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Impact of Music on College Students: Analysis of Galvanic Skin Responses

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Abstract
Purpose: The impact of music on the human body is an important trend in music research. Different kinds of music have direct and indirect effects on physiological functions and parameters in normal and pathological conditions. Among various physiological measurements, the galvanic skin response is a noninvasive, useful, simple and reproducible method of capturing the autonomic nerve response. The aim of this study is to evaluate the effect of Persian music on galvanic skin response. *Basic methods:* Galvanic skin response signals of 25 college students (10 women and 15 men) were collected. Mean, amplitude, rise time and Lyapunov exponents of the signals were calculated. *Main results:* The results show that not only the galvanic skin response amplitude is higher in men subjects during rest, but it also increased to the higher values during music than that of women. In addition, the fluctuations of it increased during music in men group; while it decreased in women group. The positive values of Lyapunov exponents suggest that all galvanic skin responses have low dimensional chaos. In addition, the complexity of galvanic skin responses is decreased during music. *Conclusions:* Our study has shown that the same music protocol has different reflections on the galvanic skin response of women and men. Furthermore, the proposed method may serve as a quantitative measure for emotional states such as listening to the music.

Keywords: Different Gender; Galvanic Skin Response; Lyapunov Exponent; Music Effect.

Introduction

Music has an important role in all human cultures and has been found to have direct and indirect effects on physiological functions and clinical symptoms [1]. Music can develop performance of reasoning tasks, diminish stress, heighten feelings of relaxation and comfort, expand the results of clinical therapy, and yield a distraction from pain [2, 3]. Music can profoundly affect our moods is a fact of everyday life. However, the manner in which music helps arouse feelings, ranging from joy to sadness, remains a great mystery [4].

Of all the difficulties that may confront a music psychologist, possibly none is more important than to explain listeners' reactions to music. In addition, some kind of musical experience is the basis for every musical activity, regardless of whether it includes performing, composing, or listening to music.

The musical features in different levels were corresponded to different physiological responses [5]. These responses include respiratory rate, heart rate (HR) and skin conductance level. Among various physiological measurements, the galvanic skin response (GSR) is a noninvasive, useful, simple and reproducible method of capturing the autonomic nerve response as a parameter of the sweat gland function [6]. Physically GSR is an alteration in the electrical characteristics of the skin in response to different kinds of stimuli. It has been shown that any stimulus capable of an arousal effect can evoke the response. In addition, the amplitude of the response is more dependent on the surprise effect of the stimulus than on the physical stimulus strength. In the measurements, changes in the voltage calculated from the surface of the skin are recorded. The skin conductance measurement device is usually placed on hands or feet, where the density of sweat glands is the highest [7]. In general, GSR has a typical startle response, which is a fast change of the GSR signal in response to a sudden stimulus. Features which are used to characterize this response include time domain and linear analyses such as extracting the amplitude and rising time of the signal.

In previous studies, some researchers have tried to investigate the effect of different kinds of music on physiological parameters in normal and pathological conditions. Mottahedian Tabrizi et al. [8], showed that listening to music during surgery under regional anesthesia has effects on cortisol levels and some of the physiological variables. Therefore, they offered to use music therapy as a complementary method in patients to reduce anxiety.

Listening to 2.5 minute excerpts of music (at three different tempos: 60, 90, 120 bpm), Ellis [9] compared changes in mean HR and heart rate variability (HRV). Burns et al. [10], Thoma et al. [11] and Labbe et al. [12] report findings that suggest listening to relaxing music, such as classical music, can increase the parasympathetic nervous system arousal and results in the participants experiencing positive emotions. In another study, Labbe et al. [13] evaluated music which the person believes is relaxing to determine whether listening to music that one is attracted to can be an effective coping response to negative emotion.

A study by Zimny and Weidenfeller [14] looked at the effects of music on galvanic skin response (GSR) in children. They tried to find evidence that stimulating and calming music would have different effects on children. They worked on the assumption that GSR is a physiological indicator of emotional response and they found significant differences in arousal effect between these two pieces.

