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The Effect of Neuroticism on Autonomic Cardiac Responses Caused by Mental Stress in University Student-Athletes

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ORIGINAL RESEARCH

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Abstract

The present study investigated whether neuroticism might have predictive ability for athletes' Heart Rate Variability (HRV) in response to mental stress, a noninvasive measurement of the interaction between the autonomic nervous and cardiovascular systems. The sample included 49 university student-athletes aged 19 to 24. Participants first completed items from the Five Factor Personality Inventory concerning neuroticism to measure neuroticism. Then, their resting HRV's were measured for four minutes. Afterward, participants took a modified version of the Stroop word-color task as the mental stressor within four minutes while their HRV responses were recorded. Results indicated a significant increase in terms of Heart Rate (HR) (z= 3.162, p= .002), Root Mean Square of the Successive (RMSSD) (z= 2.973, p= .003), Low Frequency (LF) (z= 3.027, p= .002), and High Frequency (HF) (z= 3.404, p= .001) from baseline to stressor condition in the low neuroticism group. On the other hand, no significant increase was observed in RMSSD (z= 1.314, p= .189) and LF (z= 1.173, p= .241) from baseline to stressor condition in the high neuroticism group. Results also revealed a significant increase in HR (z= 2.543, p= .011) and HF (z= 2.229, p= .026) from baseline to stressor condition in the high neuroticism group. The results observed in the present study revealed that athletes' responses to mental stress might vary due to personality traits, especially neuroticism. In conclusion, researchers and practitioners aiming to regulate athletes' psychophysiological responses to stress should consider personality traits such as neuroticism.

Keywords: Neuroticism, Stroop Test, HRV

Nevrotikliğin Üniversite Öğrencisi Sporcularda Mental Stresin Neden Olduğu Otonomik Kardiyak Yanıtlar Üzerindeki Etkisi

Özet

Bu çalışmada; nevrotikliğin, sporcuların mantal stresöre maruz kaldıklarında, otonom sinir ve kardiyovasküler sistemler arasındaki etkileşimin sonucu olarak gerçekleşen Kalp Atım Hızı Değişkenliğini (KHD) öngörme yeteneğine sahip olup olmadığı araştırılmıştır. Örneklem, yaşları 19 ila 24 arasında olan 49 üniversite öğrencisi sporcudan oluşmaktadır. Katılımcılar ilk olarak nevrotikliği ölçmek için Beş Faktör Kişilik Envanterinden nevrotikliğe ilişkin maddeleri doldurdular. Daha sonra istirahat halindeki KHD'leri dört dakika boyunca kayıt altına alındı. Daha sonra katılımcılar, KHD yanıtları kaydedilirken dört dakika içinde zihinsel stresör olarak Stroop kelime-renk görevinin düzenlenmiş bir versiyonunu uyguladılar. Sonuçlar; Kalp Atım Hızı (KH) (z= 3.162, p= .002), Ardışık NN Aralıkları Farklarının Ortalamalarının Kare Kökü'nün (AFOKK) (z= 2.973, p= .003), Düşük Frekans (DF) (z= 3,027, p= 0,002) ve Yüksek Frekans (YF) (z= 3,404, p= 0,001) açısından düşük nevrotiklik grubunda istirahat durumundan zihinsel stresör koşuluna kadar anlamlı bir artış olduğunu gösterdi. Öte yandan yüksek nevrotiklik grubunda AFOKK (z= 1,314, p= 0,189) ve DF (z= 1,173, p= 0,241) değerlerinde istirahat durumundan zihinsel stresör koşuluna kadar anlamlı bir artış gözlenmedi. Sonuçlar aynı zamanda yüksek nevrotiklik grubunda KH (z= 2,543, p= 0,011) ve YF (z= 2,229, p= 0,026) açısından da istirahat durumundan zihinsel stresör koşuluna kadar anlamlı bir artış olduğunu ortaya koydu. Bu çalışmada gözlemlenen sonuçlar, sporcuların mental strese verdikleri tepkilerin kişilik özelliklerine, özellikle nevrotikliğe bağlı olarak değişebileceğini ortaya koymuştur. Sonuç olarak, sporcuların strese karşı psikofizyolojik tepkilerini düzenlemeyi amaçlayan araştırmacı ve uygulayıcıların nevrotiklik gibi kişilik özelliklerini dikkate almaları gerekmektedir.

