Stress Detection in Individuals Due to Virtual Gaming

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Abstract: Modern gaming consists of digital games that involve interaction with a user interface to generate visual feedback through video game consoles on a monitor. These gaming have several psychological side effects like loss of spatial awareness, back pains, insomnia, addiction, aggression, stress, and hypertension. The main focus of this paper is on detection of stress levels in individuals due to virtual reality (VR) gaming as it is one of the most emerging and novel technologies in the field of entertainment. This is done by acquiring Electrocardiogram (ECG), extracting its time domain and frequency domain features before, during and after gaming [2, 3]. The physiological signal variation is analysed by performing Heart rate variability (HRV) analysis which is one of the fast emerging methods in non-invasive research and clinical tools for assessing autonomic nervous system function [1]. The features used for the analysis is measurement of successive RR interval values which constitutes a time domain feature, while the measure of Power spectral density (PSD), constituting a frequency domain feature. The game chosen for the data acquisition was '*VR city view rope crossing - 360 android VR*', during which data recording is done. It was found that there was a quantitative increase in physiological stress when individuals were exposed to virtual high heights in comparison with time relative to unaltered viewing. Mean Heart rate showed a significant increase during gaming for both boys and girls which indicates that the body is under the influence of a sympathetic activity like a physical exercise.

1. Introduction

Stress is the body's method of reacting to a condition such as a threat, challenge or physical and psychological barrier. Stimuli that alter an organism's environment are responded to by multiple systems in the body. The autonomic nervous system and hypothalamic-pituitary-adrenal (HPA) axis are two major systems that respond to stress. During stressful moments, the heart beats faster than it usually does so that the parts of your body which are needed to cope up with the stress would be supplied by enough oxygenated blood to remain functional until the stressful situation subsides. From beat to beat, heart rate is constantly changing to meet the needs of life. Heart rate variability (HRV) means the variation in time between

consecutive heartbeats. It is universally accepted as a non-invasive marker of autonomic nervous system (ANS) activity. Heart rate variability increases during relaxing and recovering activities and decreases during stress. Accordingly, HRV is typically higher when the heart is beating slowly and decreases as the heart beats more quickly. In other words, heart rate and HRV have a generally inverse relationship.

1.1 Electrocardiography (ECG or EKG)

Electrocardiography (ECG or EKG) is the method of recording the electrical action of the heart over some stretch of time utilizing non-invasive electrodes put on the skin. It represents the electrical changes on the skin that emerge from the heart muscle's electrophysiological action of depolarizing and repolarizing amid every pulse. HRV is the physiological phenomenon of variation in the time interval between heartbeats. It also signifies the variation in cardiovascular activity vasoconstrictor and vasodilatation centres in brain. It is measured by the variation in the beat-to-beat interval or the duration of the R–R interval [1].

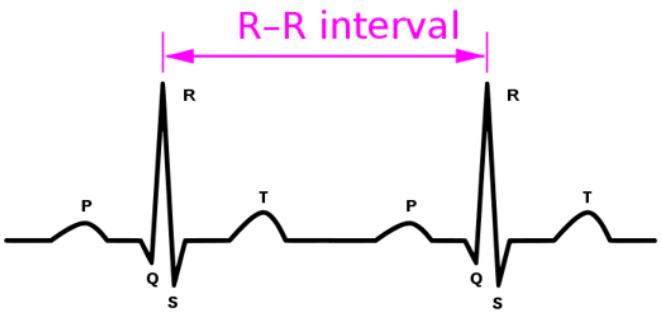

Fig. 1 ECG Waveform

Normally these fluctuations are a result of blood pressure oscillation, respiration and thermoregulation. All these factors can influence the length of beat-to-beat intervals. The actual balance between their activities is constantly changing in response to physiological and physical activities.

HRV analysis is done mainly in 2 ways: Time Domain Analysis and Frequency Domain Analysis. The time domain methods are computationally simple, and they are applied directly to the series of successive RR interval values. In frequency domain we make use of Power spectral density (PSD), using parametric or nonparametric methods, provides basic information on the power distribution across frequencies. One of the most commonly used PSD methods is the Discrete Fourier Transform. Methods for the calculation of PSD may be generally classified as nonparametric and parametric. In most instances, both methods

provide comparable results. Table.1, below shows some of the evident metrics in both time and frequency domains.

