

Investigation of Atypical Autonomic Nervous System Response of Children with Special Needs

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ABSTRACT

The children with Autism Spectrum Disorder are increasing day by day as there is no cure for autism yet. Stress in general is a contributing factor to multiple health complications. However, stress is more dangerous when experienced by children with ASD, because they often react outwardly in ways unlike developmentally typical children, so tailoring the measurement and interpretation of physiological signals to children with autism is necessary. Also, these children suffer from autonomic dysregulation, hence, their physiological responses are different than normal children. Moreover, electrodermal activity is a significant indicator of stress but in case of children with ASD, there is a conflict between two researches as one research suggests that the EDA response is higher in children with ASD during high anxiety situations whereas, another research suggests they have a blunted EDA response. Therefore, this research aims at investigating the Autonomic Nervous System response of children with ASD and aims at educating the public regarding their atypical behaviour. This paper will help future researchers, parents, caregivers, and teachers to better understand and anticipate the behaviours of such children as they tend to be different from healthy children.

Keywords: Autism, autonomic nervous system, electrodermal activity, physiological signals, stress.

INTRODUCTION

The human body is made up of complex mechanisms in which it is difficult to identify a problematic state without a battery of tests. However, the body does show multiple indications in case of distress or alarming situations and those indications are known as physiological signals [1], [2] produced by the body's physiological processes. The human physiological signals include heart rate, electrodermal activity (EDA) response, body temperature, pupil diameter, brain waves, and respiration [1]. The variations in the abovesaid physiological signals highlight some problematic state such as stress, anxiety, fear, or any other form of emotional arousal [3][4]. For instance, the variation in Electrocardiogram (ECG) signal provides meaningful information regarding the heart's functionality [5]. These physiological signals are also an indication of some underlying medical conditions, hence, making these signals interesting enough to be studied and scrutinized in order to understand them and prevent harmful outcomes. The human physiological responses are governed by the Sympathetic Nervous System (SNS) and Parasympathetic Nervous System (PNS) which are the branches of Autonomic Nervous System (ANS) [1][4]. The role of SNS is to increase the rate of physiological responses in case of any alarming situation while the PNS helps regulating these rates and bringing the body back to homeostasis. This phenomenon is known as a normal or typical or regular autonomic nervous system response. On the other hand, when the rate of physiological signals decreases in presence of a stressor instead of increasing, such phenomenon is known as abnormal or atypical autonomic nervous system response and the such person is referred to as suffering from autonomic dysregulation [6]. The aim of this research is to investigate and educate people regarding the irregularity of the physiological responses also known as autonomic dysregulation experienced by the children with Autism Spectrum Disorder (ASD).

A. Literature Review

Previously, many physiological signals have been studied for the purpose of stress, anxiety, and emotion recognition. For instance, in [7], only skin conductance was used to detect human stress along with two accelerometers and achieved an accuracy of 94.7%. The experimental phase consisted of arithmetic problems as stressors which were meant to be solved by intended subjects and decision tree classifier was used for this study. The accelerometers were used for differentiating between stress and physical activity, however, the use of skin conductance as a significant stress indicator is still under scrutiny for children with ASD. Moreover, in [8] galvanic skin response sensor was used to measure skin conductance for the purpose of stress detection. The ADWIN and Fit methods were used in this study. It is a good research with a detailed explanation but lacks the element of

wider subject range as the data was only collected from 5 subjects. Later in [9], a team of researchers monitored cardiac activity of participants during some activities with the help of a wireless chest belt. The research monitored cardiac response of 10 participants including 5 children with ASD and 5 children with language disorder between the age of 2 – 5 years. The research showed an increase in cardiac response during designed activities. In another research [10], the researchers collected two physiological signals named GSR and ECG for stress detection. The features were extracted using the Fisher's discriminant criteria and Support Vector Machine (SVM) was used for stress classification. In the same line of research, [11] used heart rate, EDA response, and body temperature signals for classifying stress levels. The researcher used fuzzy logic, decision tree, Naïve Bayes, and K-NN classifiers and found that the fuzzy logic achieved an accuracy of 96% whereas the accuracy of other techniques was lower. The data was collected from 35 participants and arithmetic game was used to induce stress in participants. In [12], changes in ANS were measured to determine stress among 15 children with ASD and 18 children without ASD. It was observed that cardiac activity was increased in children with ASD during baseline and anxiety induction test while the perspiration response was normal, and no change was found in skin temperature either. Whereas, in children without ASD, the cardiac activity, perspiration, and temperature were only elevated during the experiment. Similarly, in [13], heart rate, GSR, and temperature signals were measured from both, normal and autistic children. The research highlighted that autistic children have elevated GSR response in low-anxiety and in high-anxiety situations as well. Another research [14] also acquired heart rate, EDA response, and body temperature signals for anxiety detection and reported a blunted EDA response in children with ASD during high-anxiety situations. They used Stroop Color Word (SCW) test for inducing stress in twenty-nine children including 17 normal children and 12 children with ASD.