Anahtar Kelimeler: Nevrotiklik, Stroop Testi, KHD.

Introduction

Over the past decades, an increasing body of research has focused on the adverse effects of stress in sports (McGrath, 1970; Lazarus and Folkman, 1984; Hobfoll, 1988, 1989, 1998), which is defined as the changes created by internal or external stimuli and the organism's responses to these stimuli (Selye, 1976). In this respect, stress is the tension in the dynamic structure between the organism and its surroundings (internally and externally), and more specifically, it is described as the organism's reaction to the demands and suppressions of the environment to protect its integrity.

An enormous amount of research aimed to explore the source of stress among professional athletes from a variety of sports fields, including elite track runners (McKay et al., 2008), female soccer players (Holt and Hogg, 2002), golf players (Giacobbi et al., 2004) and tennis players (Rees and Hardy, 2004). Several instruments, mostly questionnaire-based, attempted to understand and measure the degree of stress and its regeneration (Morales et al., 2014) to perform well in the sport. Coaches appreciate these instruments' ability to help understand athletes' feelings and emotions appropriately. However, recent research findings recommend a simple physiological analysis combined with psychological measures to determine a more objective measure of arousal and stress (Mateo et al., 2011; Woodman et al., 2015; Barlow et al., 2016). This measure is Heart Rate Variability (HRV), which provides information on the sympathetic and parasympathetic sections of the central neural system. Massimo Pagani's (Pagani et al., 1986; Malliani et al., 1991; Montano et al., 2009) model accepted that three components may represent sympathetic, parasympathetic, and balanced between them. Therefore, High Frequency (HF) power (0.15 to 0.40 Hz) is recognized as an indicator of cardiac parasympathetic tone. On the other hand, Low Frequency (LF) power (0.04 to 0.15) is accepted as a marker of cardiac sympathetic outflow. The sympathovagal tone is determined by the LF/HF ratio (Reyes del Paso et al., 2013). HRV is also represented in terms of time-domain parameters, the Standard Deviation of NN intervals (SDNN), and the Root Mean Square of Successive NN interval Differences (RMSSD). SDNN is the simplest variable to calculate the standard deviation of the NN interval, i.e., the square root of variance. Since variance is mathematically equal to the total power of spectral analysis, SDNN reflects all the cyclic components responsible for variability in the recording period. The most commonly used measures derived from interval differences include RMSSD, the square root of the mean squared differences of successive NN intervals. All these measurements of short-term variation estimate high-frequency variations in heart rate and thus are highly correlated (Malik, 1996). Previous studies in sports psychology and other fields of psychology provided robust evidence that HRV could indicate mental state (Cervantes Blásquez et al., 2009; Miu et al., 2009). Therefore, HRV can be considered a psychophysiological parameter that can potentially reflect the autonomic nervous system's arousal triggered by mental state.

Recently, studies have been conducted to test psychophysiological indications (Murray and Raedeke, 2008; Mateo et al., 2011; Barlow et al., 2016) with crude psychophysiological stress indices. Among these measurements, the most preferred method is measuring the heart's electrical activity. When an individual faces a stressor, the sympathetic nervous system becomes dominant in the autonomic nervous system and increases heart rate, blood pressure, and, therefore, arousal increases. When the factor that causes stress disappears, the parasympathetic system becomes dominant, decreasing the heart rate and reducing blood pressure (Reisman, 1997; Oh et al., 2015). The predisposition to stress is determined by the complex interactions between psychological and physiological tendencies and individual differences (Hall, 1998).

