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A Survey on Human Stress Detection Using Physiological Signal

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ABSTRACT

This article presented various research studies on the analysis of bio-signal and investigates how the human stress is manifested with the bio-signal. The bio-signal such as EEG, ECG, Heart rate, speech signal are investigated for different stressors. The prime aim of such an investigation is to share the technical overview of human stress and it's mechanism for understanding human stress and it is associated with bio-signal. In this article the direction on the feature set used for stress detection are given, also the information on the fusion of feature set is presented for better recognition. In spite of that the effect of human stress and signal anatomy is surveyed. This investigation throw more light on the study of stress mechanism, stressors, bio-signals and it's feature set

Keywords: HR, R-R interval, EEG, ECG, Pitch, LF/HF

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INTRODUCTION

In the field of Neuroscience and Medicine, the human stress becomes a very interesting area of research. The term Stress defined by many researchers with different point of view, however human stress is the type of internal and external bodily changes. The external body changes are the day to day life happening problems such as, heavy work load, financial problem and relationship problems. Similarly internal bodily changes are, human body structure, way of thinking which may induce some positive and negative emotions like happiness and fear. The general conception about the human stress is, human stress is directly related to comprehension and person to person evaluation of the current situation, as well as the body reaction due to international changes [1, 2]. A stress response considered as bodily changes educe by the natural events or situations called it as “Stressor". This Stress response consists of some series of actions responsible for handling and organizing the stressors and adaptive response, make ready a myoskeletal structure for mechanical operation [3]. Moreover, to resist the lesion and metabolic demands. The term PPB is well suitable for defining various types of human stress such as Psychological, Physiological and Behavioral. There are various methods for assessing the human stress, however all these are influenced by a legion of measurement errors such as, facial expressions and gestures. Though these methods are desirable to detect the human stress, it can be manifested or hide actual level of stress. The above limitation can be resolved by using the current technology to detect the appropriate stress detection without any type of errors [4]. The distinctive attribute about the human stress through physiological signals are involuntary or automatic. These attributes can easily be identified through electrocardiogram signals, electroencephalogram signals, electromyography, blood volume pressure, and skin temperature and electro dermal activity.

After extensive survey on the human stress detection using physiological signals, it has been observed that, many researchers focus on the human stress detection that the proposed paper carried out the systematic investigation in detail. However, present information on stress detection is very limited and brief. Moreover, researchers focus on the accuracy of the system using physiological signals rather than the importance and required feature set for human stress detection.

This review paper gives detailed information about the various physiological signals and there key features useful to extract human stress related information. In this investigation we made an attempt to report the detailed information about the feature set extracted from physiological signal in terms of their behavior, efficiency, usefulness, changes and consistency. Similarly we have focused on the various stressor or stimulators for effective generation of human stress. In brief, the review study proposed here aim to put a light on the thorough and pervasive information of the available physiological signals and there importance in human stress detection.

HUMAN STRESS

Since many years, the definition of the human stress is a subject of debate, during literature survey it has been observed that the human stress is simply a body response to the sudden change to menace or threat [5, 6]. Many researchers in the field of stress recognition introduced novel components of the stress that is General Adaptation of Syndrome (GAS)[2], similarly it has been point out that the various stressors like feeling of sudden fear, opposition and the various stages of tiredness are the source of physiological reactions[3]. In view of this, the level of a source of human stress and its response is different in every human being also different in each and every human being at various situations as shown in Fig. 1. One of the scientist nicely present the human stress, human stress is simply a flexible model between a human being and it's surrounding environment[3]. The asperity and the accentuation of this flexible model assessed individually by providing respective coping methods. There are two different methods for assessment, one for outcome achievement relates to individuals attainment and other related to individual duty and presence for coping methods. Some of the research paper report the occurrence of Censorious life moments instead of its plus and minus points, cause changes in the human body part that may lead to the outbreak of stress problem in human being. During research on human stress, various study indicate the variances in male and female in stress adoption and the unique identity also special characteristic like work orientation, independence, empathy are subject to induce more stress[5]. The outcome of the extensive survey on the personality theory is such that the personality of type A out of type A and B is too famous and demanding. Personality of Type A has a habitude to overreact. Hence, more vulnerable to the human stress [6].

