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Investigation of the Effect of eSport on HRV Signal by Using Poincaré Plot Analysis

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ABSTRACT

In this work, in order to determination of effect of a puzzle video game on HRV (Heart rate variability) signal, Poincare plot analysis is used. The linear and nonlinear dynamics of HRV were evaluated using HRV recordings obtained from each player at the time of play and rest. For this purpose, we have correlated the Poincaré plot descriptors with standard HRV measures derived from time- and frequency-domain methods. In addition, the correlations between the descriptors of the Poincaré plot along with the frequency and time domain measures of HRV have evaluated for the game stage. Statistically significant values were observed in eSport players in gaming and during resting. The obtained results show that play and rest can be separated by using the features obtained from the Poincare plot.

1. INTRODUCTION

To date, competitive video gaming has not been widely studied in the literature [1]. Professional competitive video games, also known as electronic sports (eSports), consist of professional players who regularly compete in tournaments and are managed by the gaming community [2]. In recent years, the popularity of eSports events has grown tremendously [3], especially among youth. Video gamers may be happy with eSports events. But especially when teenagers play for a long time, the person may show pathological symptoms. Even situations such as depression, loneliness, and anxiety can be seen in addicted teens [4]. Due to the increase in popularity and its positive and negative effects, research interest in eSports has increased. Physical and psychological signals have been ever increasingly used for gaming studies. The most popular biomedical signals studied are electroencephalography, cardiac activity, facial electromyography, event-related potentials, skin conductance level, and functional magnetic resonance imaging [5].

In this work, physiological responses to the eSport game were measured using cardiac activity signals. The heart rate is the heartbeats number per minute, calculated by measuring the time interval between two R peaks in the electrocardiogram (ECG) signal. The heart rate is influenced by various facts, such as stress conditions and exercise [6, 7].

HRV is the phenomenon of the variation in the time intervals between sequential heartbeats [8]. The HRV analysis can be performed as long-term, short-term and ultra-short-term [8, 9]. While short recordings are generally more useful when the acute effect of any factor is wanted to be studied, long-term recordings are preferred for cardiac health evaluations [9].

There are many techniques including, frequency domain, time-domain and non-linear methods for the analysis of HRV. Time domain analysis derives HRV using either statistical or geometrical methods. The root mean square of successive differences (RMSSD) and the standard deviation of NN intervals (SDNN) values are obtained by using the time-domain technique. The method of frequency domain uses results at different frequency bandwidths by converting the NN interval using the FFT (fast Fourier transform). The used ranges in this technique are the VLF (0.003 Hz – 0.04 Hz), the LF (0.04 Hz –0.15 Hz), the HF (0.15 Hz –0.4 Hz), and the LF/HF ratio.

The HRV is closely associated with the autonomic nervous system and reflects the influences of sympathetic and parasympathetic nervous systems in the sinoatrial node. The RMSSD [10, 11], and the HF indicates the degree of the parasympathetic activity, while the LF reflects the degree of sympathetic activity [12]. The power of HF is highly correlated to the RMSSD [13, 14]. The ratio of LF/HF represents the balance among the sympathetic and parasympathetic nerves. The sympathetic nervous system activity conduces to LF power, and parasympathetic nervous system activity mainly conduces to HF power [15].

The Poincaré plot, a nonlinear technique used to visually search for patterns buried from within a time series, is a scatter graph by plotting each RR interval against the previous interval. This analysis is insensible to changes in trends in the R-R intervals differently from frequency-domain measurements [16]. Four nonlinear measurements as SD1, SD2, SD2 / SD1 and S were derived using the Poincaré plot technique in this study. The ellipse area (S) representing total HRV is correlated with BRS (baroreflex sensitivity), power of LF and HF, and RMSSD. SD1 measures short-term HRV (in ms) correlated with BRS, and the power of HF. The RMSSD is identical to the nonlinear parameter SD1, which reflects short-term HRV [17]. SD2 measures short-term and long-term HRV (in ms) correlated with the power of LF [18-21].

