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Electroencephalography Activity during Sensory Organization Balance Test

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Abstract**—**Postural balance plays essential role throughout life in daily activities. Somatosensory, visual and vestibular inputs play the fundamental role in maintaining body equilibrium to balance the posture. The aim of this study was to find out electroencephalography (EEG) responses during balance activity of young people during Sensory Organization Balance Test. The outcome of this study will help to create the fitness and neurorehabilitation plan. 25 young people (25 ± 3.1 years) have been analyzed on Balance Master NeuroCom® with the coupling of Brain Vision 32 electrode wireless EEG system during the Sensory Organization Test. From the results it has been found that the balance score of samples is significantly higher under the influence of somatosensory input as compared to visual and vestibular input ($p < 0.05$). The EEG between somatosensory and visual input to balance the posture showed significantly higher ($p < 0.05$) alpha and beta activities during somatosensory input in somatosensory, attention and visual functions of the cortex whereas executive and motor functions of the cerebral cortex showed significantly higher ($p < 0.05$) alpha EEG activity during the visual input. The results suggest that somatosensory and attention function of the cerebral cortex has alpha and beta activity, respectively high during somatosensory and vestibular input in maintaining balance. In patients with balance impairments both physical and cognitive training, including neurofeedback will be helpful to improve balance abilities.

Keywords**—**Balance, electroencephalography activity, somatosensory, visual, vestibular.

I. Introduction

POSTURAL balance is a fundamental motor skill, which keeps the body in equilibrium. It is considered the integral ability of human movement [1], and it plays the role to maintain the balance of body for daily activities, sports and helps to prevent the injuries. Balance depends on muscle strength, central processing, motor control and sensory input of somatosensory, vestibular and visual [2], [3]. The visual information dominates to maintain balance in static condition as compared to somatosensory and vestibular function and detail effect of these systems were studied [4], [5]. However, when the condition and surrounding change, the sensorial information changes according to the difficulty of balance condition [6], [7].

Balance maintenance is the problem in Parkinson's disease, ageing, vestibular function disorder and neuromuscular disorders [8]-[11]. The mechanism of balance has been widely studied, but cortical activity during balance state was rarely discussed to understand the response of the brain during balance maintenance in humans. Even in balance activity high cognitive processing level is involved [12]. The human cerebellar vermis is responsible to coordinate the centre of gravity and help to maintain the balance [13]. Reference [14] has also studied the postural reaction against fall with the burst of gamma activities.

The aim of this study was to find out the cortical response during somatosensory, vestibular and visual input to maintain balance in respect of alpha and beta frequencies of the EEG. The findings of this study can support for the planning of fitness and neuro rehabilitation plan for the people who are facing postural balance problem.

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II. Material and Methods

A. Participants and Equipment

The faculty committee of the Otto-von-Guericke University Magdeburg has approved this study. All procedures were in compliance with the declaration of Helsinki for human subjects. 25 young males aged 25 ± 3. 1 years' old without any neurological disorder have participated in this study. The Brain Products GmbH wireless MOVE EEG 10/20 system alone to EEG balance master coupling system, which was made by the Otto-von-Guericke University Magdeburg and Balance Master NeuroCom® has been used in this study.

B. Procedure

The skull of the subject has been measured to select the EEG cap, which has been fixed on the head as per 10/20 system alone with 32 active electrodes. The conductive gel was applied till we get impedance till 5 Ohms with the help of the actiCAP control software. The base line of subjects was recorded with help of Brain Vision Recorder in the sitting position in darkness and the sound proof room till 10 mints.

After preparation, all participants performed a Sensory Organization Test with Balance Master NeuroCom®. The balance master and EEG systems were together used with the help of EEG balance master coupling system, which help to synchronize the recording of both systems. The balance master computes the equilibrium score by averaging of 3 trails, each trail consisted of 20 sec; during this time balance master computed the averaging of centre of pressure over the force platform from the theoretical range of normal anteroposterior sway (12.5°).