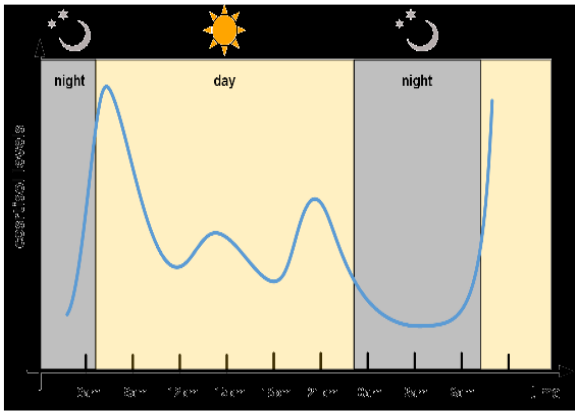

Fig. 1. Graphical representation of Blood Cortisol level

PHYSIOLOGY OF HUMAN STRESS

When a human being aware of the forthcoming threat, a series of processes of living organism occurs in human body. All these processes are comes under the stress response. The living organism response for these processes helps to cope up with the level of stressor[7]. A human brain is the actual source of the generation of human stress in controlled and avoidable condition. Besides, the part of the human brain which is deeply attached with the temporal lobe, the collection of the cells associated with limbic system of human brain and amygdala and the cerebral cortex has major involvement in the stress generation [8]. The thalamus in the brain process the stressful stimuli

provoked from the audio clips and visual information and then the extracted information transferred through two distinct ways. First way of communication is amygdala which is more faster than the other one, where the stimulus analysis is bit lesser than the higher level without the involvement of any cognitive functions. The other slower way relays the important information to the prefrontal cortex in which cognitive analysis is performed from their information transferred to amygdala the faster pathway [9]. However, the level of effectiveness of acute human stress on human nervous system is not uniform. Various review study reveals that the activity region of human brain related in each and every time to the stressors.

The realization of human stress is almost equal by the two different important ways. One way of realization or experience is Hypothalamus-Pituitary-Adrenal (HPA) axis where, Hypothalamus, pituitary glands and Adrenal cortex involves in this human stress. Moreover, SAM system in which the logical elements of autonomous nervous system and adrenal medulla plays an important role [11, 12]. In the mechanism of human stress system direct activation of HPA axis in hypothalamus and indirect activation of neurotransmitter sent by the amygdala presents the actual human stress. In the human nervous system the glucose level which provides strength for fibrous tissues in human body and nerve cells in order to serve adaptation to stressors gets increased due to three different stress harmonies.

HUMAN STRESS AND HUMAN EMOTIONS

In 1926, first time the term human stress was presented by a scientist Selye. Besides, the definition of human stress vary person to person or in other way it is subjective in nature. The researcher Cohen, proposed its definition as " a process where the robustness of an organism varies psychologically and biologically". In experimental use, the common phenomena used in psychology presented for emotional phase negatively. However, various research on the human stress are more positive about the effect of stress. These studies proposed that, in some situations the human stress may have reliable good effect on immune system as well as on the human health with its performance as per the mental state of that person due to the stress [13]. Thus, one should not consider human stress as a negative concept related to human state of mind only but also helpful with many psychological manifestations.

In practice, the human stress is represented on valence and arousal axis, where phase representation of stress is negative valence and positive arousal [14]. The mapping of human stress on valence and arousal model shows the position of stress in first quadrant of V-A model as shown in fig. 2.

Regarding practical study and useful observations stress is presented in two useful categories one is positive stress and other is negative stress. The study reveals that the level of arousal decides the intensity of stress which affects the performance level of human being can be observed in Fig. 3. The performance level normally imitates paradigm Hebb's curve. In this survey it is observed that the performance of human system gets reduced when level of stress is bit higher or smaller depends on the situation. Moreover, the performance improvement is possible in moderate stress level. The valence of emotional phase are directly propotional to the time or in other word it is time dependent.

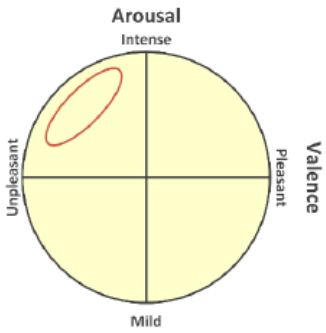

Fig. 2: Valence Arousal model of emotion

CONCEPT OF HUMAN STRESS AND OUTCOME

The term human stress and anxiety are two different words, however the meaning and concept of both the terms are very close to each other and are almost overlap with each other. The study says that the Anxiety is an actual outcome of human stress. Many researcher often presented these two

terms parallelly for same objective. Sometimes anxiety can be observed after the application of an intensed stress agent. As mentioned earlier, the anxiety is the outcome of human stress, many researcher presented that the emotional reaction of continuous state of anxiety is ultimate part and parcel of the human stress [15, 16]. Hence the symptoms that can be observed due to human stress and anxiety are somehow similar. One can observed that the regular appearance of human stress in human being may leads to a very serious psychiatric disease like mental disorder and apathy.

