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Detection of stress of a Children with ASD using Biological Signals

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Abstract-- Autism spectrum disorder (ASD) is associated With the impaired integrating and segregating of related Information that is expanded within the large-scale brain Network. This review investigates the effects of psychological stress on the human body measured through bio signals. When a potentially threatening stimulus is perceived, a cascade of physiological processes occurs mobilizing the body and nervous system to confront the imminent threat and ensure effective adaptation.

Autism spectrum disorder (ASD) and language learning impairment (LLI) are among the most common neurodevelopmental disorders, and they share overlapping symptoms. Based on a publicly available dataset, the EEG brain networks were constructed, and four types of EEG metrics were calculated. Then, we statistically compared the brain network differences among ASD children with varying severities.

Keywords-- Stress, bio signals, EEG, ECG, EDA, HRV, functional brain network.

I. INTRODUCTION

Autism spectrum disorder (ASD) is a largely heritable neurological condition that significantly reduces the social interaction abilities of the affected individual. A considerable amount of studies are dedicated to the development of various techniques for the identification of biomarkers of ASD based on neurophysiological data analysis. In recent decades, lots of related studies have paid great efforts to pursue the pathological explanations for the socio communicative and other impairments in individuals with ASD. As demonstrated in previous studies, both individuals with ASD and those deemed to be typically developing (TD) display a wide range of ASD symptoms in a variety of behaviour's. This variability may mask neural abnormalities associated with these symptoms, and limit the success of finding the potential biomarkers for understanding this neurodevelopmental disorder.

The brain functions as a large-scale complex network and is comprised of the spatially distributed but functionally linked regions. Given ASD has its origins in the atypical development of brain networks, the brain network analysis has been well concerned and the network deficits (hyper- or hypo-connectivity) have been identified and reported. Furthermore, the corresponding brain network metrics have also been investigated in ASD to mine the potential mechanisms for ASD pathology. The metrics, i.e., nodal degree, clustering coefficients (CC) and characteristic path length (CPL), have been adopted to characterize the ASD.

In recent years, increasing studies report the findings on the ASD symptom severity. In fact, the ASD severity has been demonstrated to be related to children's language processing and attentional control etc. For example, children with more-severe symptoms spent less time watching relevant information in simple movies than those with less-severe autism.

In the clinic, the diagnosis of ASD is achieved by applying the Autism Diagnostic Observation Schedule (ADOS), along with varying ADOS scores implying the symptom severity. However, this remains largely reliant upon clinician and caregiver measures, the urgent need for objective, reliable, and quantitative biomarkers are now drawing great attention.

The multidimensional nature of stress can be decomposed into three main components: the psychological, the behavioural and the physiological. Available methods for assessing the subjective experience of stress are by definition influenced by a multitude of systematic measurement errors, such as the response bias (e.g., the tendency to respond in a manner considered as desirable to the experimenter. Besides, even though some behavioural bodily patterns (such as facial expressions and body gestures) are manifested in response to stress, they may also be subject to intentional or even partially conscious control. Consequently, related recordings may also contain systematic errors when used to estimate the magnitude of the stress response.
This paper investigates systematic and consistent biosignals patterns during stress conditions. Towards this objective, an

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extensive investigation of published studies based on biosignals was performed focusing on acute psychological, social and mental aspects of stress detection. In particular, it is stated precisely for each biosignal feature the studies that report significant changes (increase/decrease), or no difference between the neutral and stressful emotional states.

In this paper, we study the features of functional brain networks in ASD children based on the analysis of EEG data obtained in the resting-state experimental paradigm. We focus on age-related changes in the characteristics of functional networks during the particularly important age period from early childhood to adolescence.

II. BIO-SIGNALS RELATED TO STRESS

Biosignals are time-varying measures of human's body processes that can be divided into two main categories

- Physical signals
- Physiological signals

Physical biosignals are measures of body deformation as the result of muscle activity and include pupil size, eye movements, blinks, head, body and extremity semi-voluntary position movements, respiration, facial expressions and voice. Physiological signals are more directly related with body vital functions, such as cardiac activity (Electrocardiogram [ECG], Blood Volume Pulse [BVP]), brain function (EEG), exocrine activity (sweating assessed through electrodermal activity [EDA]), and muscle excitability assessed through electromyography (EMG). The distribution of associated measures on the body is shown in Fig.