There are four conditions that have been measured to find out the influence of somatosensory (SOM), visual (VIS) and vestibular (VEST) inputs. At condition one the equilibrium score has been measured with still platform and surroundings condition, while subject's eyes were open, it was considered as a baseline.

Further to measure the influence of SOM function, the average of equilibrium score has been taken with still plate form and surrounding condition, while subject's eyes were closed, which is considered condition two. VIS impact has been taken when the platform is moving up and down position, and the subject's eyes were open; this condition is considered as condition three. The VEST input has been considered during the equilibrium position of subjects on the platform when the platform was moving up and down, while the eyes of the subject were closed, and it was considered as condition four. The data of the above three conditions were computed with the baseline to find the impact of a specific input (see Table I)

TABLE I
THE CALCULATION OF SPECIFIC INPUT DURING SOT

Function	Calculation to measure the impact of input
SOM	Condition 2/condition 1 x100
VIS	Condition 3/condition 1 x100
VEST	Condition 4/condition 1 x100

C. EEG Recording

The workspace of the sensory organization system has been developed according to three trials in each condition of sensory organization test in Brain Vision recorder software, which can automatically save the data of each trial and each condition. The sampling rate was 250 Hz, Sampling Interval was 4000 µS and recording filters, low cutoff 0.31831 Hz and high cutoff 35 Hz were applied.

D. EEG Data Analysis

The EEG recorded data were analysed by EEG brain, vision Analyser 2.0.3 software. Infinite impulse response (IIR) filter was used to filter the data with high cutoff: 0.1 Hz Butterworth zero phase filters low cutoff: 0.1 Hz, time constant 1.591549, 24 dB/oct high cutoff: 32 Hz, 24dB/oct were applied to the data of baseline of 600 sec. The first 120 sec and last 120 sec data were removed and made the segment of 480 sec. The segment of 360 sec was further divided into 18 segments of 20 sec each, which is similar to each condition duration of postural balance test. The artifacts have been rejected from the EEG data by using semiautomatic artefact rejection method with the criteria of maximal allowed voltage: 50 µV/ms, mark as bad: before and after the event: 200 ms, maximal allowed difference of values in intervals: 200 µV, interval length: 200 ms, lowest allowed activity in intervals: 0.5 µV. Further ocular correction with independent component analysis was applied with blink marker channel: Fp1 channel with the value trigger algorithm for blink detection, blink trigger value: 97%, blink correlation trigger: 70% was used. After finishing this process the average of all 24 segments has been taken and applied Fast Fourier Transformation (FFT) with Resolution: 0.03052 Hz.

The data on EEG with the coupling balance master system were also analysed with the above mentioned criteria. The work space had the data of each condition with three trails. The first filter was applied on segmented data of 20 sec trials, each trial was further divided in 1 sec segment to prevent loss of data due to artefact rejection, so we can save the data as much as possible, then we applied the semi-automatic artefact rejection and ocular correction with independent component analysis, after that we removed the markers, which were used to divide each trial in one second. The averaging three trails of each condition were done and then applied FFT and exported the alpha 7 to 13 Hz and beta 13 to 30 Hz frequencies as text files.

E. Data Analysis

The exported data of the EEG base line and EEG balance activity during the sensory organization test were organized by the areas of interest (see Table II).

TABLE II
AREA OF INTEREST FROM 32 EEG CHANNELS

Region of interest	Calculation to measure the impact of input
Executive functions	FP1, FP2, F8, FC5, FC6
Motor Functions	CZ, FC1, FC2, F3, Fz, F4
SOM	C4, C3, CP2, CP1, CP5, CP6
Attention	P3, P4. Pz
VIS Function	Oz, O1, O2

Average of activities in different area of interest was imported to excel. The data were normalized in consideration to baseline and the percentile of activity was measured by following method.

$$\frac{\text{EEG Activity percentage during balance EEG}}{\text{Activity during baseline}} \times 100$$

By having the average data from the formula, we can compute activity average in different conditions. Now we compute the activity during the influence of SOM, VIS and VEST for that we used the formula of Table I. The above results were analysed on SPPS 20. First the normality of the data was checked using Shapiro Wilk test and it was not normally distributed, so Kruskal-Wallis test statistic test was applied for further analysis.