The Poincare plot is frequently used to study nonlinear dynamics. The plot simpler to study the dynamics of heart variability [22]. The visual analysis of the Poincare plot is referred to as a qualitative analysis technique [23]. In this study, the heart rate variability of eSports players was visualized and analyzed on the Poincare graph. It has been observed that the eSports game's Poincaré graphics effectively characterize the change on the players' cardiac function. The differences in HRV pattern for eSports game are shown from nonlinear analysis of Poincare parameters.

HRV analyzes can be used to evaluate the acute physiological effects of activity in the field of computer games, and the obtained results can be used to determine the effects of parameters such as gender, age, previous experience differences in the same game and the type of game.

Hamm et al. [24] found that importantly reduced HRV indices are primarily indicative of vagal withdrawal. Their results provided additional information regarding the physiological response of emotional stress to HRV measurements. Polli et al. [25] explored the relationship between oxidative stress and parasympathetic activity. They have found that the more the increase in parasympathetic activity during exercise, the more the reduction in oxidative stress levels (inversely related). Peçanha et al. [26] pointed out that RMSSD, SDNN, and HF parameters can be used to determine parasympathetic activity. Concerning LF, no consistent response to stress compared to previous studies. While some studies in the literature observed a rise of LF during stress, some other studies indicated an opposite trend [27]. In another study, Chen et al. [28] suggested that Poincaré plot (SD1) is a very good indicator candidate for stress level assessment.

Yeo et al. [12] reported a study evaluating the psychological effects of games on users by analyzing biomedical signals. As a result of their analysis on pulse transit time, skin temperature and, heart rate variability, they showed that sympathetic nerve activities during computer games were more active than parasympathetic activity. Shapiro et al. [29] aimed to examine the impact of the unfair game on different participants. During the game, ECGs were recorded for measuring HR. The results reflected an increase in stress while an unfair game playing. Haghshenas and Pooyan [30] showed that during playing computer games, the values of the nonlinear parameters (such as the SD1/SD2 ratio) were reduced. Some researchers in the literature [31-35] have asserted that in resting states, the LF band reflects activity of baroreflex, not sympathetic innervation of cardiac [36].

The aim of our work was to assess the linear and nonlinear dynamics of HRV in eSport players. We aimed to (1) evaluate four descriptors of the Poincaré plot, (2) to compare and (3) to contrast them with conventional parameters of HRV. To that purpose, we correlated Poincaré plot descriptors with standard HRV parameters obtained from time domain and frequency domain analysis.

2. MATERIAL AND METHODS

A study was carried out to investigate by using Poincare plot analysis of HRV during gaming and resting. In the experiment, nine adults (8 males and 1 female) with a mean of 33±7.6 years, ranging from 24 to 41 years took.

All volunteers provided written informed consent before participation. This study was approved by the Medical Ethical Committee of the Akdeniz University and the experiment was undertaken in compliance with national legislation and the Declaration of Helsinki.

The R-R intervals were records using a heart rate monitor (Polar V800) during the resting and gaming.

The Poincare plot analysis could be used in order to graphically define the beat to beat variability of R-R intervals. It is built by plotting every R-R interval as a function of the immediately previous one. R-R interval time series is indicated by the RR_n.

The values of SD1 and SD2 represented the second moment measure of the distribution of points forming the Poincaré plot. The SD1 and SD2 can be described as follows [36]:

$$SD1 = \frac{1}{N-1}\sum_{i=1}^{N-1}(D_i')^2 \tag{1}$$

$$SD2 = \frac{1}{N-1}\sum_{i=1}^{N-1}(D_i'')^2 \tag{2}$$

where, D′ and D″ denote the distances of any point from the identity line ($RR_n=RR_{n+1}$) and the line perpendicular to the identity line ($RR_n+RR_{n+1}=2RR$). These operators can be expressed as follows [37]:

$$D_i' = \frac{1}{\sqrt{2}}\left|RR_n - RR_{n+1}\right| \tag{3}$$

$$D_i'' = \frac{1}{\sqrt{2}}\left|RR_n + RR_{n+1} - 2\overline{RR}\right| \tag{4}$$

S represents area of the ellipse and can be formulated as:

$$S = \pi * SD1 * SD2 \tag{5}$$

SPSS Statistics 24.0 (IBM Corporation) software was used for the statistical analysis. The results are presented as mean. Wilcoxon signed-rank test in this study were used to determine if there was a significant statistical difference before and after the game. Correlations were evaluated with the Spearman's rank correlation method.