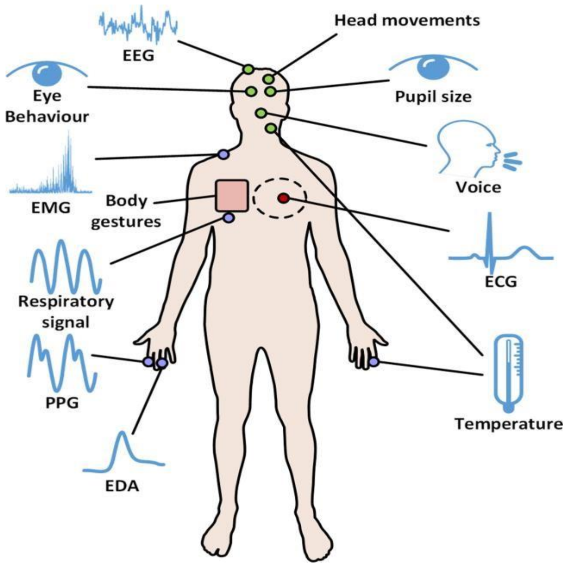

Fig. 1 Measurement of stress to various parts of body

In subsequent sections, bio signals are categorized according to their source on the body into those recorded from the head, the heart, and the remaining body parts.

2.1 Head

2.1.1 Electroencephalogram (EEG)

Electroencephalogram (EEG) is a widely used technique to estimate changes in neurophysiological activity associated with external stimuli and/or with the performance of specific tasks. EEG asymmetry index is a robust stress feature revealing emotional arousal implicated in many studies to differentially dissociate psychological states. The most common positions used in the estimation of alpha asymmetry are channels F3-F4 as they are located above the dorsolateral prefrontal cortex a region directly affected by stressful conditions. The majority of studies support the notion that in stress state there is generally greater frontal right alpha activity in relation to the left alpha activity. This phenomenon occurs during stressful periods (e.g., students during exams period) when exposed to stressful stimuli such as sad/happy films, fearful films or in the case of chronic stress.

2.1.2 Pupil Diameter (PD)

Pupil size is controlled by two sets of muscles, the constrictor and dilator pupillae, which are governed by the sympathetic(SNS) and parasympathetic (PNS) divisions of the ANS. Thus, it reflects autonomic involuntary activity and it is associated with emotional, cognitive or sexual arousal.

Pupillary response to images inducing negative valence also tends to be higher among persons reporting higher overall levels of stress. When investigating pupil size, some limitations have to be taken into consideration. Pupil size variation is affected by age as various studies refer a marked reduction of pupil size with the ageing. The usage of pupil changes in research studies should be performed with caution and in relation to well-established reference points such as pupil size in the normal state.

Fig. 2 Normal (left) and dilated (right) human pupil

2.1.3 Speech

Stress conditions may cause variations to speech compared to speech in neutral conditions .A scientific area called Voice Stress Analysis (VSA) has been established to estimate stress in the voice, dealing with the vocal characteristics influenced from the stress, in order to discriminate stressed and neutral speech. The mechanism of human speech production is shown in Fig.

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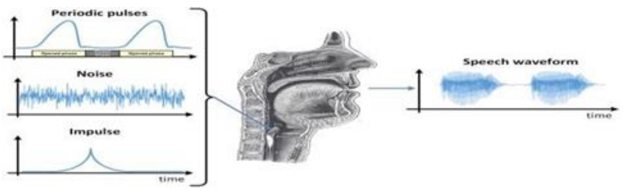

Fig. 3 Mechanism of Human speech production

A. EEG Datasets

The EEG data were obtained from the publically available ABC-CT dataset which can be assessed via the National Database for Autism Research (https://ndar.nih.gov/, #2288.). In current study, we enrolled the corresponding EEG data of 257 ASD children and 110 TD children in the following analysis, with childrens ages ranging from 6 to 11 years old.