Neurological studies have identified that music may be a valuable tool for evaluating the brain system [15]. In addition, it has shown that listening to music increases the power at theta and alpha frequencies of the human electroencephalogram (EEG) [16]. Sammler et al. [17] examined that when subjects listen to the pleasant music the changes were reflected in the EEG and there was an increase in the frontal midline (Fm) theta power [17]. In the recent study, Geethanjali et al. [18] evaluated the impact of music on brain function during a mental task. In their work [18], spectral power features were extracted at different brain rhythms: alpha, theta and beta.

In this study, the effects of listening to Persian music on galvanic skin response are examined in order to test common and feature-specific responses to music. Mean GSR level and amplitude of the GSR give information about the arousal state, which reflects the sympathetic nervous system activation. Both will be extracted for data analyses. In addition, in this study rise time and Lyapunov exponents are examined. The application of chaos theory and evaluation of this nonlinear feature (Lyapunov exponents) for estimation of variation in GSR during music is new to the best of our knowledge.

The outline of this study is as follows. At first, we briefly describe the sets of data, which are collected for this study. Then, we explain the extracted features. Finally, we present the results of analyses of these features on data set, and we conclude the study. Figure 1 demonstrates the flow chart of the proposed method.

Material and Method

Data Collection

To study the effect of music on GSR signals, twenty-five college students attending Sahand university of technology participated, 15 males (age range: 20-22 years; mean age: 21.6 years) and 10 females (age range: 20-24 years; mean age: 21 years). All of the participants were Iranian students.

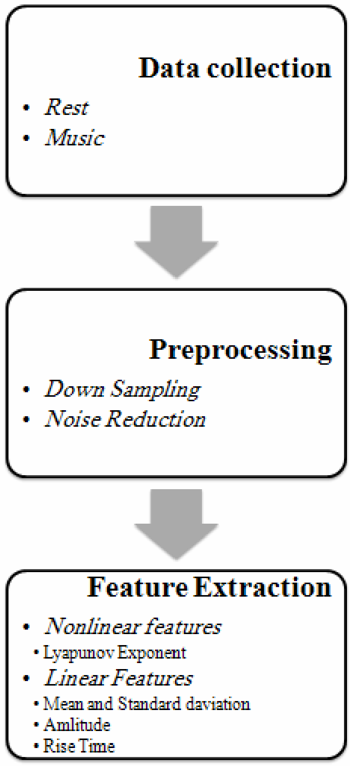

Figure 1. Flow chart of our integrated method

The experimental procedure was divided into two different stages: Subjects were first instructed to lay in supine position quietly for 5 minutes and keep their eyes closed. After five minutes of rest, 5 minutes and 10 seconds of GSR were recorded when the subjects listen to the Persian music. Five minutes of rest were used as the baseline to compare with music. During the GSR measurement, participants laid supine on a comfortable bed in the Computational Neuroscience Laboratory at Sahand University of Technology. The musical piece was composed by Dr. Keyvan Saket and presented via headphone at a comfortable volume using KMPlayer software. Participants were asked to listen carefully to the music and to keep their eyes closed during the whole experiment, making the measurements more comfortable. All participants reported normal hearing and no history of neurological diseases. The subjects were asked not to eat salty or fat foods before data recording. Mean temperature of the room is about 27.64°C.

The GRS of all subjects were recorded using 16-channel PowerLab (manufactured by ADInstruments). The sampling rate was 400 Hz.

Morphological Analysis

The autonomic nervous system, in response to emotional stimulus, changes the activity of the sweat glands. A potential can be detected [19, 20] by means of a pair of electrodes. The signal is less than 1 mV in amplitude with a frequency band of DC to 5 Hz. The acquisition of the signal is difficult due to DC potentials produced by the electrode skin interface. The GSR is also used for emotional state monitoring (lie detector) and for various biofeedback applications [21].

Finding the most similar time-series pattern (e.g. GSR or skin temperature) from the database is a beneficial feature which can enable the domain expert to study the effect of music on different subjects. The mean skin conductance amplitude is the most frequently used quantification procedure for temporal characteristics of the GSR because its physiological meaning is understood best.