3. RESULTS AND DISCUSSION

The nine volunteers who played the puzzle video game at sitting position. HRV data of the participants were recorded during the game and rest sessions. The linear and nonlinear dynamics of HRV were evaluated using HRV recordings obtained from each player. Figure 1 shows the instance of the graphic of change of the RR of the any volunteer during rest and game state. According to this figure, the RR values of the volunteer were decreased during the game. This means that the heart rate is accelerated during the game.

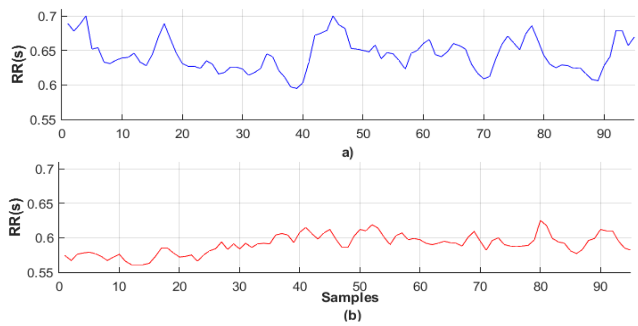


Figure 1. The change of the RR of the any volunteer during (a) rest and (b) game state

Figure 2 shows the Poincare plot with proper delay of HRV signals in states of rest and game for a participant. SD1, and S were importantly reduced ($p \leq 0.05$) in game state compared to rest state.

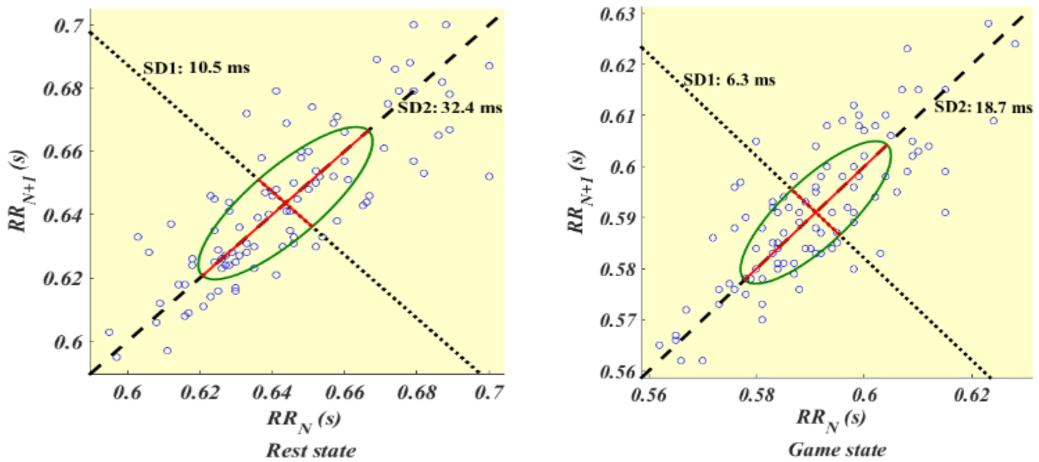
The resulting boxplots of the linear measures of HRV indices parameters are shown in Figure 3.

We used Wilcoxon signed-rank tests to examine possible differences in linear measures of HRV parameters (used mean values) between rest and game states. By taking six HRV parameter variables (HR, SDNN, RMSSD, LF, HF and ratio of LF/HF) as independent and test scores as dependent variables, Wilcoxon signed-rank has been conducted and obtained results are shown in Table 1.

Table 1. Comparison of linear measures of HRV indices parameters between rest and game status

Parameters	Rest	Game	p-value
HR	**80.79**	**85.97**	**0.050***
SDNN	42.62	29.07	0.051
RMSSD	**33.54**	**23.12**	**0.021***
LF	**1646.11**	**172.82**	**0.028***
HF	**785.08**	**270.73**	**0.008****
LF/HF	2.58	2.40	0.678

*significant at p≤0.05, **highly significant at p≤0.01.



