Source Localization based Healthcare Diagnostic System using ERP signals: An application to ASD

Joy K.Singhv[1]and DeeptiKakkar[2]

[1,2]*NIT Jalandhar, Panjab, India*

Abstract

Aim: Autism spectrum disorder is a complex disorder in which persistent challenges are introduced in communication, social interaction and repetitive patterns are introduced that affects 1% individuals in United Kingdom and 1.5% individual in united states. The number of individuals affected by autism is 1 in 110 in india and 1 in 68 worldwide. It has been estimated that 2 million people in India are affected by autism spectrum disorder.In this study we used Evented Related potentials(ERP) to investigate the brain area in order to diagnose ASD

Methods: This study enrolled 20 individuals with Autism and 20 typically developing individuals. Low-resolution electromagnetic tomography (LORETA) was used to analyze ERP data to reveal the mechanisms underlying Autism in individuals

Results: There were significant difference in current density between Autistic and typically developing individuals. In the entire brain area, the occipital lobe concerned with visual perception exhibited the most significant difference between the individuals with autism and typically developing individuals groups. Differences were also observed in parietal and frontal lobes

Conclusions: LORETA can prove to be a revolutionary tool for investigation of autism spectrum disorder. In comparison to other techniques ERP is a promising biomarker for autism . By comparing activation maps at different time instants one can diagnose Autism at a early stage Our study aims to address diagnostic approach for autism in individuals.

Keywords

ASD, LORETA, ERP, Tomography, ADHD

1. Introduction

Neuro-developmental disorders refer to the class of the disorders in which the brain dysfunctionalities occur with the growth of the individuals. The disorder manifest in early developmental age, even before the second birthday of child and are characterized by different deficits. The deficits are not limited to this but lead to motor skill impairment, verbal and non-verbal communication deficit, learning deficit and lack of interaction, memory and emotions. The list of the developmental disorder involves huge variations of symptoms and heterogeneity. The widely occuring neuro-developmental disorders are epilepsy (Bozzi et. al., 2012), Autism Spectrum Disorder (ASD), Attention Deficit Hyper Disorder (ADHD), cerebral palsy, intellectual disability, language disorders, communication disorder and dyslexia. These disorders can co-occur in themselves such as ASD with epilpesy, ASD with intellectual disability. These disorders are called developmental since some deficits keep on changing or developing with the age while some of them remain permanently in the individual. The subset of deficit is different for each and every individual making the individual unique in himself. This diversity in the nature of the disorder is the reason that the diagnosis as well as intervention is a very complex process [https://www.epilepsy.com/learn/about-epilepsy-

International Conference on Emerging Technologies: AI, IoT, and CPS for Science & Technology Applications, September 06–07, 2021, NITTTR Chandigarh, India

EMAIL: joysachar@gmail.com (A. 1)

ORCID: XXXX-XXXX-XXXX-XXXX (A. 1); XXXX-XXXX-XXXX-XXXX (A. 2); XXXX-XXXX-XXXX-XXXX (A. 3)

basics/epilepsy-statistics]. The cause of the disorder has not been particularly defined but it is related with the neuro-developmental manifestations. These disorders are included in the Diagnostic and Statistical Manual of Mental Disorders (DSM) manuals and the DSM-5 [American Psychatric Association] is the latest one. The new edition of DSM-5 has combined these three diagnoses under the single diagnosis of ASD (American Psychiatric Association, 2013). The modification in the diagnostic manuals and techniques highlight the fact that neurodevelopmental disorders are complex disorders and for better diagnosis the approach needs to be based on multi-modal ways of detecting behavioral traits.

According to a report, in United States 15% of the individuals of age-group are suffering from neuro-developmental disorders. The number of individuals affected with autism are 1 in every 68 and in india it is 1 in every 110 [http://unstats.un.org/unsd/demographic-social/meetings/2016/bangkok- -disability-measurement- and-statistics/Session- 6/India.pdf].The number is very high and this is the reason of including autism disorder in to this thesis work. The range of epilepsy in United States is 5-8.4 in every 1000 or in lifetime it is 1 in 26 have suffered from epilepsy in their entire lifetime. The cases of disorders are getting more diagnosed day by day with the prevalence of much more techniques and ushering technology. There is no report of predicting that these disorders have only one symptom which can be the marker of the disorder. There is no cure of the disorder but definitely the disorder can be controlled and can be retraced to some extent with the help of medication and some therapies. These therapies and medication will be more effective only when the disorder is diagnosed at early period of its manifestation. The diagnosis and intervention technologies are on their way of better detection and treatment but till now there is no robust technique or marker which can diagnose these disorders at very early stages of life.