Features which are extracted to characterize the GSR response to music stimuli include the amplitude and rising time of the signal. The onset and the peak of signals are detected. The time course between the occurrence of the onset and the peak is referred to as the rise time. In other words, skin conductance response (SCR) rise time is the mean temporal interval between skin conductance response initiation and SCR peak. SCR amplitude is the mean amplitude of the SCR occurrences. An example of measuring these two linear features is shown in Figure 2 (subject 21).

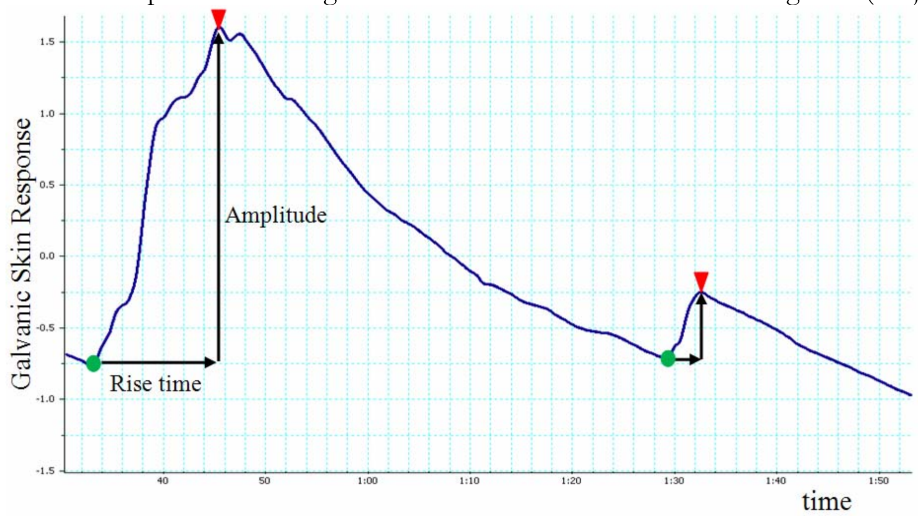

Figure 2. Galvanic skin response during music (subject 21), the detected peak is marked with red '∇' and the onset is marked with green 'o'

Lyapunov Exponents

Consider two (usually the nearest) neighboring points in phase space at time 0 and at a time t, and being the distances of the points in the i[th] direction, respectively. Using the average growth rate λ_i of the initial distance, the Lyapunov exponent is delineated:

$$\frac{\|\delta x_i(t)\|}{\|\delta x_i(0)\|} = 2^{\lambda_i t} \quad (t \to \infty)$$
$$\lambda_i = \lim_{t\to\infty} \frac{1}{t} \log_2 \frac{\|\delta x_i(t)\|}{\|\delta x_i(0)\|} \tag{1}$$

An exponential divergence of initially nearby trajectories in phase space coupled with folding of trajectories, confirms that the results will remain finite, and is the general mechanism for generating deterministic randomness and unpredictability. Consequently, in a bounded dynamical system the existence of a positive λ for almost all initial conditions is extensively used. To discriminate between chaotic dynamics and periodic signals the Lyapunov exponent (λ) is often used. Applying Lyapunov exponent calculation one can measure the rate at which the trajectories separate one from other. For chaotic signals the trajectories follow typical patterns in phase space. Trajectories which are closely spaced converge and diverge exponentially, relative to each other. In the study of the dynamical systems, the sensitivity to initial conditions can be quantified by the Lyapunov exponent (λ). They illustrate the average rate of divergence of the neighboring trajectories.

- A negative exponent implies that the orbits approach a common fixed point. These systems are non-conservative (dissipative). The degree of stability is indicated by the absolute value of the exponent.
- A zero exponent means the orbits maintain their relative positions on a stable attractor. Such systems are conservative and in a steady state mode.
- Finally, a positive exponent implies the orbits are on a chaotic attractor [22, 23]. A measure of the sensitivity to initial conditions is reflected in the magnitude of the Lyapunov exponent, which is the primary characteristic of a chaotic system.

Statistical Analysis

In this study, the t-test of the null hypothesis is that data in the vector x are a random sample from a normal distribution with mean 0 and unknown variance. The result is shown in p-value. P-value→0 indicates a rejection of the null hypothesis at the 5% significance level ($p<0.05$). P-value→1 indicates a failure to reject the null hypothesis at the 5% significance level.