(a) Rest state (b) Game state

Figure 2. Poincare plot of HRV signals in rest and game state

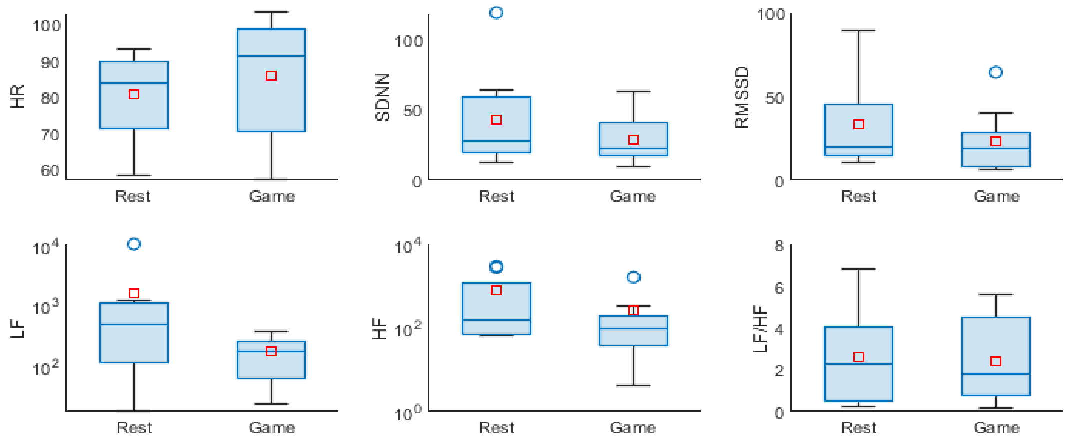


Figure 3. The box-plots of the linear measures of HRV indices parameters

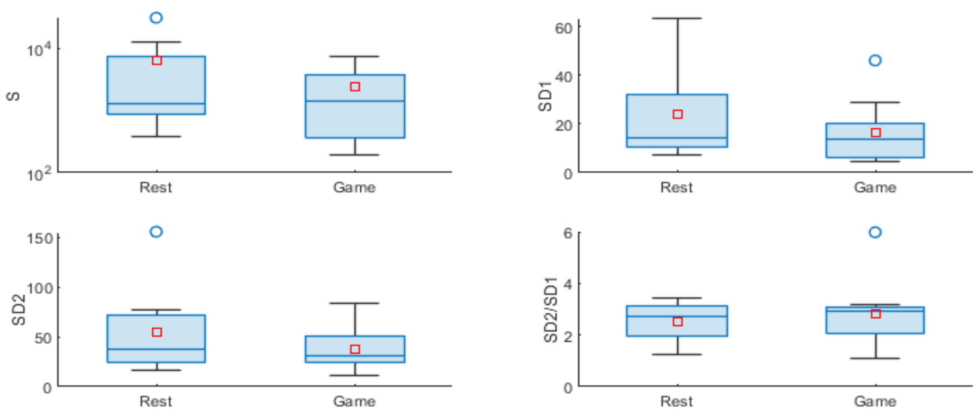


Figure 4. The box-plots of the nonlinear measures of HRV indices parameters

As can be seen from the obtained results in Table 1, it was observed as other than SDNN and LF/HF, the other four variables (mean-HR, RMSSD, LF and HF) indicated significant difference.

Shapiro et al. [29] reported, there is an increase in stress while game playing (for unfair game on different participants).

The previous studies showed that RMSSD, SDNN as well as HF decreased during stress [27]. In our study, RMSSD and HF power also were decreased. Although games can evoke different emotions in individuals, in our study, considering the average of the volunteers, puzzle video game increased stress.

The resulting boxplots of the nonlinear measures of HRV indices parameters are shown in Figure 4.

By taking four mean of nonlinear measures of HRV parameters variables (the area of the Poincaré plots (S), SD1, SD2 and SD2/SD1) as independent and test scores as dependent variables, Wilcoxon signed-rank has been applied and obtained results are shown in Table 2.

Table 2. Comparison of nonlinear measures of HRV indices parameters between rest and game status

Parameters	Rest	Game	p-value
S	**6336.31**	**2466.58**	**0.028***
SD1	**23.87**	**16.46**	**0.021***
SD2	54.76	36.96	0.051
SD2/SD1	2.54	2.81	0.767

*significant at p≤0.05, **highly significant at p≤0.01.