Table.1: HRV metrics for both Time and Frequency domain Analysis

	Time Domain Metrics		Frequency Domain Metrics
Method 1	RMSSD (ms) – The square root of the mean of the sum of the squares of differences between adjacent NN intervals	**Method 5**	LF measurements - Low Frequency ranging from 0.04 to 0.15 Hz
Method 2	SDNN (ms) – Standard deviation of the NN intervals in all 5-minute segments of the entire recording.	**Method 6**	VLF Measurements-Very low frequency ranging from 0.0033 to 0.04 Hz
Method 3	NN50: The number of pairs of successive NNs that differ by more than 50 ms	**Method 7**	HF Measurements - High Frequency ranging from 0.15 to 0.4 Hz
Method 4	pNN50: The proportion of NN50 divided by total number of NNs.	**Method 8**	LF/HF ratio- derived from peaks of periodogram of the ECG signal

1.2 Organization of the paper

This paper provides an overview of variation of HRV when individuals are subjected to VR gaming. Chapter 2 gives a glimpse of literature survey. Chapter 3 discusses about the game setup and the methodology used. The results are depicted in Chapter 4 and a brief conclusion along with future works are discussed in Chapter 5, followed by bibliographic references as Chapter 6.

2. Literature Review

In most of the literature viewed, Analysis of HRV consists of a series of measurements of successive RR interval variations of sinus origin which provide information about autonomic tone Different physiological factors may influence HRV such as gender, age, circadian rhythm, respiration and body position. Measurements of HRV are non-invasive and highly reproducible [1]. They may generally be performed on the basis of 24-hour Holter recordings

or on shorter periods ranging from 0.5 to 5 minutes particularly in the field of dynamic electrocardiography [1].

A study on virtual high height condition increased heart rate variability and heart rate frequency power relative to virtual low heights [7]. Virtual reality provides realistic experiences that can induce physiological stress in humans during dynamic balance tasks, but virtual reality use impaired physical and cognitive performance during balance.

The HRV parameters that were standardized were RMSSD, LF (n.u.), HF (n.u.), LF/HF ratio. Parameters like pNN50, NN50, SDNN, VLF and ULF were considered in very few papers [2, 3, 4]. All the papers claimed that the HRV parameters were standardized for their respective group. Due to the highly variable nature of the pNN50, SDNN, VLF and ULF which were more prominent for 24-hour HRV, the LF/HF ratio and RMSSD (used in 4 papers) is used to determine SNS activity during Virtual Reality Gaming.

Depending on the above litrature, we have used *Method 1*, for time domain Analysis and *Method 8,* for frequency domain analysis. Hence we measure RMSSD(in ms) and LF/HF Ratio for data evaluation and conclusions.

3. Methodology:

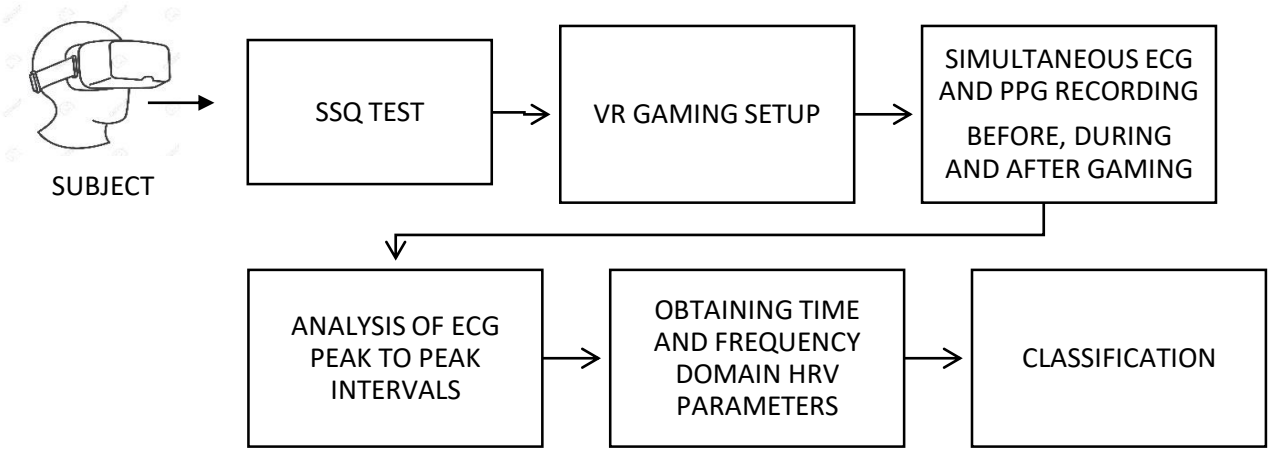

Fig. 2: Block Diagram view of the Proposed Methodology

3.1 Data Acquisition:

We have acquired ECG recordings, using the BIOPAC-MP36 Module from 30 individuals (15 males and 15 females) of Indian race between the age group of 18-22, along with subjective question are and feedback before and after gaming respectively.