III. RESULTS

The average equilibrium score during 20 sec SOM input has been found significantly higher than the VIS and VEST input ($p < 0.05$). The equilibrium score during VIS input has been found significantly lower ($p < 0.05$) than the SOM input and higher then VEST input ($p < 0.05$) and the VEST input equilibrium score is significantly lower than the SOM input and VIS input ($p < 0.05$), Fig. 1.

A. Alpha and Beta Activity in Cerebral Cortex

The EEG alpha and beta activities during SOM input balance test have been found significantly higher ($p < 0.05$) in SOM, attention and VIS function and only alpha activity have been found significantly higher ($p < 0.05$) in executive function and motor function of the cerebral cortex as compared to VIS input. The EEG alpha and beta activity during VEST input has been found significantly higher ($p < 0.05$) in SOM, attention and VIS function and only alpha activity has been found significantly ($p < 0.05$) higher in executive function and motor function of the cerebral cortex compared to VIS input Fig. 1.

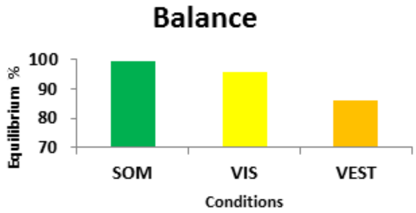

Fig. 1 Balance score during the Sensory Organisation Test

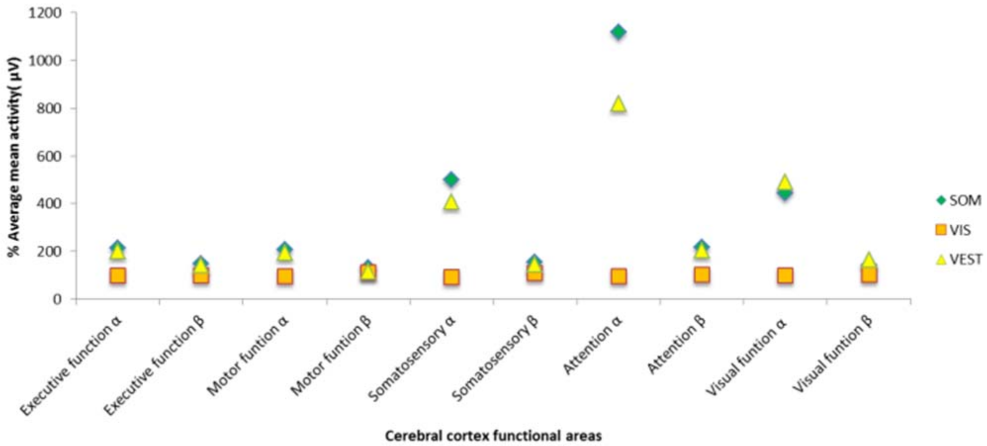

Fig. 2 Alpha and beta activities in cerebral cortex functions

The EEG alpha and beta activities during conditions 1, 2, 3, and 4 in the cerebral cortex are presented in Topographic Map, Fig. 2.

IV. Discussion

Sensory Organization Test is reliable to find out the impact of SOM, VEST and VIS systems on the equilibrium score. The results of this study suggested that in the presence of SOM input the equilibrium score indicates high ability of balance as compared to VIS and VEST input. These findings indicate that people use more SOM information to maintain the body balance as compared to the VIS or VEST input. VIS input helps to maintain the balance lesser than SOM input, but more than VEST input and the least information used to maintain balance is VEST input. The result of this study supported [10].