Results

In order to reduce the computational time, GSR data were down sampled to 100 Hz. The GSR time series were filtered by using a low pass Butterworth filter with a cutoff frequency of 3 Hz. All calculations were done using MATLAB and the GSR response was localized by using the EDA toolbox.

Average galvanic skin response for all subjects is calculated. Figure 3 shows the observed means during rest and listening to music in two groups: women (top panel) and men (bottom panel).

According to the results, mean and standard deviation of galvanic skin response before listening to music are about -2.014±0.4629 and -1.3203±0.7668 for men and women, respectively; whereas, in music section these values are about -1.5155±0.552 and -0.6646±0.7392 for men and women, respectively. The results show that in men group mean GSR signals decreased as subjects listen to music; however, it increased in the same protocol in women. In addition, the fluctuations of mean GSR increased during music in men group; while it decreased in women group.

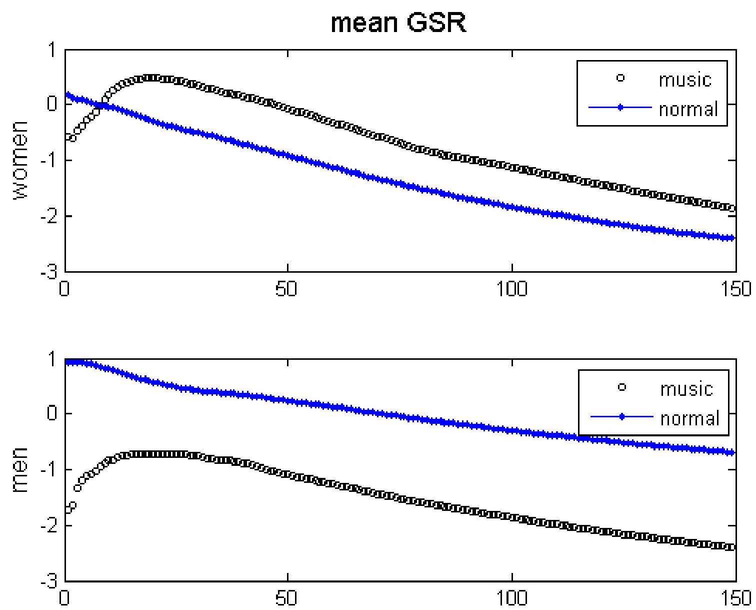

Figure 3. Average changes in galvanic skin responses during rest and music for women (top) and men (bottom)

In order to compare the GSR patterns of men and women during music and rest, representative examples of the amplitude of GSR are shown in Figure 4. Different patterns of GSR are observed in men and women's groups during rest and music (Figure 4).

Figure 4 demonstrates that the average value of amplitude is about 3.73×10^{-3} and 9.81×10^{-3} during rest in women and men, respectively. In addition, the results indicate that the mean amplitudes are increased during music in both groups ($p<0.05$). It is roughly 14.1×10^{-3} and 53.4×10^{-3} in women and men, respectively. It is not only referred that the GSR amplitude is higher in men subjects during rest, but it also increased to the higher values during music than that of women ($p<0.05$). In sum, for both groups, music periods evoke different reactions on GSR than that of the silent periods (rest).

Figure 5 shows the rise time variations of GSR within each group. Finally, the Lyapunov exponents of GSR are calculated during rest and music. Figure 6 depicts the box plot of Lyapunov exponents in women and men groups.