All subjects provided written informed consent. Thirty healthy subjects participated in the study (18 female, 16 male, age 20±3 years old (mean ± SD). All Subjects were enquired for any orthopaedic, cardiac, or neurological conditions and injuries, for which the interaction turned out to be positive. Any subjects indicating, they experienced acrophobia (fear of heights) were excluded from the study because we wanted all subjects to be able to complete the full experiment. Prior to the main experiment session, subjects were screened for motion sickness in virtual reality. Subjects were asked to fill in a Simulator Sickness Questionnaire (SSQ). The data collection environment is a sound-proof room with normal conditions. *BIOPAC-MP36* instrument is used to record ECG data from the individuals. It consists of 4 separate channels CH1-CH4 the channel CH1 was used to connect the ECG leads. The game chosen for signal acquisition was 'VR city view rope crossing - 360 android VR' The setup was made keeping in mind the level of immersion the subject feels and the difficulty level was kept at par with the rope crossing in reality as much as possible.

The data, ECG signals were recorded for a total duration of 5 minutes and 40 seconds, which includes 5 minutes [7] of data recording while gaming and 20seconds data recording before and after gaming. After initial 20 seconds of data recording, test subjects were then asked to put on the head mounted display (HMD) of the VR (VR Box version 2.0) and adjust the sharpness of the image if necessary. We chose the game *"VR city view rope crossing - 360 android VR"*, during which 5 minutes of data recording while gaming was taken. Another 20 seconds of data was recorded after gaming.

3.2 Gaming setup

The setup consisted of a stable wooden plank (21x14 inches) with a little elevation from the ground. A thick rope was cut according to the dimensions of the plank and fixed across the middle. All subjects were made to balance on the rope, keeping their feet aligned and placed on the rope as shown in Fig. 3 below. They were asked to hold a wooden pole (46 inch), equally weighted at both ends (using pebbles in bottles), in their hands, near their centre of gravity. They were asked to keep their body and hands stable, during the activity. The VR box was used with the smartphone placed inside it, projected at the eyes, creating a stereoscopic effect which gives users the illusion of depth. The VR Box was attached to the subject's head and the VR- compatible game was started while holding the wooden pole and balancing on the rope.

Fig. 3: Gaming Set

3.3 Observation

The following table (Table. 2) gives details of all the subjects who have signed a consent form to give their acceptance for acquisition of ECG signals

Table. 2 Subject details

SEX	No. of Samples	Age in years	HEIGHT	WEIGHT in (Kgs)
MALE	15	18-23	150 cm – 190 cm	45 Kgs – 90 Kgs
FEMALE	15	18-23	140 cm – 175 cm	45 Kgs – 65 Kgs

We have made use of limb leads in the lead II configuration. (Right Hand-White, Left leg-Red, Right leg(reference)- Black). Lead II is used more frequently because most of the heart's electrical current flows toward its positive axis. This lead gives the best view of the ECG waves and best shows the heart's conduction system's activity. Table. 3, below gives the specifications are chosen for CH 1 and CH 2 on BSL software:

Table. 3: BIOPAC Channel Specifications

Parameters	**CH-1 Specifications of BIOPAC-MP36**	**CH-2 Specifications of BIOPAC-MP36**
Input signal range	0.5-35 Hz	0.5-35 Hz
1st Order Digital LPF	Cut off frequency: 66.5 Hz, Q=0.5	Cut off frequency: 66.5 Hz, Q=0.5
Amplifier gain	1000	5000
Input Coupling	AC	AC
Sampling frequency	1000Hz	1000Hz

3.4 Data evaluation

Data evaluation was carried out in a series of 4 steps:

1. RR interval extraction of ECG signal using Pan-Tompkins algorithm [7].
2. R wave (ECG) – Foot of P wave (PPG) interval extraction using Pan-Tompkins algorithm
3. Calculate the HRV using time domain parameters.
4. Calculate the HRV using frequency domain parameters.