Neuroticism is one individual difference variable that deserves research attention regarding its potential moderating role under stress. Substantial empirical evidence (Duffy, 1966; Eysenck, 1967) supports the notion that physiological arousal induced by stressful situations might be related to personality traits, especially neuroticism (Binboğa et al., 2012). Neuroticism is an individual's tendency to experience distress and to be able to handle, emotionally, any such pressure situation. Researches suggest that low neuroticism can exposed and react to stressors more frequently (Bolger and Schilling, 1991), demonstrate higher sensitivity to criticism and negative stimuli (Tellegen, 1985; O'Sullivan et al., 1998), lower self-confidence (Bandura, 1977) and more significant adverse reactions to a stressful situation (Ormel and Wohlfarth, 1991; Bolger and Zuckerman, 1995). Research findings in sports and exercise psychology indicated that high neuroticism or lack of neuroticism might deteriorate athletic performance (Silva et al., 1985; Davis and Mogk, 1994).

The present study aims to examine the effect of emotional inconsistency on the HRV under mental stress for athletes. Studies designed to understand the effects of stress on performance have been insufficient, especially regarding the autonomic cardiac responses of certain personality traits, such as neuroticism to stress. Extending this concept, it seems worthwhile investigating the effect of neuroticism as a personality trait that may influence an individual's tendency to experience stress under pressure. Therefore, examining the neuroticism associated with elevated mental load (as the source of stress) is the most natural starting point for this line of investigation. We hypothesized that low neurotics might adapt to different stressors more successfully. Moreover, we anticipated that low neuroticism might give rise to more adaptive autonomic cardiac responses to stress.

Materials Methods

Research Model

This research was designed to be descriptive, using the questionnaire technique and an experimental model as a data collection tool. The study used a descriptive survey model that questioned the personality (neuroticism) of the participants. Each participant individually attended a laboratory session lasting approximately 30 minutes in the experiment. Upon entry to the laboratory, we first briefed individuals about the experiment; after participants had read and completed the informed consent form with additional demographic data (age, sex), they were asked to complete the personality inventory to measure the degree of participants' neuroticism. We measured four minutes of HRV activities to obtain objective cardiac activity in resting conditions. Participants then completed the Stroop Test in mental stress condition, which lasted about four minutes for each participant. We also measured HRV activities while the participants performed the Stroop Test.

Participants

Forty-nine undergraduate sport science students aged 19 to 24 (38 men, 11 women) voluntarily agreed to participate in the study. All participants provided written informed consent and a demographic information sheet. The local ethics committee (University of Manisa Celal Bayar Scientific Research Project Coordination) approved (Ethics committee approval ID 20-478-486) all experimental procedures, and all data were collected following the latest version of the Helsinki Declaration.

Data Collection Tools

Neuroticism (The Short Form of the Five Factor Personality Inventory)

We used the items from the short form of the Five Factor Personality Inventory measuring the neuroticism factor. The 85-item short form of the Five Factor Personality Inventory measures neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness on a five-point Likert scale (1 = totally agree; 5 = totally disagree) (Tatar, 2016). The internal consistency for neuroticism was .82.

Cardiac Activity

We used a Nexus-10 system and associated software of Biotrace to measure HRV derived from an Electrocardiogram (ECG) in a lead II configuration. We placed one electrode below the right clavicle and one on the left side of the chest below the sixth rib. We fixed the ground electrode under the left clavicle. ECG signals were saved at 16-bit resolution with a sampling rate of 1,024 Hz. The HRV of each participant was obtained based on the time series of beat-to-beat (RR) intervals, which were immediately extracted from ECG data. Before HRV analyses, we detected the RR intervals visually, and artifacts were corrected. Then, the corrected RR intervals were converted to interbeat intervals time series and subjected to a fast Fourier transform to compute frequency domain indices of HRV. In the present study, the sympathetic activity was represented by the frequency domain parameters of LF (0.04–0.15 Hz) power (ms2), and the parasympathetic activity was represented by the frequency domain parameters of HF (0.15–0.40 Hz) power (ms2). We also used the Heart Rate (HR) and time-domain parameter of the RMSSD to indicate HRV.

Stroop Test Protocol

We adopted a Stroop word color interference test. In the experiment's first phase, participants were instructed to read word names (blue, red, green, yellow, and purple) printed in black ink as quickly as possible. In the second phase of the experiment, participants viewed 100 colors of names printed in the same ink. Participants' task in this phase was to read aloud the color name as quickly as possible. In the last phase of the experiment, the participants viewed color names printed in different color inks (e.g., red printed in green ink). Participants were asked to omit the color name and pronounce the color in which the words were printed.