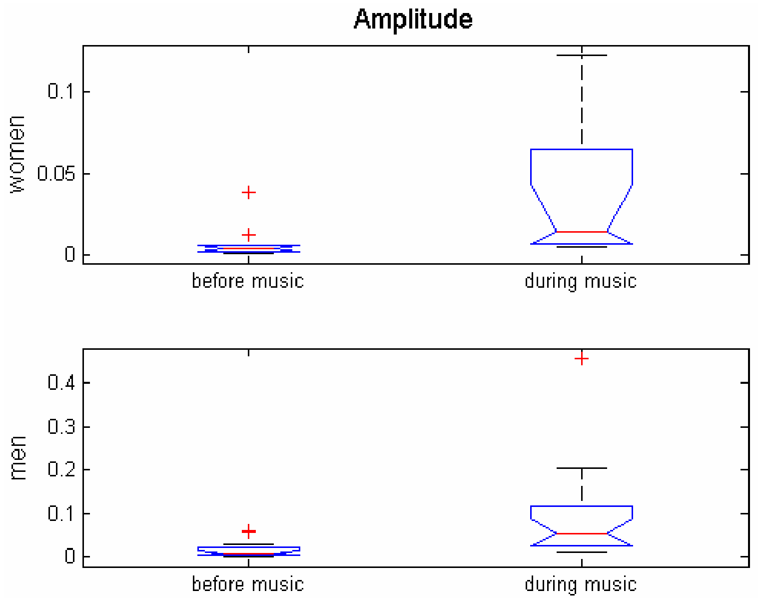

Figure 4. The box plot of the amplitude of GSR for all subjects. Top: women; Bottom: men

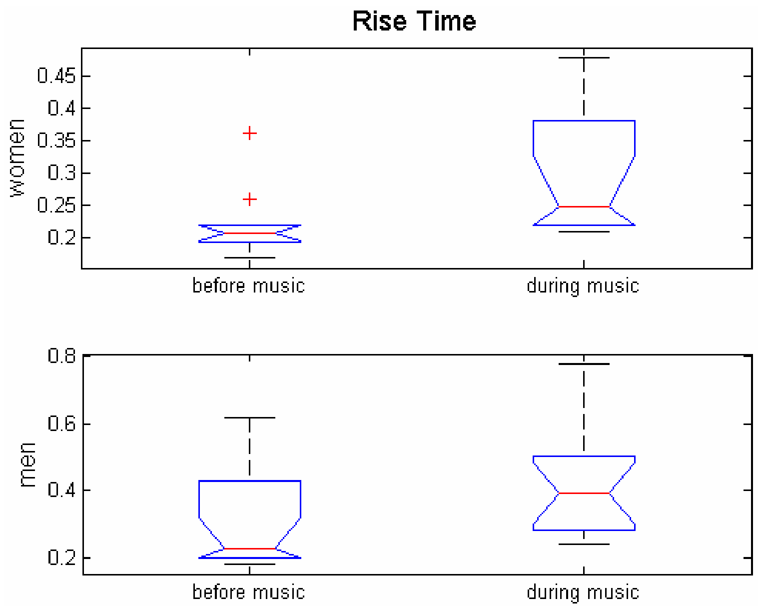

Figure 5. The box plot of the rise time of GSR for all subjects. top: women, bottom: men

According to Figure 5, rise time of GSR is increased during music in both groups. It is approximately 0.2064 and 0.2273 during rest in women and men, correspondingly. Whereas, when the subjects listen to the music, this value is about 0.2461 and 0.3915 for women and men, respectively. This increment is significant for men group ($p<0.05$), while no significant changes are observed in the women's group ($p= 0.0532$). It means that this feature is not appropriate for GSR analysis during music with a women's group.

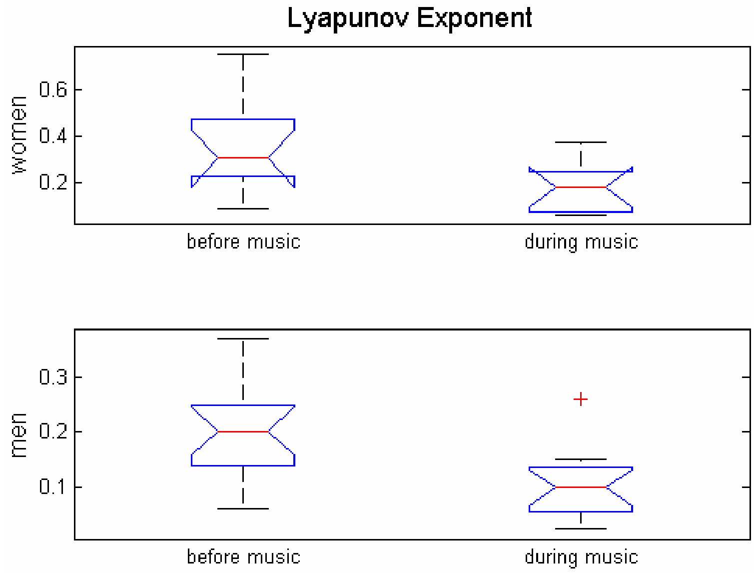

Figure 6. The box plot of Lyapunov exponents of GSR for women (top) and men (bottom)