B. Data Preprocessing

In present study, the EEG data were first preprocessed to acquire the artifact-free EEG segments per child by following the standard protocols in the reference. Concretely, the data were first re-referencing to the Reference Electrode Standardization Technique (REST) and then bandpass filtered within a frequency range of Hz

C. Prediction Analysis

As reported in the previous studies, the ASD symptom severity had been found to largely affect the behaviors and cognitive processes of ASD children, such as language processing the accurate quantification of the symptom severity was thus crucial for their clinical evaluation and intervention.

The correlations between network properties and ADOS scores were also investigated, to fulfil the goal of the ABC-CT dataset. Finally, the prediction of the severity of ASD was achieved by using these EEG metrics as predicting features.

IV. COMBINED MULTIMODAL BIOSIGNAL ANALYSIS.

Recent stress recognition studies base their analysis on multimodal bio signal analysis in order to acquire a more complete picture of emotional states. The accuracy is considered a more complete measure, thus it is used widely in research studies. An overview of multimodal analysis studies, along with study population, stimuli used, biosignals recorded.

V. STRESS INDUCING METHODS.

There are many studies of affect that use pictures from the International Affective Picture System (IAPS) . The IAPS is a set of emotionally bearing pictures that have been evaluated on a 9-scale rating of arousal and valence dimensions.

The Stroop Colour-Word Test (SCWT) date back to 1883 and it is a task asking to name a series of words with colour names written in congruent and incongruent colours.It has been validated in terms of reaction in physiological measures and it is considered a reliable stressor.

Mental Arithmetic (MA) tests have been considered to induce stress and they have been used in stress studies . The Paced Auditory Serial Addition Test (PASAT) is a neuropsychological test for assessing attention processing that has also been used towards this direction.

VI RESULTS.

Using the NBS and FDR, we revealed the influence of the Diagnosis factor on the functional connections in the θ- band. In particular, a network pattern was determined as shown in below fig.4, where the connections vary significantly between the ASD and Typical groups.

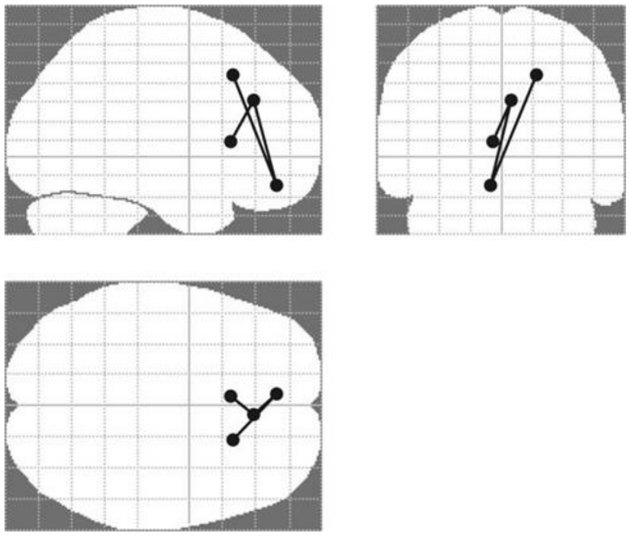

Fig.4a The functional connectivity in the coronal, axial, and sagittal projections of the brain in the θ range (2–6 Hz) assessed via NBS and FDR.

The presented connections differ significantly between ASD and Typical groups: (connection 1, f -value =17) right superior frontal gyrus, dorsolateral area 8 (A8dl)— left orbital gyrus, medial area 14 (A14m); (connection 2, f -value =18.3) A14m—right superior frontal gyrus, medial area 9 (A9m); (connection 3,f -value = 19.2) A9m—left cingulate gyrus, rostroventral area 24(A24rv).

The results indicate that neuro typical children have a higher level of integration in the identified sub network than children with ASD, which suggests a stronger interaction between the brain areas responsible for emotions and consciousness in the Typical group.

We revealed that the interaction of the factors Diagnosis and Age group does not affect the coupling strength in this subnet as shown in fig 5.