ASD is a problem in the youngsters present upon entering the world time no illness portrayed by the group of three of issues: chemical imbalance, Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS) and Asperger Syndrome (AS; Muñoz et al., 2012; Bouras, 1999; American Psychiatric Association, 2000). Rett condition and youth degenerative confusion are likewise found in youngsters yet less habitually when contrasted with the group of three of issues (Matson et al., 2007). Mental imbalance is a tenacious formative set out by a range of side effects comprehensively arranged into three spaces: (I) sparsity of social association, relations and colossal lack of approachability (ii) unfit to impart and share feelings, engine weaknesses, and subjective and quantitative language incapacity, (iii) monotonous exercises, bothered conduct and obliged interests (Brandwein et al., 2015; Kanner, 1943; Tas et al., 2007). The vulnerability of side effects can change from one person to another pretty much and can't be restricted to a specific degree..

ERP(Event related potentials)have been used to detect various neurodevelopmental disorders in individuals.ERPs have high temporal resolution and can detect changes in a matter of milliseconds.ERPs are inexpensive and noninvasive tools which can help to clinically access changes in functional connectivity related to autism. In this paper ERP data of autistic and TD individuals was taken in the presence of visual stimuli.

Electromagnetic signals are generated during activation inside the brain.The restriction of dynamic sources inside the mind is named as cerebrum source limitation. The course of the assessment of dynamic sources in the cerebrum is named as EEG-based mind source limitation. The course of EEG-based source restriction is useful in understanding the practical, obsessive, physiological anomalies identified with the mind. The brain source localization approaches are helpful in diagnosis of various neurodevelopmental disorders such as autism and epilepsy. There are different approaches available that are used to localize the active sources including LORETA, standardized LORETA,exact LORETA, minimum norm etc. In this paper brain source localization techniques such as Sloreta has been discussed.ERP dataset of subjects with visual stimuli at four different time instants in terms of activation maps, scalp map has been discussed in this paper.

a) Brain source localization techniques

S.No.	Method or Technique	Reference/Author	Advantages	Limitations
1.	Minimum norm solution[1]	Matti.S.Hamalainen(1984)	Current estimation and resolution are provided with good results	Localization error is introduced and deep source localization is not addressed
2.	LORETA[2]	RD PASCAL(1994)	Provides better capabilities for localizing deep sources	It provides low resolution with blurred images,which is highly undesirable for feature selection.
3	FOCUSS[3]	F.Irina.et.al(1995)	Non uniquely defined sources are properly localized and provides stable outputs	It involves large mathematical calculations and involves large computational time
4	Recursive MUSIC[4]	J.C.Mosher(1998)	Recursive MUSIC provides low localization error with better estimation	Errors and noise increase the complexity of the algorithm
5	sLORETA[5]	R.D Pascual(2002)	Zero Localization Error	Low resolution imaging method.
6	Shrinking LORETA-FOCUSS[6]	He Sheng(2003)	Provides better localization as compared to sLORETA	It has limitation while using real time data
7	Hybrid weighted minimum norm[7]	C.Y Song.et.el(2005)	Provides in depth localization with less errors	Large computations which increase computational time
8	eLORETA[8]	R.D Pascual(2007)	Authentic localization technique with zero localization error	Low resolution feature causes blurring of images
9	WMN-LORETA[9]	R.Khemkhan(2008)	Hybrid technique which provides better localization than LORETA WMN alone	System is complex and requires high computational time
10	Recursive Sloreta and FOCUSS[10]	R.Khemkhan(2008)	More efficient in terms of localization and computational time	No validation provided.Results were produced on simulated data.

2. Material and Methodology

Subjects:

Two groups of participants were included in the study.17 TD individuals[1.5-25years] and 17 ASD patients[**2-20 years**] were a part of this experiments.ERP data was taken for comparison which was provided by Dr. Michaela Esslen, Institute of Neuropsychology, university of Zurich. Visual Stimulus in the form of pictures of flowers was provided to the participants.Electrodes taken were 25 with sampling rate of 256 Hz. For this study, different time instants were considered 253.906, 480.469, 42.968ms.The results For recruitment of ASD individuals special schools of Jalandhar were consulted.Parents and caretakers of autistic individuals were also consulted.

Table 1.

Parameters used for analysis.