4. Results

4.1 Simulator Sickness Questionnaire (SSQ) Feedback

All subjects were asked to give a feedback before and after the gaming, called the Simulator Sickness Questionnaire (SSQ) Feedback, where 16 parameters were evaluated. This questionnaire contained 16 symptoms that were identified [8] as relevant for indicating simulator sickness. The symptoms are: 1. General Discomfort, 2. Fatigue, 3. Headache, 4. Eye Strain, 5. Difficulty Focusing, 6. Increased Salivation, 7. Sweating, 8. Nausea, 9. Difficulty Concentrating, 10. Fullness of Head, 11. Blurred Vision, 12. Dizzy (Eyes Open) 13. Dizzy (Eyes Closed), 14. Vertigo, 15. Stomach Awareness, and 16. Burping. For each of the symptoms four different level of response is possible i.e. None, Slight, Moderate and Severe. The details are shown in Table. 4 below.

Table. 4 Simulator Sickness Questionnaire (SSQ) Feed-back

Sl. No.	SSQ symptom	Before Gaming				After Gaming			
Severity Range		None	Slight	Moderate	Severe	None	Slight	Moderate	Severe
1.	General discomfort	97%	3%	-	-	67%	30%	3%	-
2.	Fatigue	97%	3%	-	-	93%	7%	-	-
3.	Headache	93%	7%	-	-	77%	20%	3%	-
4.	Eye strain	87%	13%	-	-	53%	37%	10%	-
5.	Difficulty in focusing	83%	17%	-	-	73%	24%	3%	-
6.	Increased salivation	93%	7%	-	-	90%	10%	-	-
7.	Sweating	83%	17%	-	-	73%	20%	7%	-
8.	Nausea	100%		-	-	97%	3%	-	-
9.	Difficulty concentrating	87%	13%	-	-	77%	20%	3%	-
10.	Fullness of head	87%	13%	-	-	57%	33%	10%	-
11.	Blurred	100%		-	-	73%	24%	3%	-

	vision								
12.	Dizziness (eyes open)	97%	3%	-	-	87%	10%	3%	-
13.	Dizziness (eyes closed)	97%	3%	-	-	93%	7%	-	-
14.	Vertigo	93%	7%	-	-	87%	10%	3%	-
15.	Stomach awareness	97%	3%	-	-	93%	7%	-	-
16.	Burping	100%		-	-	97%	3%	-	-