As shown in Figure 6, in both groups maximum Lyapunov exponents are higher before music than that of during the music ($p<0.05$). Furthermore, the values of Lyapunov exponents are lower during rest and music in men than that of women. Mean Lyapunov exponents before music is about 0.352 and 0.208 in women and men, respectively; whereas, it is about 0.1716 in the former and 0.0685 in the latter during music. At last, a positive exponent in all subjects of both groups before and during music implies the orbits are on a chaotic attractor.

Discussion

The impact of music on the human body is a crucial trend in music research [24]. It has shown that HRV decreased as the tempo increased [9], indicating that the "challenge" of arousing music prompted a withdrawal of peripheral nervous system (PNS) activity. Despite significant correlations between mean HR and measures of HRV at baseline ($p < 0.001$), there are no significant changes in mean HR [9]. Nevertheless, there have been relatively few empirical investigations of HRV and music compared to mean HR and music. HRV is not mentioned in either of the major literature reviews of music and physiological response [25,26].

van der Zwaag et al. [27] showed that music listening prevents the increase of negative feelings during office work. In another study, Lesiuk [28] found an increment in work performance and claimed that after five weeks of music listening during office work, the quality of work is increased.

Labbe et al. [13], concluded that listening to some types of music genres elicits positive emotional and cognitive states, and reduces sympathetic nervous system arousal compared to sitting in silence or listening to heavy metal music.

The interaction of the affective state of the human with the environment can be reflected in the measurements of electrodermal activity (EDA). In addition, electrodermal activity is solely innervated by the sympathetic nervous system. It has been known that GSR has a characteristic to react quickly to an event (in this study, listening to music) but has a very slow decreasing response to go back to the previous baseline [29]. Although galvanic skin responses react quickly, they have different rates in arousal while presenting affective pictures or sounds [30, 31].

It has been documented that there are differences in emotional experience between women and men, women experiencing more tension during music and between different age groups. In addition, older people experience more attraction to music than younger ones [32].

Zimny and Weidenfeller [14] postulated from their results that a decrease in skin resistance indicated an increase in emotional excitement and response to the exciting music, and an increase in electrical skin resistance indicated a decrease in the emotional excitement in response to the calming music.

van der Zwaag et al. [27] showed that the pop music, which is appreciated more, causes a smoother EDA signal than rock music. It might imply that EDA measures are able to reflect differences in music appraisal. In addition, they have shown [27] that the amount and the amplitude of SCRs are higher while the rise time is shorter during high percussive music than during the low percussive music. The results of the current study show that both features are increased during the music. In addition, in this study it has been shown that the calculated features are different in women and men's group. In this study, the results also demonstrate that in men's group mean GSR signals decreased as subjects listen to music; however, it increased in the same protocol in women. In addition, the fluctuations of it increased during music in men group; while it decreased in women group. This means that the music may have different effects on men and women.

To the best of our knowledge, in this study for the first time the application of Lyapunov exponents for estimation of variation in GSR during music is examined. It has been shown that in both groups maximum Lyapunov exponents are higher before music than that of during music ($p<0.05$). Although, the values of Lyapunov exponents are lower in both conditions (rest and music) in men, positive Lyapunov exponents in both groups before and during music implies the orbits are on a chaotic attractor. However, mean amplitudes together with rise time and Lyapunov exponent could also have an important meaning regarding to physiological and emotional processes.

Conclusions

It has shown that the music may have different effects on men and women. The results suggest that the proposed method may serve as a quantitative measure for emotional states such as listening to the music. The influence of other factors such as cultural background, music experience could be analyzed in other biological signals like electroencephalogram and heart rate signals in future. Although our results show that the GSR was differed in women and men, further studies with a larger sample size are required to prove the usefulness of the proposed methodology.

Conflict of Interest

The authors declare that they have no conflict of interest.

Acknowledgements

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