Measure Projection Analysis of VEP Localization Neuron Generator

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***Abstract*—Measure Projection Analysis (MPA) method based on EEGLAB and Matlab Toolbox is used to analyze the projections of brain signal sources that are responsible for the measured potentials at the scalp electrodes. These projections are based on probabilistic multi subject algorithm abandoning the notion of distinct independent component clusters. It examines voxel by voxel for brain regions having event related independent components process dynamics that exhibit statistically significant consistency across subjects by probability density representation. Neuron source locations are responsible in generating current in different brain regions through the measured potentials. The projections of visual evoked potentials (VEP) sources in different age groups are investigated. The result shows a slight difference in the projections with respect to the age. These findings represent the maturity level and re-grasp the development of brain and visual pathway with age.**

Keywords—VEP; EEG; MPA; measure projection analysis; localization.

I. INTRODUCTION

Since the first introduce of electroencephalogram (EEG), most researchers rely on identifying scalp channels analysis of all subjects and trails [1]. The responses from channel analysis may include non-brain response activity from a specific electrode position and may introduce interference between electrodes responses. This practice is not really accurate; instead, many algorithms are applied to overcome this problem. The common method is by decomposing the EEG signal to its independent components using independent component analysis (ICA) algorithm and followed by clustering the matched components to extract responses. One of the most interesting application of clustering is to fit and investigate the dipoles by fitting dipoles of different components of different subjects and finally localize event related potentials (ERP) responses [2, 3].

The most recent method introduced was measure projection analysis (MPA) of multi subject or multi session analysis of EEG [4]. MPA statistically characterize the spatial consistency of EEG dynamics across a set of data records by combining the information across large number of subjects associated with its own set of sources and scalp projections [4]. This method has demonstrated and applied on first application of MPA to EEG datasets collected in a visual task and decomposed separately using extended infomax algorithm of ICA [5]. Even MPA method are not highly sensitive to the chosen parameters but still provide statistically significance values with fewer parameters applied to surrogate data derived from rapid visual serial presentation (RVSP) tasks compare to clustering method[4].

Visual evoked potential (VEP) is important brain response to focus on due to its clinical applications [6], but most of the age related works rely only on differentiating between changes in latency and amplitude of VEP responses based on channel analysis [7] and do not consider independent components and different dipole sources. The aim of this research is to compare VEP responses of different age groups and investigate the maturity level of brain by studying the neuron sources generator of VEP response using MPA.

II. METHOD AND MEASUREMENT

A. VEP Participants

Selected 34 male participants were volunteered as subjects for the VEP tasks recordings. The subjects were healthy with no history of visual, neurological and psychological diseases. They were divided into two age groups; first, between 7 to 17 years old (young group) and second, aged between 22 to 30 years old (mature group). Most subjects were right handed and all have normal or corrected to normal visual acuity tested using Snellen Chart. The subjects were instructed to sit comfortably on a chair with a fixed distance from the monitor and were reminded to avoid any physical movements such as head or body movement as well as not to yawn or bite to prevent from unwanted muscular artifacts elicited with the useful EEG signal. A standardized recording scheme was developed. Every subject should perform the tasks in a fixed and repetitive pattern according to the scheme displayed on the monitor.

B. Signal Measurement

The data collected using commercial KT88-2400 system (Digital EEG Topography). The impedance matching of each electrode was monitored with the help of LED indicators. Electrodes positions were distributed using 10-20 electrodes system as recommended by [9]. The right and left hemispheres were referenced to the right and left earlobes (A1, A2) respectively and grounded to the forehead (A). The data was digitized at 200 Hz sampling frequency, and filtered using band pass filter with 1-35 Hz frequency band. Checkerboard pattern stimulation was used to evoke the brain to generate the response. The recorded data was saved onto the hard disc for further processing. For each subject, the data was recorded from 19 electrodes (Fp1, Fp2, F3, F4, F7, F8, Fz, T3, T4, C3,

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C4, Cz, T5, T6, P3, P4, Pz, O1, O2). Phase locked averaging for groups of data were performed, followed by ICA and finally clustering the matched components in order to measure the projection and to localize the sources.

C. Measure Projection Process

MPA started by computing the location of each source independent component resulted from ICA decomposition on the brain template model in the form of equivalent dipole source followed by smoothing of these dimples locations using 3-D Gaussian spatial kernel model. Similarities between local independent components were measured in the subspace of brain voxels locations. Finally, affinity clustering is used to identify brain domains that have sufficient difference in the brain subspace[4], as summarized in Fig. 1. Measure Projection Toolbox an extension to EEGLAB, allows the user to display graphically the domains in different patterns. It also gives a summary of anatomical location with Brodmann area.