Statistical Analysis

Based on the median value of the self-report measures of neuroticism, participants were grouped into high and low-neuroticism groups. Then, the changes in HRV parameters under stress conditions were examined in the high and low neuroticism group via the Wilcoxon Signed Rank Test. We performed a series of Wilcoxon Signed Rank tests to test whether HR and HRV indices of LF, HF, and RMSSD changed from baseline to stressor conditions in both high and low neuroticism groups.

Results

As illustrated in Table 1, the Wilcoxon Signed-Rank test results indicated a significant increase in HR (z= 3.162, p= .002) and time domain parameter of RMSSD (z= 2.973, p= .003) in the low neuroticism group from baseline to stressor condition. Wilcoxon Signed-Rank test also demonstrated that frequency domain parameters LF (z = 3.027, p = .002) and HF (z= 3.404, p= .001) increased significantly in the low neuroticism group from baseline to stressor condition.

Table 1
HR and HRV Difference Between Baseline and Stressor Conditions in Low Neurotics

	Baseline		**Stressor**			
Variables	**Median**	**SD**	**Median**	**SD**	**p**	**Z**
HR	80.530	12.644	86.130	13.543	**.002***	3.162
RMSSD	33.880	15.980	51.040	27.912	**.003***	2.973
LF	2349.600	1951.885	3929.900	4745.163	**.002***	3.027
HF	779.500	1140.087	2219.700	2651.226	**.001***	3.404

***p<.05**

Similarly, HR (z= 2.543, p= .011) and HF (z= 2.229, p= .026) in the high neuroticism group increased significantly from baseline to stressor condition. However, LF (z= 1.173, p= .241) and RMSSD (z= 1.314, p= .189) did not change significantly from baseline to stressor condition in the high neuroticism group (Table 2).

Table 2
HR and HRV Difference Between Baseline and Stressor Conditions in High Neurotics

	Baseline		**Stressor**			
Variables	**Median**	**SD**	**Median**	**SD**	**p**	**Z**
HR	84.190	10.549	88.455	8.451	**.011***	2.543
RMSSD	42.890	27.084	54.875	24.876	.189	1.314
LF	4263.000	3955.038	4812.400	3189.636	.241	1.173
HF	1886.300	2164.412	2260.950	2419.142	**.026***	2.229

***p<.05**

Discussion and Conclusions

The present study investigated whether the autonomic cardiac activity response to mental stress triggered by the Stroop Test may vary due to neuroticism. Results observed in the present study indicated that mental stress might give rise to more noticeable and complete changes in autonomic cardiac activity in individuals with a lower neuroticism level. Accordingly, HR, RMMSD, LF, and HF increased significantly from baseline to stressor condition in the low neuroticism group. In other words, low-neuroticism individuals' autonomic nervous system could produce a noticeable response to mental stressors. On the other hand, only HR and HF increased, and RMSSD and LF remained almost stable in individuals with high neuroticism, which means that high neuroticism individuals could not develop a complete response to mental stressors.

Considering Eysenck's (1967) theory suggesting an association between neuroticism and the excitability of the limbic system, one would argue that individuals with high neuroticism may have a lower limbic system arousal threshold level, leading to more intense responses to mental stress. However, the results of the present study indicated the opposite direction. Based on Eysenck's (1967) argument, it can be concluded that there is an inconsistency between our research results and the previous literature. Research has indicated that autonomic cardiac responses reflect an individual's capacity to readily adjust to shifting intra-individual or inter-individual conditions (Thayer et al., 2012) and environmental demands (Gostimirovic et al., 2020). Also the studies found that a higher HRV, both in time and frequency domains, were associated with finest cognitive performance, even after adjustment for the confounding variables commonly associated with HRV (Forte et al., 2019). Drawing from our findings, which reveal that individuals with low neuroticism tend to elicit more robust HRV responses to mental stressors, it is reasonable to infer that their adaptability is more effective. A close examination of the results reveals that individuals with low neuroticism responded to the mental stressor by elevating their parasympathetic activity. On the other hand, parasympathetic activation response to the mental stressor in high-neuroticism individuals was more limited. Accordingly, we concluded that high-neuroticism individuals failed to develop an adaptive response to the mental stressor by elevating their parasympathetic activity. The change in HRV may indicate the ability to adapt to the stressor in low neurotics.