STRESSOR

In biomedical term any type of agent that causes a human stress to an organism is a stressor. In line with this, the stress response is possible by having internal or external type of stimuli called "stressor" in human body. During literature survey, researchers presented various types of stressors. However, during experimentation no any stringent classifications technique is considered for all these types of stressors. The list of stress agents or stressors in stress elicitation presented in table I [17]. As far as biomedical /psychological research is concerned Human stress are categories in two important groups viz. Acute stress and chronic stress. The chronic and acute stress are presented differently in the literature survey, the chronic stress response is about the presence of stressor whereas, the acute stress response is about time limit [18]. Precisely in this concepts of stressors, the chronic stress which will remain for long time is the outcome of the repetitive acute stress [19].

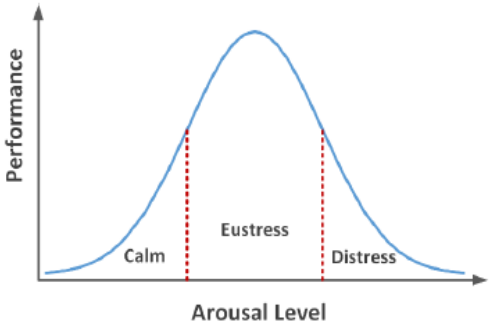

Fig. 3. Arousal and Human performance level diagram

PHYSIOLOGICAL SIGNALS FOR HUMAN STRESS

The Physiological signals are represented in time domain and are used to predict the important functions of various body parts. All these body functions are absolutely related with Electrocardiogram, Blood volume pulse, Electroencephalogram, Skin functions, Electromyogram.

Table 1 : Relevance of Stressors used in the research on human stress

Type	Relevance
Type I	Physical activity related to health issue
Type II	Environmental stimuli like high temperature, noise, humidity etc.
Type III	Person's mental or cognitive strength related
Type IV	Social critics related stimuli
Type V	Human emotional state due to unwanted situations
Type VI	Personal financial, health, job related problems
Type VII	Due to traumatic experience

PHYSIOLOGICAL SIGNALS FOR HUMAN STRESS

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ELECTROCARDIOGRAM (ECG)

The electrocardiogram signals reveal the activity of human heart in the form of electrical signals. It is a two dimensional signal used to detect and record the strength of human hearts electrical activity. The graphical

representation of ECG signals are denoted by various peaks such as P,Q,R,S and T. The intervals from two dimensional graph such as P wave, QRS complex, ST wave, R peak, RR intervals. In ECG analysis process all these interval plays an vital role in the disease diagnosis and prediction [20].

Fig. 4. P Wave, QRS complex, ST wave and T wave representation of ECG signal

HEART RATE (HR)

The actual estimation and analysis of heart rate is called heart rate variability. It's measure through any type of mode is the candid way for recognizing the level of human stress. The biological definition of Heart rate is the number of heart beats per unit minute is a heart rate. The another way to measure heart rate is the mean value of RR interval, which is the time difference between two heart beats. During extensive literature survey it is observed that, the human stress is directly related with the heart rate, in other word human stress is directly proportional to the heart rate. Whereas, some of the literature reported less significant change in human stress with respect to heart rate.

HEART RATE VARIABILITY (HRV)

Heart rate variability is the measure of intervals between two R peaks, it gives an information about the allocation time interval of RR interval as represted in Fig. 4 The Heart Rate Variability reflects various components of Autonomous Nervous System such as, the activity of vegus nerve and sympathetic components [21, 22]. The research says that, the heart rate variability provide very important information in the form of statistical parameters of heart activity in various domains like, frequency, time and nonlinear [19, 23].

During literature survey we come to know that, five minutes of recording is sufficient for HRV parameters, However few studies inferred that the recording less than five minutes can also have sufficient estimators for predicting human mental stress [24, 25]. In the analysis of HRV parameters in spectral domain has high frequency band and low frequency band. The vagal modulation reflects in high frequency band while, the sympathetic and vagal modulation reflects in low frequency band.

During experimentation it is observed that the HRV representation in human emotional state like, anger, anxiety or sadness is abnormal, the cardiac coherence is suppose to use to estimate the rhythemicity of that abnormal HRV signals.