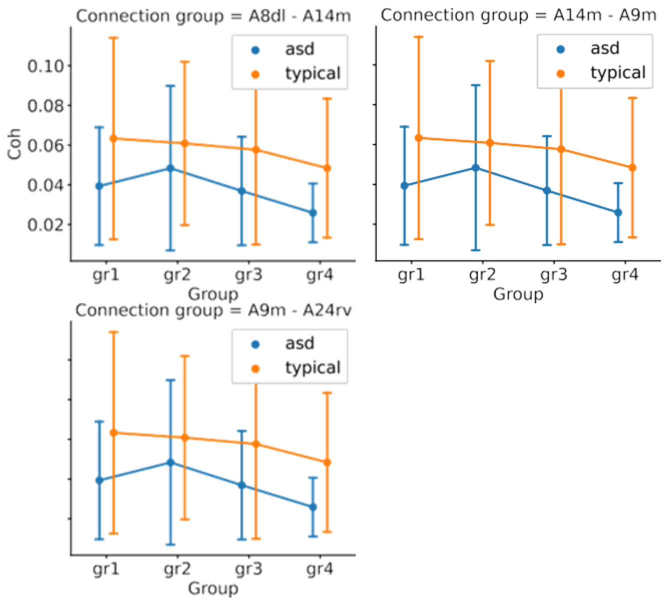

Fig 5.The difference in coherence measure of the connections between the age groups gr1–gr4 for ASD and Typical groups: mean± SD.

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Statistical analysis using the FDR revealed another network pattern in the extended α-band as shown in fig 6. in which the coupling strength is influenced by the interaction of the factors Diagnosis and Age group. In the first and second age groups, these connections are stronger for the ASD group, and in the third and fourth— for the Typical group.

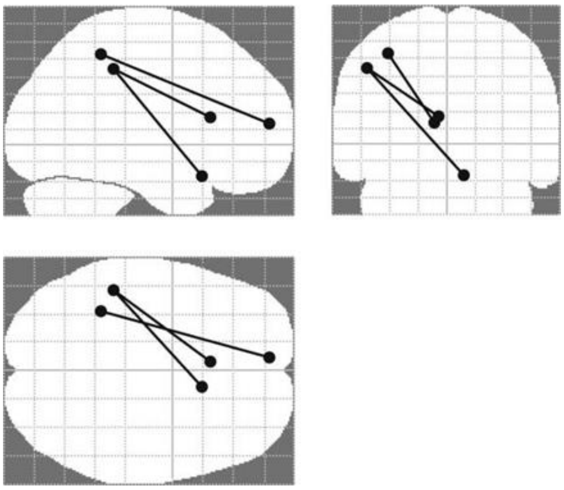

Fig. 6 The functional connectivity in coronal, axial, and sagittal projections of the brain in α-range (2–6 Hz)assessed via FDR.

The presented connections differ significantly both between ASD and Typical groups and gr1–gr4 groups: (connection 1, f -value =14.3) right orbital gyrus, area 13 (A13)—left lower parietal lobe, rostrodorsal area 40 (A40rd); (connection 2, f -value =14.9) A40rd—left cingulate gyrus, rostroventral area 24 (A24rv); (connection 3,f -value = 15.2) right superior parietal lobe, lateral area 5 (A5l)—left superior frontal gyrus, medial area 10 (A10m).

The underlying functional network differences among different ASD children groups with varying symptom severities. Specifically, after dividing ASD children into low- and high-scoring groups, those related differences were primarily investigated. As shown in fig 2.