4.2 HRV Measurement

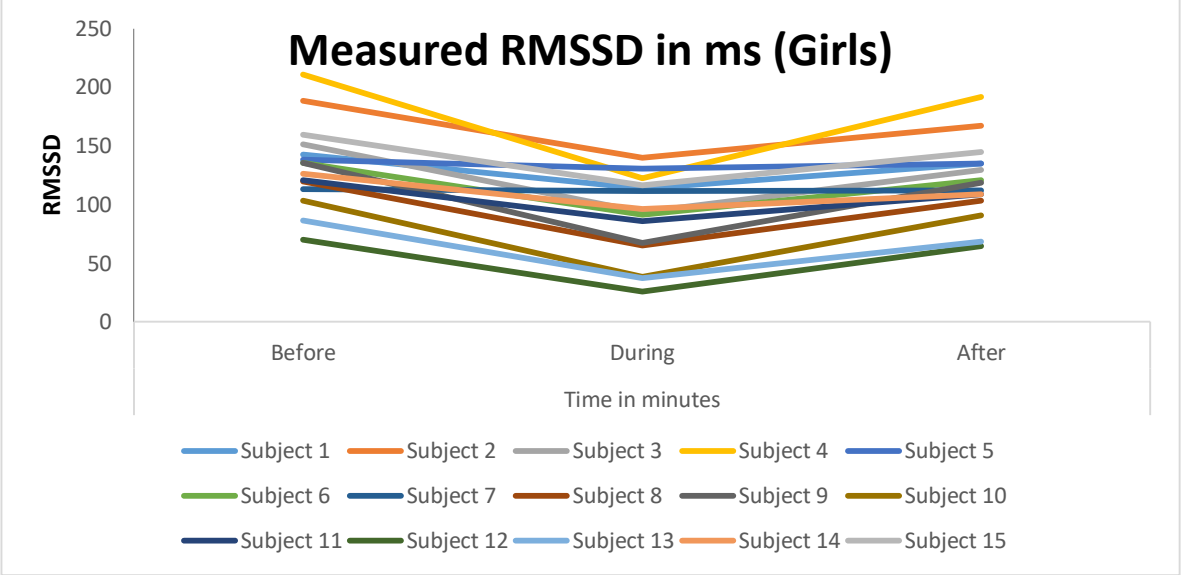

Fig. 4: RMSSD Variation for Girls

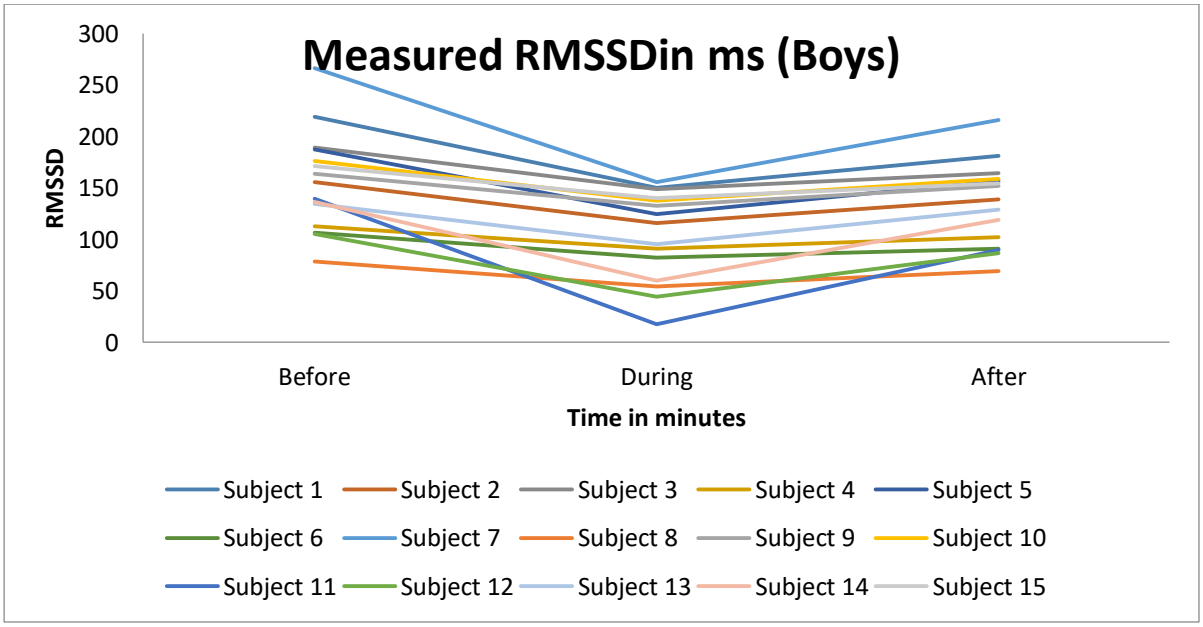

Fig. 5: RMSSD Variation for Boys

We found significant decrease in RMSSD during virtual reality gaming compared to unaltered vision for both girls and boys are respectively shown in fig. 4, 5 above. Heart Rate (HR) was found to increase for all subjects with the mean HR significantly higher for boys in all cases fig. 6, 7. Boys showed a higher mean RMSSD (Higher HRV) than girls. The LF/HF ratio showed an increasing trend while gaming, shown in fig. 8, 9 below. Also the ECG recordings of subject 9 under male category is shown below in Fig. 10.