MATERIALS AND METHODS

A. Participants

The physiological signal datasets were collected from two groups of children with a total number of 90 participants. The first group (G1) was of normal children ($n = 55$) within the age range of 4 – 12 years and the second group (G2) was of children with ASD ($n = 35$) within the age range of 4 – 12 years. The children in ASD group were selected from autistic centers and are diagnosed with ASD. The children in normal group were selected from a school and do not have any mental or physical disabilities. All the parents of children were given consent forms prior to the data acquisition which contained all the information regarding the study. Further demographic details of all the participants are provided in Table I.

TABLE I. DETAILS OF PARTICIPANTS

	G1	G2
Participants	Normal Children	Children with ASD
No. of Participants	55	35
Gender (Male:Female)	30:25	24:11
Age Range (years)	4 – 12	4 – 12

B. Stress Inducing Technique

The Stroop Color and Word Test (SCWT) is a neuropsychological test extensively used for both experimental and clinical purposes [20]. It assesses the ability to inhibit cognitive interference, which occurs when the processing of a stimulus feature affects the simultaneous processing of another attribute of the same stimulus [21]. In the most common version of the SCWT, which was originally proposed by Stroop in 1935, subjects are required to read three different tables as fast as possible. Two of them represent the “congruous condition” in which participants are required to read names of colors (henceforth referred to as color-words) printed in black ink (W) and name different color patches (C). Conversely, in the third table, named color-word (CW) condition, color-words are printed in an inconsistent color ink (for instance the word “red” is printed in green ink). Thus, in this incongruent condition, participants are required to name the color of the ink instead of reading the word. In other words, the participants are required to perform a less automated task (i.e., naming ink color) while inhibiting the interference arising from a more automated task. This difficulty in inhibiting the more automated process is called the Stroop effect.

The SCW test was used for inducing stress in the participants based on [20] and was divided into two segments; congruent and incongruent. The test consisted of three phases and each phase comprised of 30 questions. The first phase was relatively easier, then the second phase was designed to be a bit more difficult as it introduced the time limit while the third phase was designed to be very difficult. The first phase was of 5 minutes and the second phase was of 2.5 minutes with a time limit of 5secs/question. The third phase of the experiment was of 1 minute and 20 seconds with a time limit of 2 secs/question. The first two phases were based on the congruent segment of the SCW test while the last phase was based on the incongruent segment. The SCW test was designed with the help of a software named “Wondershare Quiz Creator” as it offered all the necessary features required for this experiment. A snapshot of the quiz (experiment) is shown in Figure 1 and the summary of the phases are as tabulated in Table II.

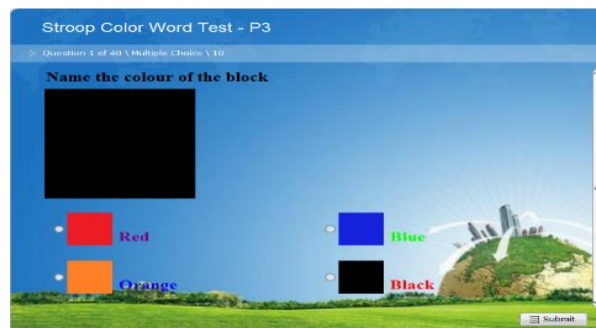


Figure 1. Sample of SCW Test

TABLE II. SUMMARY OF PHASES

Phase	Duration (time limit)	No. of questions	Frequency	Difficulty
P1	5 mins	30	NA	Low
P2	2.5 mins	30	5 secs / question	Medium
P3	1 min 20 secs	30	2 secs / question	High

C. Data Acquisition

The procedure for data acquisition was completely non-invasive and took approximately 10 minutes per participant and each participant was required to visit only once for this session. The E4 wristband by Empatica [15], was used for recording physiological response signals from all the participants. The device houses four sensors including photoplethysmography (PPG) sensor, EDA sensor, temperature sensor, and a 3-axis accelerometer [16]. The detailed step by step procedures for data acquisition are as follows:

- i. Participants were asked to sit in a calm environment.
- ii. Participants were asked to fill a form consisting of details such as, random identification number, age, gender, and medical history/diagnosis/condition.
- iii. The E4 wristband was fastened to the participant's wrist in a manner that it was neither too tight nor too loose as shown in Figure 2.



Figure 2. E4 Wristband Fastened to Participant's Wrist

- iv. For the baseline recordings, the participants were asked to close their eyes and relax for 1 minute.
- v. The participants were asked to solve the SCW test consisting of the abovementioned three phases.