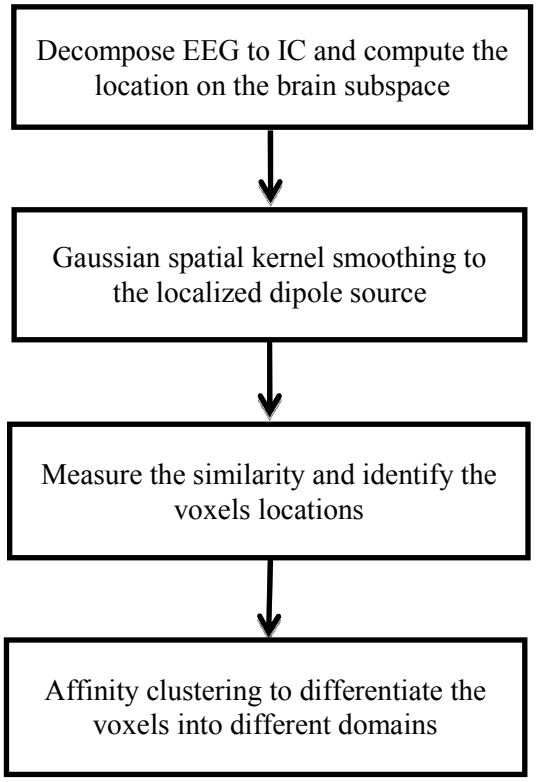

Fig. 1. Measure projection processing.

III. RESULT AND DISCUSSION

A. VEP Response

The brain signals from two groups (young and matured) were analyzed using EEGLAB. The VEP responses were extracted from background noise by time lock averaging (grand average) to the entire channels as suggested in [8].

Fig. 2 shows the VEP response recorded from the occipital electrode. The P100 exhibit a prominent peak indicated that, relatively little variations between subjects for each group, within subject interocular difference, and with repeated measurements over time. P100 peak time is affected by non-pathophysiologic parameters such as pattern size, pattern contrast, mean luminance, signal filtering, patient age, refractive error, poor fixation, and miosis.

The VEP peaks at 100ms clearly reflect after the onset of the visual stimulation which is called P100 as previously reported. Another peak which appear prior to P100 at around 75ms is called N75. According to ISCEV 2010 standard[6], appends to P100 is a late negative peak appear at latency 145ms which is called N145. The delay or even absence of this peak is normally due to the characteristics of stimulus parameter and the variability of wide number of subjects as well as number of trials. Researcher believe that the N75 wave originated mainly from the activity of the foveola, whereas the more eccentric regions contribute more to the formation of P100, and the interaction of both regions elicited the late response after 145ms [9]. Decreasing pattern stimulation frequency from the ubiquitous 2Hz to 1Hz usually will convert the morphology of VEP from "W" wave shape into a conventional P100 peak. This is fully agree with the result since the P100 peak is clearly appear but relatively absence of the other peaks. Check size and alternation rate is the main factor and by changing these parameters one can obtain "W" or a conventional P100 response[9].

The brain topography was also plotted and its clearly shown that, the activation power is much higher and concentrated in the occipital lobe. The P100 responses are matched in both hemispheres and no significant difference in the amplitude and latency. On the other hand there is obvious difference based on the age group. P100 peak is much greater in the young age group as compared to the matured age group. This reflects the changes and development in the brain, scalp and visual pathway. At early age of less than 3 years, the VEP response change repeatedly as reported in [7]. The amplitude and speed of VEPs only remains stable after 6 years old [7]. The brain reaches 90% of adult size as early as 6 years. Preadolescence is the period when the brain is relatively the largest as compared to skull, scalp and muscle thickness. Therefore, at the age of about 7-8 years, the amplitude of the matured P100 will be at the highest.

As children enter adolescence and matured these tissues thicken and therefore, attenuating the brain's signal as recorded from the overlying scalp. Thus, VEPs only reflect the integrity of the primary visual pathways from eye to primary visual cortex which include (photoreceptors in the retina, optic nerve, optic chiasm, optic tract, lateral geniculate nucleus (LGN), optic radiations and primary visual cortex in the back of brain. They do not reflect perceptual parts of the brain or intra-brain connectivity, or visual areas outside primary visual area. That why VEP affected in the development or illness of the human brain and visual pathway but not the brain perception.