Features	ASD	TD
Number of individuals	20	20
Age	8-20	4-25
No of electrodes	25	25
Sampling frequency	256Hz	256Hz
Visual Stimuli	Pictures of flowers	Pictures of flowers

Data acquisition and processing

A Generation of activation maps

The methodology of source localization is carried out using sLORETA software. KEY Institute of Brain-Mind Research, Zurich Switzerland developed this software package. Data of young normal individuals was provided by Peter anderer, Professor of biomedical engineering.10-20 international system electrode international system is used for placing the electrodes. The data have following specifications: a ERP file was used with 5s worth of data, 25 electrodes were used in the dataset. The data set is of 20 young patients and 20 ASD patients in resting state.

Step1: The first step involves the conversion of .txt file to. sxyz file format.The sampling rate is 102.4Hz

Step 2:ERP data files(.asc) are entered along with the transformation matrix in the software utility.sLORETA file is selected from the utility window.

Step 3: After applying all the necessary transformations, sLORETA explorer utility is selected from the software.

Step 4: For visualization of activation,the selected data is examined at three different time instants.Slice viewer,3D cortex map and scalp map are examined and different activated regions are shown.

STEP 1 STEP 2 STEP 3 STEP 4

Fig 1 Steps for data acquisition and processing

3. Result and Discussion

The outcomes were taken utilizing Sloreta utility and actuation was seen at various areas of the mind as per the upgrade given at three diverse time moments. The actuation maps produced are reliant upon the boost given and consideration of the concerned subject.It was observed that maximum activation was observed in the occipital region in case of TD individuals while maximum activation was observed in parietal regions in case of ASD individuals. Occipital lobe is responsible for vision and visual tasks[2].Decrease in functional connectivity in task related regions is one of the promising biomarkers for detection of autism at a early stage.

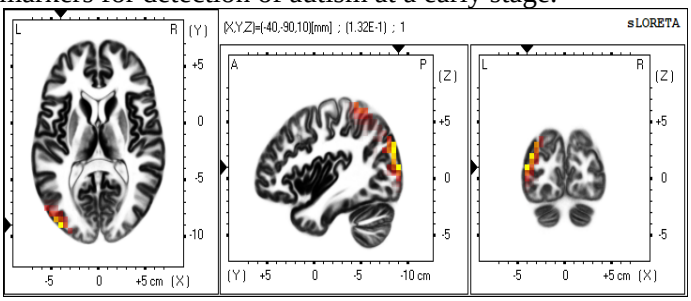

Fig 2. Activation map for TD individuals at 253.906 ms

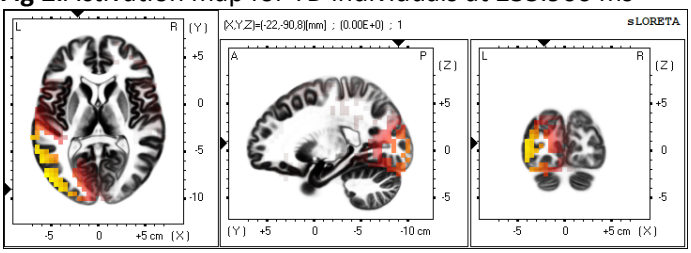

Fig 3. Activation map for TD individuals at 480.906 ms

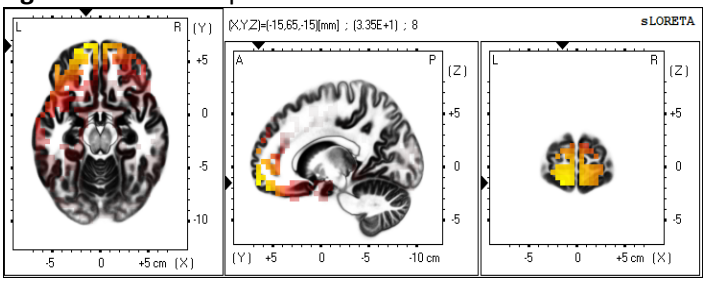

Fig 4. Activation map for TD individuals at 42.96 ms

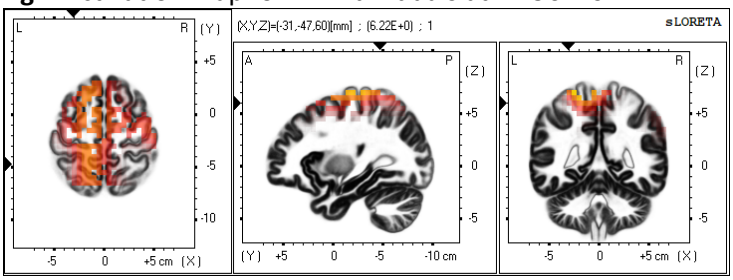

Fig 5. Activation map for ASD individuals at 253.906 ms.