D. Data Analysis

The obtained signals of both groups G1 and G2 were preprocessed in MATLAB for noise and artefact removal. In addition to that, the signals were statistically analyzed with the help of t-test to identify the significance of difference between the two datasets. If the obtained value of the t-test is less than 0.05, then it is said to be statistically significant, otherwise, the difference will be statistically insignificant.

RESULTS AND DISCUSSIONS

The E4 wristband acquired 1920 samples of EDA response at a frequency of 4Hz, 15360 samples of heart rate signal at a frequency of 32Hz, and 1920 samples of temperature signal at a frequency of 4Hz. The obtained signals were preprocessed by applying an averaging filter for removing noise and artefacts. Later, the signals were compared in MATLAB using the built-in Signal Analyzer application to identify the differences in signal amplitudes between the two groups.

The typical/normal response of a person during the presence of a stress is that the physiological signals including heart rate, skin conductance, and temperature are increased in magnitude. This typical response was observed in G1 and in G2 as well, except for the EDA response signal. As in case of children with ASD, as found in previous literature, they suffer from autonomic dysregulation, therefore, they have atypical ANS response. Similar case is highlighted in this research that the mean of obtained samples of EDA response shown in Figure 3 depict that the EDA response of G2 is either blunt or decreases in the presence of a stressor as compared to G1. Such EDA response reflects that the children with ASD have atypical ANS response. Furthermore, the obtained results also support the research [14], stating that the EDA response of children with ASD is blunt or lower as compared to the EDA response of normal children. Hence, resolving the conflict between the two researchers [13], [14] mentioned earlier in section I.

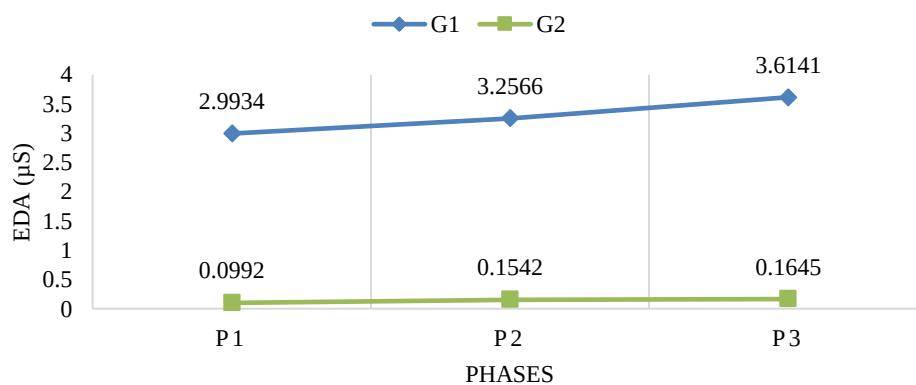


Figure 3. Mean of EDA Response Signals of G1 and G2

Moreover, after performing the statistical analysis, the research obtained a t-test value of 0.0254 which shows that the difference between the physiological signals obtained from children with ASD and normal children is statistically significant. The SCW test caused a significant increase of tonic and phasic EDA levels in G1 and this effect is in accordance with the regular ANS response to a stressor. This also proves the applicability of the SCW test for inducing stress. However, there was minimal changes in phasic and tonic EDA responses of G2. The obtained results show that the children with ASD suffer from autonomic dysregulation, hence, they depict an atypical ANS response in the presence of stressors. Furthermore, the results also support the research [14], stating that the EDA response of children with ASD is blunt or lower as compared to the EDA response of normal children. Finally, the variance of the acquired signals was also calculated, and it highlighted that the variance of G2 was very low as compared to the variance of G1 only in case of the EDA response signals. Hence, this can be used in the development of a classifier that can differentiate between the children with ASD and normal children as this is greatly required for stress monitoring applications.

CONCLUSIONS

The study aimed at developing an understanding of the sympathetic response of children with ASD in presence of unpleasant (stressing) stimuli. The physiological response datasets were acquired from two groups G1 and G2, where, G1 included 55 normal children and G2 included 35 children with ASD. The obtained results of this study highlight that EDA response is a significant indicator of distress in case of G1. However, in case of G2, the results show an atypical ANS response in presence of a stressor, hence, making the EDA response an insignificant distress marker for children with ASD.

Nevertheless, the temperature response of both groups was found to be normal as it increased in the presence of stressor. Moreover, an increased heart rate activity was also observed in the two groups during the SCW test. Thus, this study found a hypoactive sympathetic response of G2 only in case of the electrodermal activity response as opposed to the hyperactive response which was suggested in previous research. However, a normal behavior was observed in the remaining two signals. The obtained results also show a possibility of classifying the normal children and children with ASD based on the variance of EDA response signal only. Hence, it is concluded that the children with ASD do suffer from autonomic dysregulation and further research on the physiological signals of these children is required in order to better understand their emotional states and educate the parents and caregivers.

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