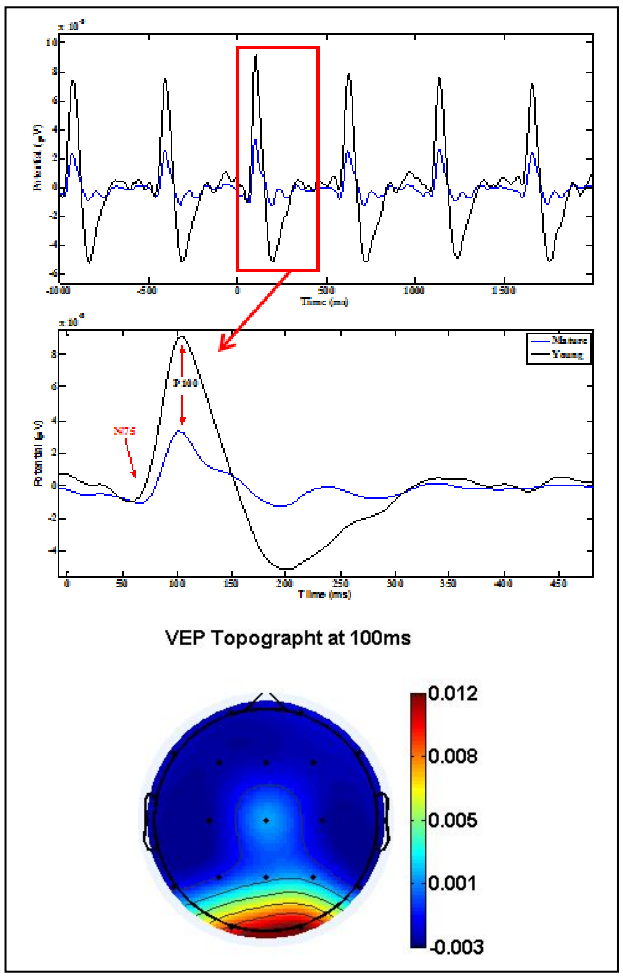

Fig. 2. VEP response from occipital area and brain topography at 100ms.

B. *Measure Projection Analysis (MPA)*

MPA was used to analyze the VEPs source generator of these potentials in order to reveal further details information anatomically and functionally of its sources and locations inside the brain. The results were shown in Fig. 3 and 4 for young and matured group respectively.

As discussed previously the VEP signal generated in the area with the highest component of P100. The literatures demonstrate conflicts of the exact location (source) of VEP signals in the occipital area. Some reported its in primary visual area V1, some reported on secondary visual area V2 while some others go to associative visual (V3) [10]. In this study, the arguments for source localization by estimating the neural generators using MPA are implemented. VEP sources are localized in the occipital area with a higher probability for both age groups. Some other component is marked in the frontal lobe. Table 1 summarizes the anatomical information of projected VEP in young group. The projection of the components is classified in three domains, see Fig. 3. The main domain is associative visual area V3, which is located on the middle occipital gyrus; that is area 19 according to Brodmann. Other two domains are associated with premotor and supplementary motor in the area 6 according to Brodmann.

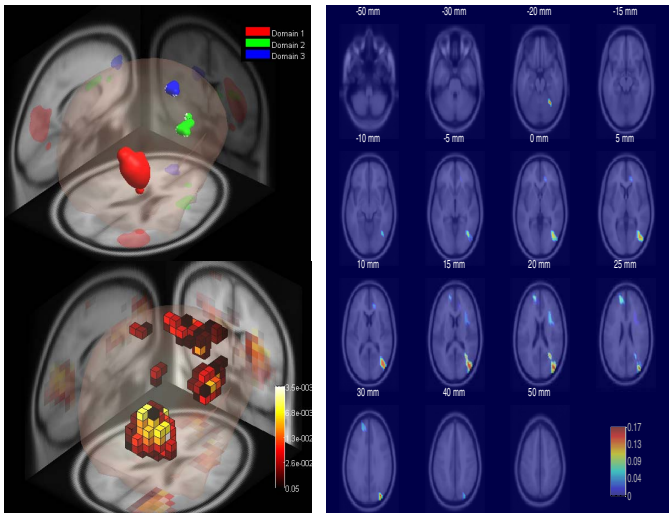

Fig. 3. Measure projections of VEP in young group.

