 (G2>G3>G1) (G2/G1 (p=0.022) area. The group effects for Cz, O1, and F8 were F(*df*)= 7.408(*2,36*), F(*df*)= 4.415(*2,36*), F(*df*)= 4.178(*2,36*), respectively (Table 1).

The highest significant amplitudes of the P300 ERP component were revealed at Fz (G3>G2>G1) (G3/G1, p=0.028) and FP1 (G2>G3>G1) (G2/G1, p=0.015) electrode locations. The group effects were F*(df)*=3.925*(2,36)* andF*(df)*=4.625*(2,36),* respectively. Comparing G2 (at FP1) and G3 (at Fz) of P300 amplitudes, G2 evoked the highest amplitude (8.28±4.52 µV) compared to the G3 (5.87±2.73 µV) group. There were no significant differences in P300 latencies among groups (Table 1).

Results of neuropsychology Tests:

The scores of neuropsychological tests among groups were given in Table 2. WCST and ZCT showed significant differences among groups. G2 group revealed the highest significant scores in WCST (p=0.001), followed by the scores in ZCT test. G1 group had the highest significant scores in ZCT (p=0.001). G2 group revealed highest scores in ZCT, but lowest scores in WCST tests. The group effects for WCST wereF(*df*)=843.776(*2,36*) and for ZCT were F(*df*)=528.598(*2,36*). No significant difference was found in PAS, RAVLT, and BDI test scores among groups (Table 2).

Table 2: Table 2showed the scores of different neuropsychological tests among groups as mean (SD).

PAS	WCST	ZCT	RAVLTs	RAVLTim	RAVLTdr	BDI
G1:41.50(9.95)	G1:2.14(1.41)	G1:27.50(1.95)	G1:50.93(6.31)	G1:5.29(2.61)	G1:17.00(6.86)	G1:8.00(7.11)
G2:45.58(7.41)	G2:1.58(1.83)	G2:26.75(2.90)	G2:58.00(19.99)	G2:7.83(3.97)	G2:13.00(6.45)	G2:8.58(8.17)
G3:45.00(11.64)	G3:2.42(1.73)	G3:26.42(2.27)	G3:56.33(11.06)	G3:7.08(2.27)	G3:16.67(13.46)	G3:8.17(5.78)
G2>G3>G1	G2>G1>G3	G1>G2>G3	G2>G3>G1	G2>G3>G1	G1>G3>G2	G2>G3>G1

Discussion:

The aim of this study was to investigate the cognitive functions, like auditory attention and memory among pregnant women in the 2nd (G2) and 3rd trimesters (G3) of pregnancy by comparing them with non-pregnant women (G1), the control group. Amplitudes and latencies of the P50, N100, and P300 ERP components were analyzed among groups using auditory oddball task in ERP study. The ERP components of P50, N100, and P300 are the

reflection of sensory gating, auditory perception, and attention, respectively. We assessed the executive function and auditory memory function using five different tests such as WCST, ZCT, RAVLT, COWA or PAS/FAS, and BDI. The 3rd trimester group (G3) evoked significantly highest amplitudes for P50 (at two areas), N100 (at two areas) and P300 (one area) ERP components. The 2nd trimester group (G2) possessed significantly highest amplitudes for the P50 (at one site) and P300 (at one site) and also significantly prolonged latency at one site for N100 ERP component among groups. However, control (G1) group evoked significantly highest amplitudes at two sites and prolonged latencies at two sites also. G2 group had the highest significant scores in WCST, whereas G1 group had the highest ZCT scores. On the other hand, G3 group revealed poor scores in both WCST and ZCT.

P50 ERP component

The interpretation of amplitudes and latencies of both the P50 and N100 ERP components is opposite from the P300 component. As mentioned, higher amplitude reflects poor performance in case of P50 and N100 components, but in the case of P300, it reflects higher performance[51].

There have been no studies on the P50 ERP components of the pregnant group. Few studies were conducted only to get more information about this component. The P50 ERP component conveys the flow of auditory information from the thalamus to the auditory cortex of the brain, which is important for the detection of sensory gating process of the stimuli[52]. Moreover, this component is the pre-attentive arousal of stimuli[53]. Higher amplitudes of P50 ERP component were found in Alzheimer's patients, diagnosed as a mild cognitive impairment[51]. In our study, we found that the 3rd trimester pregnant group (G3) had the highest significant amplitudes in two electrodes (F7 and C3) and the 2nd trimester pregnant group (G2) had the highest significant amplitude of P50 component in one area (T4) (Table 1). There were no significant differences in latencies among groups. Therefore, based on the results of P50 amplitudes and taking the result from Golob et al., (2007)[51], we assume that the 3rd trimester pregnant group has mild cognitive impairment and poor sensory gating.