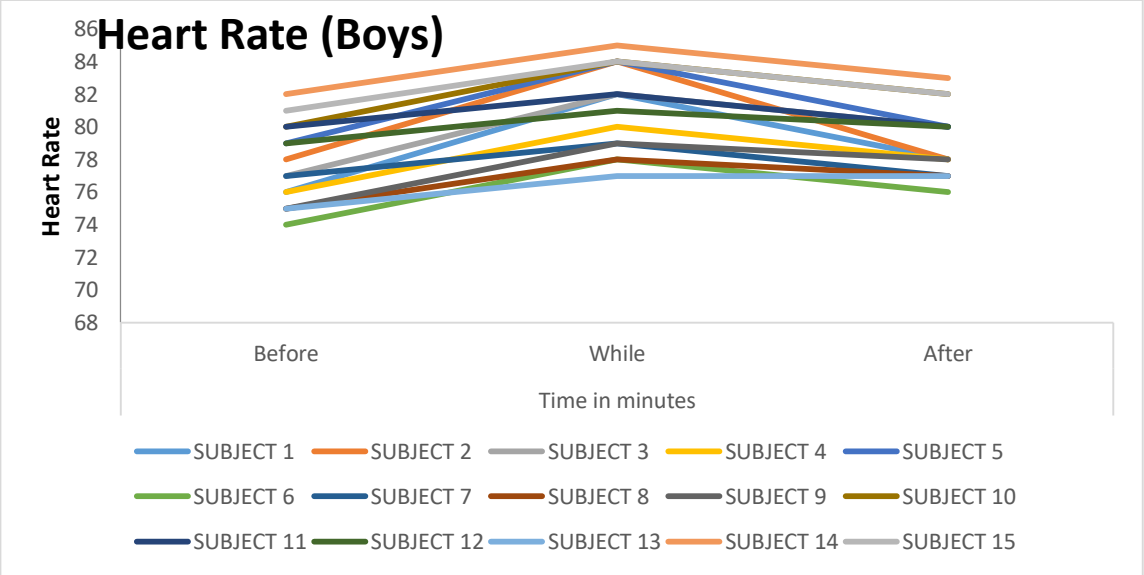

Fig.6: Variation of Heart Rate for Boys

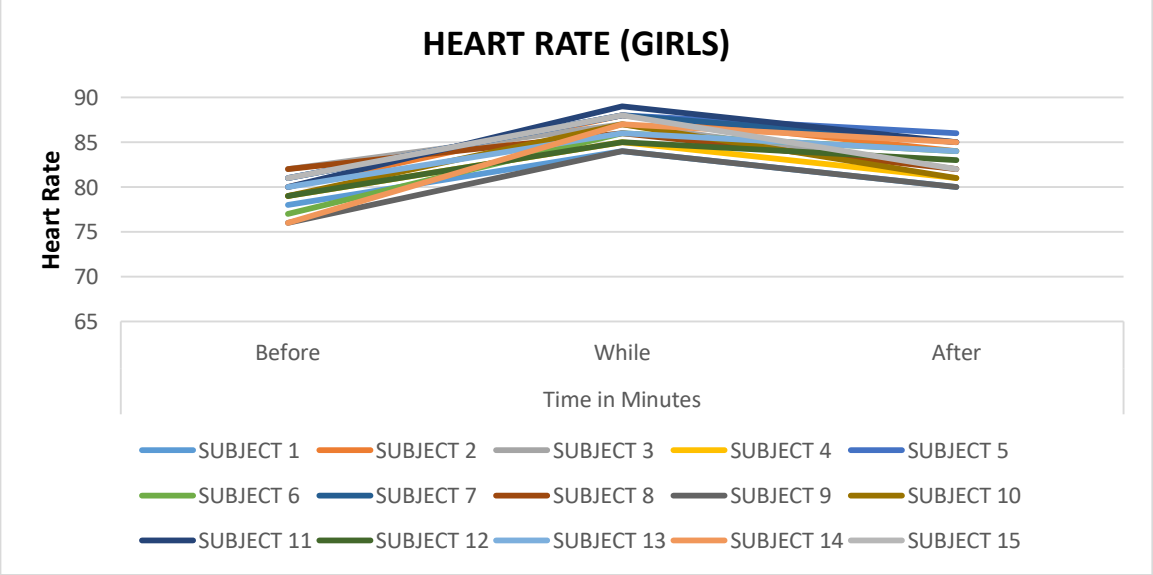

Fig.7: Variation of Heart Rate for Girls

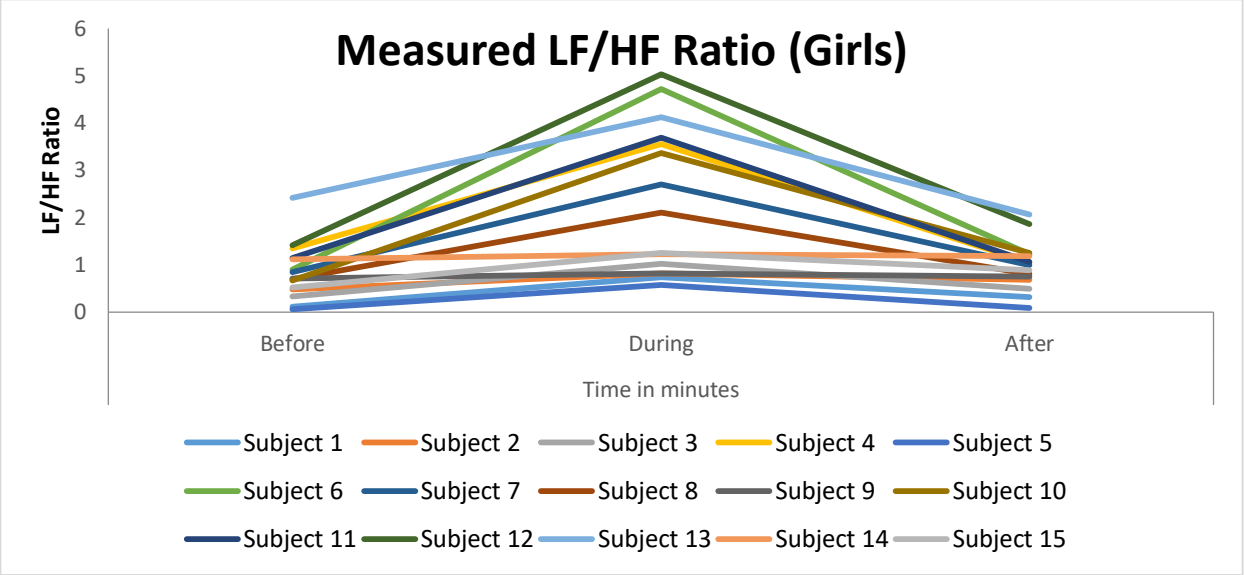

Fig. 8: LF/HF Ratio Variation for Girls

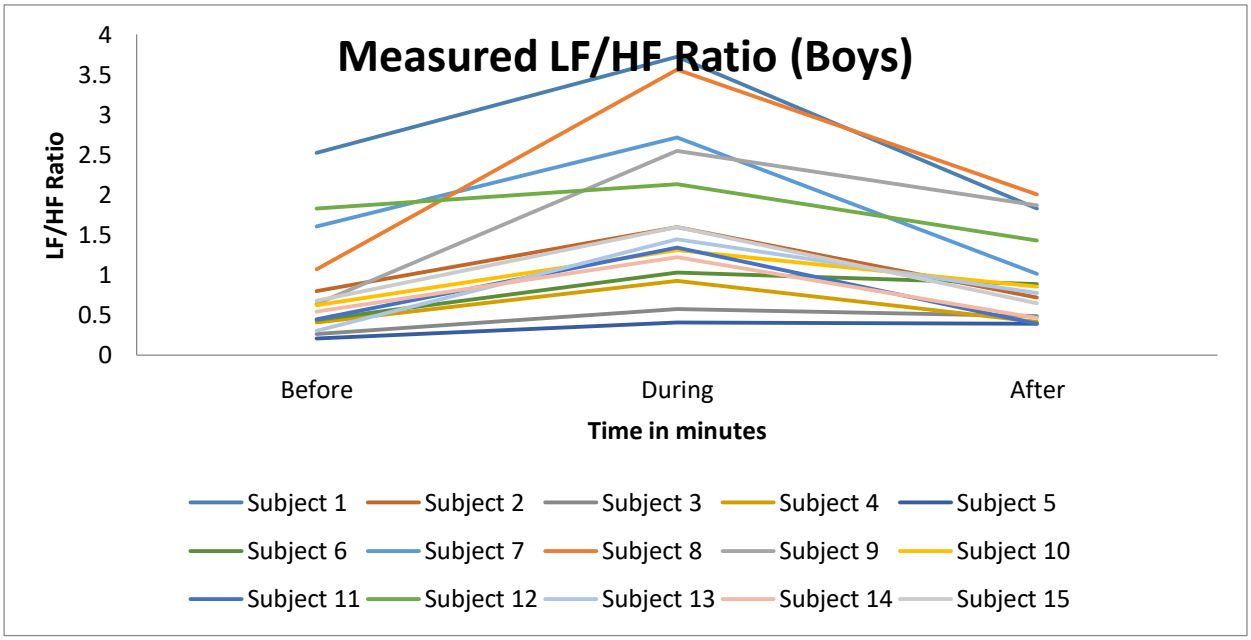

Fig. 9: LF/HF Ratio Variation for Boys

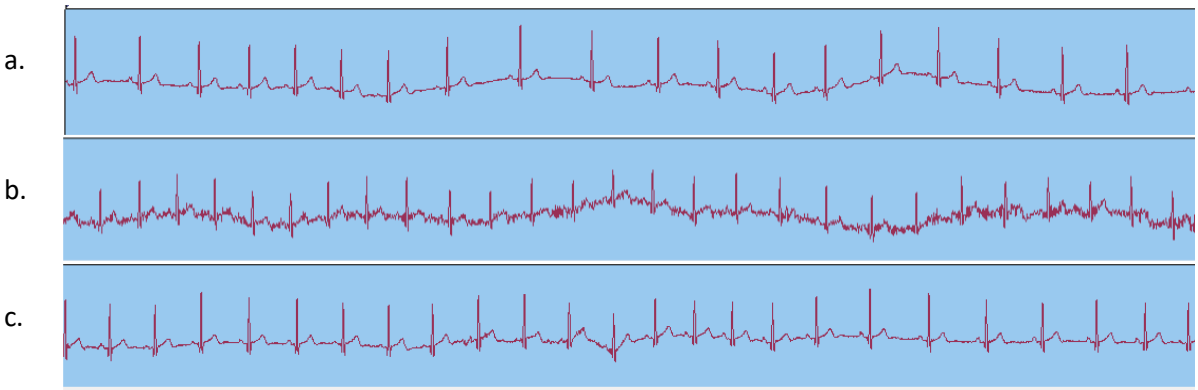

Fig. 10: ECG of subject9 under male category

a. ECG before gaming, b. ECG during gaming, c. ECG after gaming

5. Conclusions and Future works

5.1 Conclusions

RMSSD showed a significant drop during gaming as seen from Table 4.1 for both girls and boys. This indicates that the mean HRV is showing a downward trend in all subjects. A low HRV is correlated with dominant sympathetic activity and in turn can be an indicator of stress during gaming.

LF/HF Ratio: LF is an principal indicator of sympathetic activity and HF is an indicator of parasympathetic activity dominance. The LF/HF ratio is found to increase during VR gaming showing a steady LF power and a fall in HF power. The LF/HF ratio can be shown to correlate with stress and indicates a high sympathetic activity during VR Gaming.