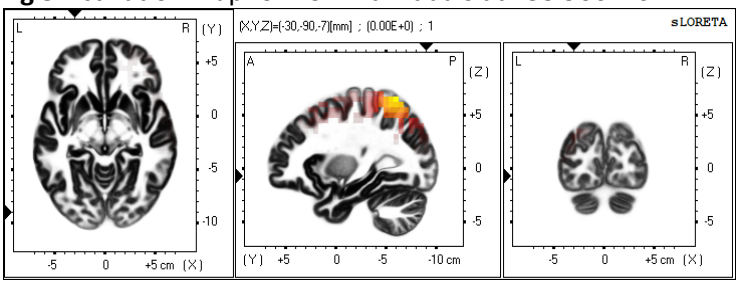

Fig 6. Activation map for ASD individuals at 480.906 ms

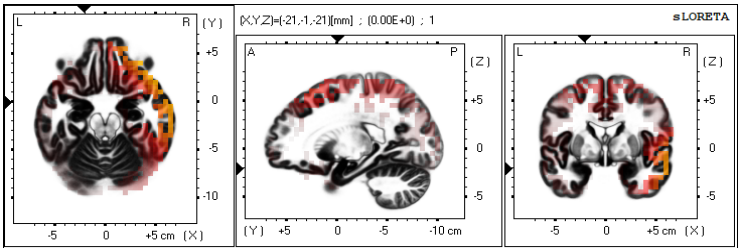

Fig 7. Activation map for ASD individuals at 42.96ms.

Table 2.
Comparative analysis of regions affected

Type of individual	Time instant	Region with maximum connectivity
ASD	253.96 ms	Parietal Lobe
ASD	480.906 ms	Parietal lobe
ASD	42.96 ms	Frontal,Parietal
TD	253.96 ms	Occipital
TD	480.906 ms	Occipital
TD	42.96 ms	Frontal,occipital

In this paper we introduced a tool known as Sloreta to demonstrate the abnormalities between ASD and TD individuals.This is the first of its kind study to demonstrate the functional connectivity in patients with Sloreta. This paper proposes ERP as a biomarker for autism.The application of the results is helpful for functional localization which helps in diagnosis of this disorder at a early stage.Sloreta is low cost software and is advanced version of LORETA. Sloreta can end up being a decent low goal device for early analysis of Autism range issues.

ERP is of high temporal resolution and is a established tool for diagnosis of nuerodevelopmental disorders.(Polich,2007) represented ERP as a valuable technique for assessing differences in individuals with ASD or ADHD. (Ducan et al 2009) investigated differences in ERP as a promising biomarkers for detection of Autism.

Conclusion

The present paper proposed ERP based source localization based healthcare diagnostic system for assisting the doctors in decision making.This work has demonstrated Sloreta as a likely apparatus for ERP based source restriction.This paper suggested altered connectivity in individuals with ASD in the presence of visual stimuli.The suggested system can help to detect autism at a early stage.

4. References

[1] M.S.Hamalainen,etal.,InterpretingMeasuredMagneticFieldsoftheBrain: Estimates of Current Distributions, Report TKK-F-A559, 1984.

[2] T.Soderstrom,G.W.Stewart,Onthenumericalpropertiesofaniterative method for computing the Moore–Penrose generalized inverse, Soc. Ind. Appl. Math. J. Numer. Anal. 11 (1) (2006).

[3] R.D. Pascual-Marqui, Review of methods for solving the EEG inverse problem.

[4] Pascual, et al., Low resolution electromagnetic tomography: a new method forlocalizingelectricalactivityinthebrain,Int.J.Psychophysiol.18(1994) 49–65.

[5] I.F. Gorodnitsky, et al., Neuromagneticsource imaging with FOCUSS: a recursive weighted minimum norm algorithm, Electroencephalogr. Clin. Neurophysiol. 95 (1995).

[6] J.C. Mosher, R.M. Leahy, Recursive MUSIC: a framework for EEG and MEG source localization, IEEE Trans. Biomed. Eng. 45 (1998) 1342–1354.

[7] J.C.Mosher,R.M.Leahy,Sourcelocalizationusingrecursivelyappliedand projected(RAP)MUSIC,IEEETrans.SignalProcess.47(February(2))(1999) 332–340.