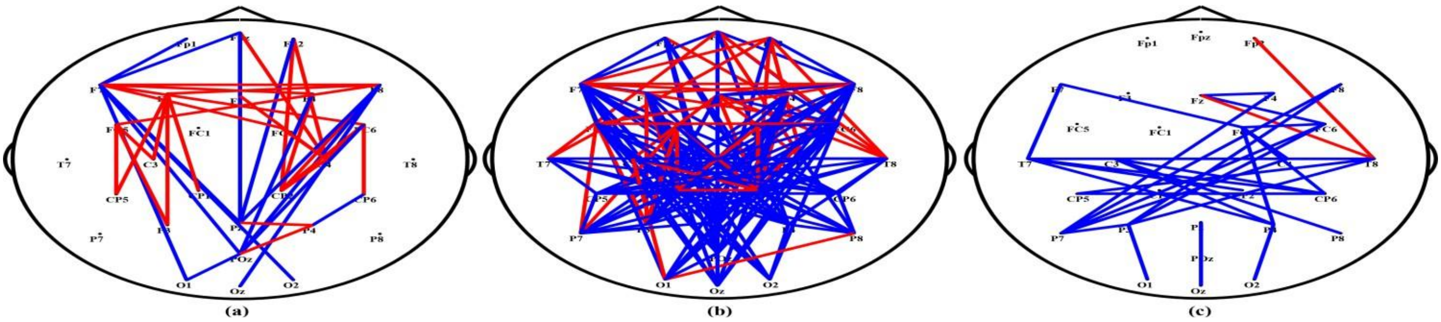

Fig.7. Scalp topological differences in functional networks among TD children, high-scoring and low- scoring ASD children. The red-solid lines in subfigure (a, b) denote that the connectivities in high- and low-scoring ASD children were significantly stronger than that of TD children, the blue-solid ones denote the opposite case.

Red-solid lines in subfigure(c) denote the decreased connectivity in high-scoring ASD children than that of low-scoring ASD children, while the blue-solid ones also denote the opposite case.

Concerning the low-scoring ASD children, both decreased long-range and increased inner frontal connectivities were consistently identified in comparison with TD children Fig.7(a)

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Apart from the network topologies, the corresponding network properties, i.e., CC, GE, LE, and CPL, were also calculated and statistically investigated, to further quantitatively the underlying network differences among the three groups.

Given the potential differences of functional networks were identified for the ASD children, the corresponding symptom severities of ASD children were further assumed to be related to their networks. Therein, for all participants (i.e., TD children, low- and high-scoring ASD children) included in this study, the potential relationships between the ADOS scores and network properties were explored. As depicted in Fig.8, the CC (r

= −0.109, p = 0.039), GE (r = −0.155, p = 0.003), and LE

(r = −0.124, p = 0.019) were negatively related to the ADOS scores, while CPL was positively related to the ADOS scores (r = 0.133, p = 0.012).

Concerning the corresponding brain networks, the Pearson correlation analysis in Fig.4 primarily validated the potential capacity of the brain networks in quantitatively explaining the pathology of ASD children, which also inspired us to further predict the corresponding ADOS scores for all of these children recruited in our present study, by adopting these network metrics as the predicting features.

Considering these EEG spectra and network metrics captured the different aspects of the EEG signals, the fusion of these features may further promote the prediction performance,

as implemented in previous studies. Therefore, the four types of EEG metrics, i.e., PSD, network properties, correlated connectivity weights, and SPN features, were concatenated together to form the new predicting features.

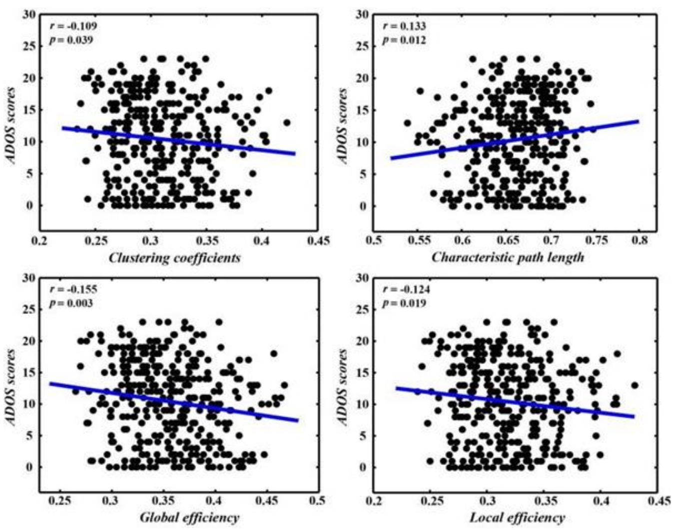

Fig. 8a. Correlation between the ADOS scores and network properties. The black-filled circles denote the children included in the Pearson correlation analysis and the blue lines denote the fitted curves of both variables.