Accordingly, low-neuroticism individuals could adapt more to the stressor than high-neuroticism individuals. Low-neuroticism individuals adapted to increasing environmental, psychological, and biological demands by promoting parasympathetic activity. Based on the results observed in the present study, we concluded that low-neuroticism individuals might have more adaptive psychophysiological responses than high-neuroticism individuals to a mental stressor. In other words, the current research results indicate the possibility of low-neuroticism individuals' ability to develop autonomic adaptation to stress.

Another critical issue must be addressed is the increases in HR observed in low and high neuroticism groups. These results made us consider that HR responses to a mental stressor might be independent of personality traits, such as neuroticism. Another possible explanation for the HR increases observed in high and low neuroticism groups might be related to HR's sensitivity to mental stressors. Hence, HR seems more easily and quickly represent autonomic regulation during exposure to a mental stressor. However, changes in HRV indices reflecting parasympathetic activation, such as LF and RMSSD, were observed only in low neuroticism individuals. Therefore, we inferred from the present results that specific HRV responses might vary depending on individuals' personality traits.

Although HRV is used in psychophysiological research in sports, as in our study, it can also indicate many health issues. Previous studies found that HRV is robustly associated with severe health outcomes such as post-traumatic stress disorder (Dennis et al., 2014; Schneider & Schwerdtfeger, 2020), anxiety disorder (Zhu et al., 2019; Lehrer et al., 2020), and depression (Koch et al., 2019; Pizzoli et al., 2021). As stated, impaired vagal activity due to anxiety might also lead to cardiovascular diseases. Therefore, individuals with high neuroticism may be more prone to health issues as they may have difficulty adapting to stress.

Increased autonomic cardiac responses might have the potential to explain the link between low neuroticism and performance in various domains. In this regard, Dobson (2000) showed that low neuroticism was inversely related to cognitive performance when stress was present. According to the findings and the results observed in the present study, it can be concluded that individuals with low neuroticism may have an advantage in developing adaptive psychophysiological responses to stress. This may positively influence their performance, particularly when faced with a stressor. However, it should be noted that in the absence of a stressor (or in a low arousal condition), performance may not differ between low and high-neuroticism individuals (Dobson, 2000). Increased autonomic cardiac responses might have the potential to explain the link between low neuroticism and performance in various domains. Hence, as Reynold et al. (2014) stated, low neuroticism individuals' performance should not be underestimated when tasks induce high anxiety levels and massive demand for information processing capacity. In addition, other research findings indicated that neuroticism decreases performance accuracy while quickening motor speed, indicative of a less efficient response strategy in the context of task demands (Crow, 2019). Besides, Munoz et al. (2020) found that neuroticism predicts greater response time inconsistency irrespective of mean performance, and this effect is driven largely by heightened negative emotionality.

The results observed in our study may have some implications for both researchers and practitioners. Accordingly, low neuroticism might be an individual difference that can facilitate the development of adaptive autonomic responses to mental stressors. In this respect, sports psychology practitioners should consider athletes' neuroticism level in mental preparation for competitions and training. Moreover, as the HRV is a robust indicator of psychological health, such as post-traumatic stress disorder and anxiety disorder, practitioners might consider high neuroticism individuals' relatively low ability to produce adaptive responses to stress. Also, high-neuroticism individuals' relatively low capacity to develop adaptive stress responses might be a risk factor for particular health concerns or life quality.

The present study has some limitations. First, we measured autonomic cardiac activity represented by HRV in response to only a mental stressor. However, many other effective stressors, such as physical load and heat, can give rise to variations in autonomic cardiac activity. Hence, we recommend testing the effect of varying stressors on autonomic cardiac responses. Further, it is unclear whether neuroticism may have accounted for an antecedent of autonomic cardiac responses to physical and mental stressors.

Ethical Considerations

Ethics review board: Manisa Celal Bayar University Ethics Committee

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Researcher's Contribution

The entire study was conducted by a single author.

Conflict of Interest

The author does not have a statement of conflict regarding the research.

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