Heart Rate: Mean Heart rate showed a significant increase during gaming for both boys and girls which indicates that the body is under the influence of a symmpathetic activity.

5.2 Gender Classification Based on Physiological Signals

Mean Heart Rate before, and during VR Gaming was found to be significantly higher for boys than for girls which could act as an indicator of more physical activity among Indian Ethic boys in their teens. ***Mean Heart Rate Variability*** before, and during VR Gaming was found to be significantly higher for boys than for girls which could be act as an indicator of better overall health among the Indian Ethnic boys in their teens. The same can be justified with the indication of a comparatively low LF/HF ratio for boys in comparison with girls, sympathetic response is high in girls when compared to boys.The same is tabulated in Table. 5 below.

Table. 5 Mean ECG Parameters

	Before	During	After
Mean RMSSD (Girls)	133.408	88.92	119.86
Mean RMSSD (Boys)	156.132	103.259	133.798
Mean Heart Rate (Girls)	79.538	86.385	82.846
Mean Heart Rate (Boys)	77.623	81.267	79.067
Mean LF/HF Ratio (Girls)	0.852	2.385	0.9824
Mean LF/HF Ratio (Boys)	0.826	1.743	0.9452

5.3 Future Scope

The following are the works that has to be taken forward regarding this paper

- Identification of levels of stress, at an early stage, during VR Gaming addiction, can increase the longevity of individuals and prevent risks associated with these disorders.
- Creating an user iterface to classify the parameters based on sympathetic and parasympathetic activity.
- Long term of HRV analysis (24 hr data) to detect metabolisim and Circadian rhythm changes while long term gaming (long term side effects).
- To find effects of VR gaming on children and understand their physiological impacts.
- Standardizing HRV values for the entire ethnic group if sufficient sample size is achieved (approximately 2000).
- HRV analysis to diffrentiate between gamers and non gamers, based on time and frequency domain parameters.

6. References

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