VII. DISCUSSION

In comparison to TD children, ASD children usually experienced hypo- or hyper-connectivity among related brain regions. In current study, we further investigated the potential dysfunctional deficits in related networks among ASD children with varying symptom severities and also in comparison with those matched TD children, to identify the reliable electrophysiological biomarkers, i.e., network properties and topologies, that help predict the ASD symptom severity.
As already presented in the introduction, various studies have investigated EEG spectral power in infants at higher likelihood of developing ASD,14–17 showing that the risk of developing ASD is associated with reduced

power. values in different frequency bands. Thus, our results are in line with these findings.
Stress detection, assessment and analysis in humans are significant processes in order to confront this phenomenon. Despite the subjective dimension of stress, research pursuits on finding reliable, objective measures to effectively represent stress and measures that would not be able to be controlled or manipulated. Most of the physiological measures (guided by the ANS) are involuntary, thus there is the notion that can represent stress levels in a more reliable way.
Skin Conductance Response (SCR) and Level (SCL) appear also to be consistent measures being typically increased during stress. They are both influenced exclusively by SNS and not by the PNS which is a very significant factor for assessing stress. Regarding brain activity, the most consistent measure is the EEG alpha asymmetry index which appears to be reduced during stress conditions.
Another important issue to concern is the substantial intra- and inter-individual variability of the stress response. For a given person, the same stimulus or condition may elicit a strong or weaker stress response depending on varying social (e.g., high vs. low peer pressure), contextual (e.g., high reward vs. low reward), and cognitive-emotional parameters (e.g., instruction to engage in cognitive appraisal of the situation). Different persons may develop very disparate stress responses to the same stressor.
This review aims not only to contribute to the effective automatic stress recognition but also to give insights in understanding the underlying mechanisms of stress and its types as they are manifested in physiological biosignals.
Nowadays, the development of classifiers for identifying ASD subjects by biomarkers at the level of a functional network using machine learning methods is an urgent problem with promising prospects. Such classifiers appear to be particularly useful in cases of mild symptoms of ASD and early childhood when objective indicators of autism may be lacking. It is especially important here to take into account the age of an individual since it has been shown that specific functional connectivity patterns are transformed with age.
We believe that identifying abnormalities in the functional networks of ASD subjects is the key to developing effective

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approaches to autism therapy, which should be based on the normalization of aberrant connections. This concept is supported by modern research. Yamada et al. concluded that successful normalization of the individual's functional connectivity pattern using functional connectivity-based neurofeedback would lead to a reduction in psychiatric symptoms. Basically, the functional connectivity normalization can be achieved by different types of neurofeedback (functional-connectivity-based neurofeedback, fMRI-based neurofeedback, EEG-based, etc.), music therapy, hormonal therapies with oxytocin or vasopressin receptor antagonists, transcranial magnetic stimulation (TMS) or transcranial direct current stimulation (tDCS) of the brain.

We believe that identifying abnormalities in the functional networks of ASD children is the key to developing effective approaches to autism

therapy, which should be based on the normalization of aberrant connections.

VIII. CONCLUSION

In current study, the potential network differences were compared among ASD children with varying symptom severities and TD children. For both high- and low- scoring ASD children, the decreased long-range functional connectivity and increased anterior connectivity were statistically identified, indicating the network dysfunction occurring in ASD children, along with deficited network efficiency.

Our study provides evidence of weaker connectivity in the theta band in the frontal and limbic lobes and lower network clustering in the delta+theta band of ASD individuals for all age cohorts Thus, we revealed in the delta+theta band the more segregated but more highly connected subnets in TD individuals compared to ASD children. We observed a unique connectivity pattern in the extended alpha band, where the strength of connections is stronger in the first two age cohorts of ASD subjects and is dominated by TD subjects in the third and fourth cohorts.

We believe that identifying abnormalities in the functional networks of ASD children is the key to developing effective approaches to autism therapy, which should be based on the normalization of aberrant connections.

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