The use of the Poincaré plot allows us to visualize all points defined by consecutive RR intervals and easily identify points corresponding to outliers in heart rhythm fluctuations. The outliers do not affect the Poincaré plot as strongly as conventional time and frequency domain measurements of HRV data [38].

From Table 2 it was observed as other than SD2 and SD2/SD1, the other two variables (S and SD1) showed significant difference at 0.05 level. Haghshenas and Pooyan (2019) [30] and the current results showed that during playing computer games, the nonlinear parameters' values were reduced. In our study, the reduction of the nonlinear parameter values of SD1 and S during the game was parallel to this study.

The acquired correlation results between the descriptors of the Poincaré plot of RR intervals (SD1, SD2, SD2/SD1 and S) and the mean RR interval in conjunction with the frequency domain and time domain measures of HRV are presented in Table 3. This correlation analysis was done by using Spearman's rank correlation method.

SD1 parameter correlated significantly with all HRV measurements studied (p≤0.05 and p≤0.01). There were high significantly correlations, all with p≤0.05 and p≤0.01, among SD2, S and all measures of HRV with the exception of LF/HF. No significant correlation between SD2/SD1 score and variables of interest was found.

There were significant negative correlations of HR with SD1 (p =0.007), SD2 (p = 0.010), S (p = 0.013). According to acquired correlation results, the RMSSD metric is almost fully correlated with the nonlinear metric SD1 (r=1, p≤0.001) at game status and this result is similar to previous study [17].

Whether SD1, SD2, SD2 / SD1, S and other parameters we determined are related to the short-term variability of heart rate and also whether they are related to the parasympathetic response can be associated with the results we have obtained.

Table 3. Correlation analysis of nonlinear measures with linear measures at game status

Parameters	SD1		SD2		SD2/SD1		S	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
RR	**0.845**	**0.004****	**0.828**	**0.006****	-0.460	0.213	**0.820**	**0.007****
HR	**-0.817**	**0.007****	**-0.800**	**0.010****	0.467	0.205	**-0.783**	**0.013***
SDNN	**0.833**	**0.005****	**0.983**	**0.000****	-0.117	0.765	**0.933**	**0.000****
RMSSD	**1.000**	**0.000****	**0.783**	**0.013***	-0.550	0.125	**0.950**	**0.000****
LF	**0.783**	**0.013***	**0.900**	**0.001****	-0.200	0.606	**0.850**	**0.004****
HF	**0.950**	**0.000****	**0.733**	**0.025***	-0.533	0.139	**0.917**	**0.001****
LF/HF	**-0.667**	**0.050***	-0.333	0.381	0.400	0.286	-0.617	0.077

**Correlation is highly significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

4. CONCLUSIONS

This work was designed to evaluate dynamics of HRV using Poincare plot in persons playing a puzzle video game. According to obtained results from linear analysis, mean-HR, RMSSD, LF and HF have significant in separation of rest and game state.

In nonlinear analysis, S and SD1 parameters are important in separation of rest and game status. SD1, SD2 and S, which are non-linear HRV measurements, are strongly correlated, except LF/HF from linear measurements. Obtained results show that linear and nonlinear dynamics of HRV has been a non-invasive marker in playing a puzzle video game. As a result, playing computer games, comparative values were obtained based on the reflection of heart rate. Using the proposed approach, the extent to which a Poincaré plot descriptors is related with low and high frequency power is determined, thus determining correlation among linear and non-linear analysis and frequency-domain spectral analysis techniques for puzzle video players.

With the nonlinear methods used in HRV analysis, a popular and non-invasive tool for evaluating cardiovascular activities, it is very useful for determining the effects and extent of esports games on the cardiovascular system. This proposed approach can be thought of as a practical way of evaluating the effects of esports play on autonomic control specifically or as a marker of sympathetic activity in terms of the cardiac effects of the related play activity.

In future studies, it can be examined whether the physiological responses that occur in the heart during playing a video game are individual and whether they are relatively independent from the performance of the game. In addition, the effects of playing video games in different body positions (as standing, lying positions etc.) on HRV and the process of returning these changes to normal in HRV can be examined.

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ETHIC STATEMENT

The study was approved by the Clinical Research Ethics Committee of the Akdeniz University.

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