The detailed study of cerebral cortex in relation to alpha (Attention demand) and beta (Cognitive tasks) [15], [16] is done. During the Sensory Organization Test, the executive, SOM, attention, VIS and motor functions areas of cerebral cortex have been considered for the interpretation of EEG results.

The comparison between SOM input, VIS input and VEST input during the test shows that the balance maintained by SOM and VEST inputs requires high attention and complex cognitive ability for SOM, attention and VIS functions of cerebral cortex. However, in this condition executive function and motor function of cerebral cortex also show the high attention state with the alpha activity as compared to VIS input with SOM and VEST inputs.

As the VEST and SOM inputs have the same alpha mean high attention and beta frequency mean complex cognitive activity trend in the cerebral cortex, but it does not lead to the same equilibrium score during the test, so cerebral cortex process the information with the same intensity from both systems, but as a result SOM input leads to the high equilibrium score as compared to the VEST condition. On the other hand, we find that lesser the alpha and beta activities in SOM, attention and VIS functions of the cerebral cortex are, then lesser the activities of alpha in executive function and motor function of cerebral cortex, as we compare the VIS input to SOM and VEST input, but it leads to the higher equilibrium score as compared to VEST condition.

The results of this study are useful to make the rehabilitation or training plan for the people, who have balance impairment and can be improved by physical and cognitive training, including neuro-feedback [17].

The balance can be problematic due to impairments in SOM, VEST and VIS systems, but according to these results, if people have problem in balance due to VEST impairment it is appropriate to devise a training plan for him, that can improve the balance system in consideration of VIS impact. The same trend can be followed by the people who get the balance disorder due to SOM impairment. The future study is proposed on the basis of cognitive and physical interventions, so the impact of training may be specified on balance and cognitive response.

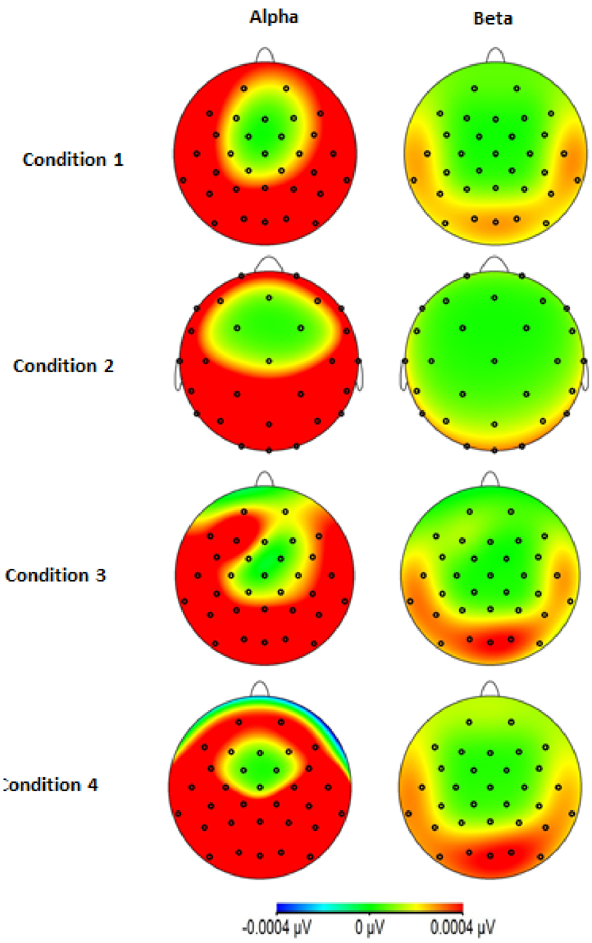

Fig. 3 Alpha and Beta Activities Topographic Map

V. Conclusion

SOM, VIS and VEST input plays the role in the balance. According to the cognitive state, the SOM and VEST inputs respond to the same intensity. There is a lesser cognitive activity which has been found with respect to VIS function. On account of these results, the cognitive training may be planned according to the impairment of the system and specific cognitive demands.

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