[8] C.Y. Song, et al., Hybrid weighted minimum norm method a new method based LORETA to solve EEG inverse problem, in: 27th Annual International Conference oftheEngineeringinMedicineandBiologySociety,2005,IEEE-EMBS2005, 2005, pp. 1079–1082.
[9] R.D. Pascual, et al., Standardized low resolution brain electromagnetic tomography(sLORETA), Techn. Details Methods Findings Exp. Clin. Pharmacol. 24D (2002) 5–12.
[10] A.M.Dale,etal.,Dynamicstatisticalparametricmapping:combiningfMRI andMEGforhighresolutionimagingofcorticalactivity,Neuron26(2000) 66–67.
[11] Howlin P, Asgharian A (1999) The diagnosis of autism and asperger syndrome: findings from a survey of 770 families. Dev Med Child Neurol 41:834–839
[12] Arthi K, Tamilarasi A (2008) Prediction of autistic disorder using neuro-fuzzy system by applying ANN technique. Int J Dev Neurosci 26:699–704
[13] Shams WK, Wahab A, Qidwai UA (2012) Fuzzy model for detection and estimation of the degree of autism spectrum disorder. In: Huang T, Zeng Z, Li C, Leung CS (eds) Neural information processing. ICONIP 2012. Lecture Notes in Computer Science. Springer, New York, pp 372–379 Australasian Physical & Engineering Sciences in Medicine 1 3
[14] Ahmadlou M, Adeli H, Adeli A (2012) Fractality and a waveletchaos-neural network methodology for EEG-based diagnosis of autistic spectrum disorder. J ClinNeurophysiol 27:328–333
[15] Pratap A, Kanimozhiselvi CS, Vijayakumar R, Pramod KV (2016) Parallel neural fuzzy-based joint classifier model for grading autistic disorder soft computing applications. AdvIntellSystComput 356: 13–26. https://doi.org/10.1007/978-3-319-18296-4_2
[16] Mythili MS, Mohamed AR (2016) An improved autism predictive mechanism among children using fuzzy cognitive map and feature extraction methods (FEAST). ARPN J EngApplSci 11:1819–1828
[17] Grossi E, Olivieri C, Buscema M (2017) Diagnosis of autism through EEG processed by advanced computational algorithms: a pilot study. Comput Methods Progr Biomed 142:73–79
[18] Hirstein, W., Iversen, P. and Ramachandran, V.S. (2001), “Autonomic responses of autistic children to people and objects”, Proceedings of the Royal Society of London, Series B, Vol. 268 No. 1479, pp. 1883-8, doi: 10.1098/rspb.2001.1724.
[19] Joseph, R.M., Ehrman, K., Mcnall, R. and Keehn, B. (2008), “Affective response to eye contact and face recognition ability in children with ASD”, Journal of the International Neuropsychological Society, Vol. 14 No. 6, pp. 947-55, doi: 10.10170S1355617708081344.
[20] Kanwisher, N. and Yovel, G. (2006), “The fusiform face area: a cortical region specialized for the perception of faces”, Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences, Vol. 361 No. 1476, pp. 2109-28, doi: 10.1098/rstb.2006.1934.
[21] Kylliäinen, A. and Hietanen, J.K. (2006), “Skin conductance responses to another person’s gaze in children with autism”, Journal of Autism and Developmental Disorders, Vol. 36 No. 4, pp. 517-25, doi: 10.1007/ s10803-006-0091-4.
[22] Lang, P.J. (2000), “Emotion and motivation: attention, perception, and action”, Journal of Sport and Exercise Psychology, Vol. 22 No. S1, pp. 122-40.
[23] R.D. Pascual-Marqui, Discrete, 3D distributed, linear imaging methods of electric neuronal activity. Part 1: exact, zero error localization, 2007, http://arxiv.org/pdf/0710.3341
[24] R.Khemakhem,etal.,Anewcombiningapproachtolocalizingthe EEG activityinthebrain:WMNandLORETAsolution,in:InternationalConferenceonBioMedicalEngineeringandInformatics,2008,BMEI2008,2008, pp. 821–824.
[25] American Psychatric Association, Diagnostic and statistical manual of mental disorders DSM-iv-TR Fourth Edition, American Psychatric Publishing, 2000.
[26] American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders: DSM-5 (5th ed.). Arlington, VA: American Psychiatric Association.
[27] A.M. Tharpe et al., “Auditory Characteristics of Children with Autism”, Ear and Hearing, vol 27, no.4, pp. 430-441, 2006.
[28] A. Tas, R. Yagiz, M. Tas, M. Esme, C. Uzun, and A.R. Karasalihoglu. Evaluation of hearing in children with autism by using TEOAE and ABR. Autism, vol.11, no.1, 2007, pp.73-79.
[29] B. H. Brask, "A prevalence investigation of childhood psychoses", Nordic Symposium on the Comprehensive Care of the Psychotic Children, pp.145-153,1972.