N100 ERP component

The interpretation of the amplitudes of N100 is the same as for the P50 ERP component, but no clear interpretation has been made for N100 latency. The N100 ERP component reflects the auditory perception. Higher amplitude of the N100 component reflected the poor developmental perception of the auditory system[54]. One study found a higher amplitude of the N100 component in alexithymic subjects, and they interpreted that they have impairment of auditory perception[55]. In our study, the 3rd trimester pregnant group revealed highest significant amplitudes in two electrodes (Cz and Pz), and the control group had the highest significant amplitudes in another two electrodes (F8 and T4). The longest significant latencies were found in the control group in two areas (Cz and O1), and one area (F8) reflected significant longer latency in the 2nd trimester group (Table 1). Taking the points from the previous interpretations[54,55], we can say that the 3rd trimester pregnant group has poor auditory perception.

P300 ERP component

Studies have proved that the P300 ERP component is the marker to diagnose cognitive impairment[56,57,58]. Lower amplitudes and longer latencies of the P300 component indicated mild cognitive impairment in the spinocerebellar ataxia type 2 (SCA2) patient groups[59], in old ages[60], and in Alzheimer diseases[61].In our study, we found that the pregnant group evoked the highest significant amplitudes at two electrodes, Fz and FP1, compared to the control group. Within pregnant groups, the 2nd trimester pregnant group evoked higher (8.28±4.52 μV) P300 amplitude at FP1 area compared to the 3rd trimester pregnant group at Fz area (5.87±2.73μV) (Table 1). Therefore, we interpreted that during the 2nd trimester, pregnant women have better cognitive function/attention compared to the 3rd trimester and control group. A little shorter amplitude of P300 in the 3rd trimester pregnant group suggested that attention might increase during pregnancy but can be reduced during the 3rd trimester nearer to childbirth [27,56].

Neuropsychological tests

To evaluate the cognitive function among the pregnant groups, we need several types of neuropsychological tests to evaluate various cognitive functions; for example, attention, memory, executive function, and speed process. Cognitive functions cannot be evaluated with one test. The Concept Shifting Test, the Stroop Color Interference Test, the Letter Digit Substitution Test, and Visual Verbal Word Learning Task were carried out in the pregnant groups to evaluate their cognitive functions like attention,

memory, and speed of processing. Pregnant groups showed poorer performance in all the tests compared to the control group[28].

Here, we performed WCST, ZCT, PAS, RAVLTim, RAVLTdr, RAVLTts, and BDI neuropsychological tests in pregnant (2nd and 3rd trimesters) and control groups. Both WCST and ZCT showed significant differences among groups and explored the executive function. The highest significant WCST scores were found in the 2nd trimester group. Control group possessed the highest significant ZCT scores among groups. The 3rd trimester pregnant group scored poorer in all tests compared with the 2nd trimester group (Table 2). The poor scores in the neuropsychology tests may be due to the hormonal effect[34]. We clarified the scores of the neuropsychology tests among the groups in our study. In our study, we assumed that the pregnancy hormone progesterone is responsible for a better executive function and auditory memory/attention in the 2nd and 3rd trimesters of pregnancy, which might be reduced in the 3rd trimester of pregnancy.

Conclusion:

We studied the auditory cognitive function and behavioral tests among pregnant women using the ERP study and neuropsychology tests. The 2nd trimester pregnancy group showed better auditory attention than the 3rd trimester pregnant group. Although the 3rd trimester pregnant group was advocated to have mild cognitive impairment compared to the 2nd trimester group, it does not significantly affect the daily life of our subjects as the 2nd trimester pregnancy group still has a better auditory cognitive function and executive functions compared to the control group. The mild cognitive impairment found among the 3rd trimester group in this study may benefit psychologists, neurologists, and obstetrics to plan rehabilitation and assessment for future mothers in order to help them improve their cognitive function throughout the pregnancy.

Limitations:

1. The sample size of this study was small. We need a large sample size to get more reliable results.
2. The 1st trimester pregnancy group is not included as this trimester is vulnerable.

Authorship Contribution

TB and FR performed data acquisition, analyses, and interpretation and wrote the manuscript.

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