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Opinion

Detection of Psychological Stress Levels Using Heartbeat Mode

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PSYCHOLOGICAL STRESS LEVELS

The effective identification and assessment of mental health has long been a research priority. The study of Heart Rate Variability (HRV) is a good method for determining psychological stress levels. However, there is no agreement on the best HRV measurements to use in psychological examinations. To identify driver stress, this study presents an HRV analysis approach based on heartbeat patterns. We employed linguistic statistical methods to detect and quantify the structure of the heart rate time series, and we summarized the various heartbeat modes in the time series. The likelihood of each pulse mode was employed as a feature to identify and distinguish stress generated by the driving environment using the k-Nearest Neighbors (k-NN) classification technique. The findings revealed that the stress of the driving environment altered the heartbeat mode. Stress-related heartbeat modes were identified, allowing for the identification of the stress state with 93.7 percent accuracy. We also discovered a link between the heartbeat mode and the Galvanic Skin Response (GSR) signal, indicating real-time aberrant mood changes. The suggested technique revealed HRV properties that allowed for the quantification and detection of various mental disorders. As a result, individualized studies might be performed to better investigate the connection between physiology and psychology.

Human health is inextricably linked to mental stress, which is subjective and constantly fluctuating. As a result, assessing the start, length, and intensity of stressful situations is a challenging and worthwhile study issue. Obtaining biomarkers of stress and health is also a difficult issue for researchers and physicians.

Stress can cause Autonomic Nervous System (ANS) dynamic changes, such as an increase in Sympathetic Nervous System (SNS) activity and a reduction in Parasympathetic Nervous System (PNS) activity. Heart-Rate Variability (HRV) characteristics are regarded as acceptable physiological indicators for assessing ANS activity when detecting stress. HRV is defined as the variation in the time intervals between successive heartbeats, which may be easily derived from Electrocardiograph (ECG) readings.

The balancing action of the SNS and PNS branches regulates Heart Rate (HR). A rise in sympathetic activity is associated with an increase in heart rate, whereas a rise in parasympathetic activity is associated with a reduction in heart rate. Sympathetic effects occur slowly, on the order of seconds, whereas parasympathetic effects occur quickly, on the order of milliseconds. Sympathetic effects can cause fast variations in heartbeat intervals, with large individual variability. As a result, the optimal HRV index for stress detection must show the changing rule of the heartbeat interval on the smallest time scale while accommodating individual variances.

McCraty et al. examined the HRV power spectrum induced by various emotions and discovered that good emotions (e.g., admiration and compassion) are associated with a more coherent heart-rhythm pattern, but negative emotions (e.g., stress) can negatively influence heart-rhythm pattern coherence. McCraty et al. suggested a model of psychophysiological coherence in which various emotions are reflected in unique heart-rhythm patterns that are independent of HRV levels. However, frequency domain analysis requires longer data (about 5 minutes) and is heavily influenced by anomalous Normal-to-Normal Interval (NNI) values generated by erroneous detection. Dalmeida et al. demonstrated that HRV time-domain measures (for example, average of NNIs (avNN), Standard Deviation of Average NNIs (SDNN), and Root Mean-Square Differences of Consecutive NNIs (RMSSD)) are crucial characteristics for stress identification. Pereira et al. studied numerous heart-rate variability indicators for stress-level assessment across a short time window and shown that time-domain analysis is the most robust stress detection approach. The four-stage Trier Social Stress Test (TSST) was utilised as a stress-inducing protocol, and the avNN metric allowed fine-grained examination of stress effects; it is the most trustworthy metric for determining stress levels.

Despite the huge quantity of research on HRV analysis and its possible application to the building of a stress index, there is no conventional stress index based on ANS evaluation. As a result, we present an HRV analysis approach based on heartbeat mode to assess the dynamic changes in the ANS under stress.

In this work, heart-rate time-series patterns were detected and quantified using statistical approaches commonly employed in linguistics. We concentrated on the fluctuation between heartbeat intervals and ignored the interval values itself. This approach reveals the variation rule of heart-rate variability in a shorter time scale ($m + 1$ NNIs; in this study, $m = 4$) that is less impacted by the anomalous NNI value induced by erroneous detection. The various beating modes (bms) in the time series were summed, and the

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unique bm associated with different individuals' stress levels was found. The frequency of bm (bmNN) was employed as a feature to identify and recognise stress using the k-Nearest Neighbour (k-NN) method for classification. We validated the method's practicality by comparing the recognition accuracy of bmNN with the traditional avNN index in the public driving stress database. To increase the overall accuracy of stress assessment, we additionally reduced the influence of anomalous occurrences during the rest period in the driving stress database by analysing the Galvanic Skin Response (GSR) signal waveform.

The following is how this document is structured. Section 2 describes the suggested stress-level assessment method based on heartbeat mode. Section 3 discusses the study's findings and compares them to the traditional avNN index. Section 4 explains the data obtained and compares them to earlier stress detection methods, while Section 5 concludes the work.

According to McCraty et al., the synchronisation of emotional and physiological dynamics is directly tied to rhythmic patterns in the heart rate (the order of the rate of change over time), rather than the heart rate itself at any moment in time. Furthermore, the findings of this investigation indicated the existence of an HRV rhythm alteration in synchrony with emotions. We discovered that the HRV cycles corresponded to driver stress after integrating ML approaches and heartbeat mode analysis, as well as selecting values for m and bm. The time series' various heartbeat modes were summed, and unique heart-rhythm patterns connected to distinct driving stressors were discovered. The heartbeat mode was also shown to be associated with the GSR signal, indicating real-time aberrant mood changes.