TABLE I. PROJECTIONS OF VEP IN YOUNG GROUP

Domains	Area	Brodmann	Description
1	Middle Occipital Gyrus	19	Associative visual (V3)
2	Inferior Frontal Gyrus Middle Frontal Gyrus	6	Premotor and Supplementary Motor
3	Middle Frontal Gyrus Superior Frontal Gyrus	6	Premotor and Supplementary Motor

Similarly, VEP response projection in the matured group age is shown in Fig. 4. The main domain is allocated in the Inferior Occipital Gyrus, which are associative visual area V3 and secondary visual area V2. Some domains are also allocated with Lingual Gyrus and Fusiform Gyrus which is more or less close responsible for vision as summarized in Table 2. The Lingual Gyrus is a brain structure that linked to vision processing, especially related to letters and encoding visual memories and encoding of complex images [11]. The fusiform gyrus is part of the occipital and temporal lobe in (Brodmann area 37). The lateral and medial portions are separated by the shallow mid-fusiform sulcus. There is still some dispute over the functionalities of this area, but there is relative consensus on the processing of color information, face and word recognition [12-14]. Both of lingual and fusiform gyrus contributes with V1, V2 and V3 in the complementary of visual processing. Some part of the temporal lobe associated with the auditory system process. Along with above the frontal domain is also present strongly in middle frontal gyrus as a second domain that includes frontal eye fields and lateral and medial supplementary motor area (SMA). Of course, frontal domain is a bridge to complete the visual pathway, as already known that, the negative response is present in frontal area of VEP stimuli, which was called N100 [6].

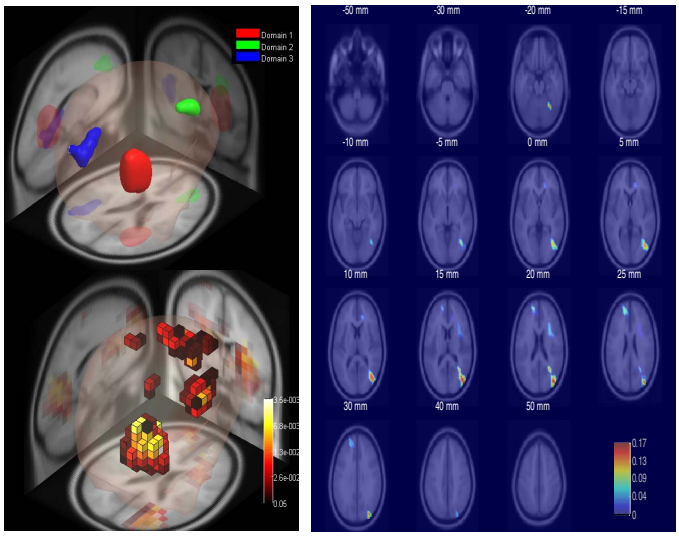

Fig. 4. Measure projections of VEP in matured group.

TABLE II. PROJECTIONS OF VEP IN MATURED GROUP

Domains	Area	Brodmann	Description
1	Lingual Gyrus Fusiform Gyrus Inferior Occipital Gyrus	19 18 30 37	Associative visual (V3) Secondary visual (V2)
2	Middle Frontal Gyrus	8 9	Includes Frontal eye fields and Lateral and medial supplementary motor area (SMA)
3	Middle Temporal Gyrus Superior Temporal Gyrus Fusiform Gyrus	41 19 34	Primary and Association Auditory Associative visual (V3)

That brain maturity is seen clearly developing in the visual system and it is integrated with age as we can see more visual information details (color, stimulus recognition that include word or face etc.). MPA of the VEP sources can estimate the sources accurately and it reveals three domains in every group. The first main highest domain represents the visual field domain, which is located in the occipital area of brain. The second domain, which is slightly smaller than first domain, located in the frontal area of brain. The third domain described advanced visual processing which is more to the brain perception of visual system analysis.

IV. CONCLUSION

The present study discussed and analyzed VEP signal in different age groups. Phase locked response, topographical brain distribution are discussed. MPA is used to project the sources of VEP generator. The VEP responses are compared in both age groups and found no difference in the latency of P100 response but there is much difference in the amplitude since it is much higher in the young than matured age group. Brain topography result showed that, the activation power is much concentrated on the occipital area of brain for both groups. However, the estimated sources domains are projected and indicated that VEP potentials are generated from associative visual area (V3) located on the mid occipital gyrus for young age. While for the matured group, the estimated sources in addition to V3 also covered secondary visual area (V2). Other sources are also noticed in matured group such as lingual gyrus and fusiform gyrus which is strongly reflect the brain maturation of advance visual processing such as (color, recognition etc.).

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