Table 2: List of feature set used in the stress detection system

Author	Features
G. Giannakakis et al.(2017) D. McDuff et al. (2014) E. Hynynen et al. (2011) B. Cinaz et al.(2013) H.-K. Yang et al.(2008)	HR
B. Cinaz et al. (2013)	STD HR
B. Cinaz et al. (2013) H.-K. Yang et al.(2008) J. Taelman et al. (2011) Z. Visnovcova et al. (2014)	RR
E. Hynynen et al. (2011) B. Cinaz et al.(2013) H.-K. Yang et al.(2008) J. Taelman et al. (2011) Z. Visnovcova et al. (2014)	SDNN
E. Hynynen et al. (2011) B. Cinaz et al.(2013) J. Taelman et al. (2011)	RMSSD
H.-K. Yang et al.(2008) D. Giakoumis et al. (2012)	NN50
B. Cinaz et al.(2013) H.-K. Yang et al.(2008) J. Taelman et al. (2011)	pNN50
B. Cinaz et al. (2013) H.-K. Yang et al.(2008) J. Taelman et al. (2011)	HRV triangular
L. Salahuddin et al. (2007) E. Hynynen et al. (2011)	VLF

J. Taelman et al. (2011) Z. Visnovcova et al. (2014) E. Hynynen et al. (2011)	LF
J. Taelman et al. (2011) Z. Visnovcova et al. (2014)	HF
J. Taelman et al. (2011) L. Salahuddin et al. (2007)	VLF relative
H.-K. Yang et al.(2008) J. Taelman et al. (2011) L. Salahuddin et al. (2007)	HF relative
H.-K. Yang et al.(2008) J. Taelman et al. (2011) L. Salahuddin et al. (2007)	LF relative
J. Taelman et al. (2011) P. Melillo et al. (2011) L. Salahuddin et al. (2007)	SD1
J. Taelman et al. (2011) P. Melillo et al. (2011) L. Salahuddin et al. (2007)	SD2
D. McDuff et al. (2014)	BR
J. Taelman et al. (2011)	DBP
L. Salahuddin et al. (2007)	SBP

In this discussion various stress related parameters in time, spectral and frequency domain are discussed. In this study it is observed that the HRV, SDNN and RMSSD parameter values varies on the scale of lower to higher in stress condition. It is also observed that, these HRV parameters like RMSSD and HF available in male and female in stress condition and are significantly different. These parameters are very less in female subject than the male due to biological nature [26]. The LF band and HF band in frequency domain are having different modulation parameters such as sympathetic and parasympathic in LF band and parasympathetic in HF band [27]. The value of a ratio of low frequency and high frequency band is significantly increases in the stress condition, this ratio is an important feature for stress detection in frequency domain. In addition to that the very high frequency (VHF) band also get increase in stress condition [28]. The HRV parameters, heart rate and carbon dioxide are lesser for different stressor. Whereas, the state of mind gets disturbed in a heavy mental workload [29, 30, 31]. The important feature for human stress detection through electrocardiogram (ECG) signal is the amplitude of the T wave(TWA). The sudden increase in SNS activity during acute stress decreases the heart beat interval (IBI) which in turn affects the amplitude of T wave in ECG signal [32, 33]. It has been observed in the actual experimental study on stress detection that the human stress response and the autonomous nervous system (ANS) response through heart rate variability parameters is random [34]. However, the representation of HRV parameters are very consistent in human stress condition.

ELECTROENCEPHALOGRAM (EEG)

The brain activity estimation is very important investigation in neuroscience. The input signals in this type of system used for the activity investigation are Electroencephalogram (EEG) signals. The performance estimation of neurological system are totally depends on the EEG signals, which can be used to estimate changes in the various brain activity. As we know the EEG estimation value is directly proportional to the sensitivity of brain activity either in any of the emotional state of human mind. The right and left region of human brain are classified based on the type of emotions. The type of human emotions like happiness, and anger due to the positive arousal and positive valence on valence arousal diagram are related to the left anterior region of the human brain [35, 36]. Whereas, the emotions such as sadness and fear those are under avoidance type of emotions are related with right anterior region. One of the best and robust feature in stress recognition which is used in exhibiting the arousal part in emotional state is asymmetry index (AS) [10, 37]. The practical use suggested in various literature of this feature is for extract the emotional states. The mathematical representation of asymmetry index is the logarithmic difference of left and right hemisphere of alpha power in EEG signal as given by equation.

AS = ln(a)l left. - ln(a)l right

The experimental result presented in various research paper on the estimated value of asymmetry index shows that the alpha values are greater in right activity than the left activity. The index value of right activity observed during experimentation is substantially greater when any of the stimuli is successfully applied to human being [38]. The positive and negative stimuli listed here are the audio visual

clips such as horror movie clips or comedy movie clips. However, the greater energy level induced in left frontal with the help of a situation which may associated with valence axis inclined towards the positive side of affective state [39]. The intense level of human stress are recognized from the very small intra changes from the power indices and its spectrum[40, 41]. The frequency bands associated with EEG signals are alpha, beta, delta, gamma and theta. The frequency range of every wave reveals the various state of mind [42, 43]. The frequency range 8-13 Hz is associated with alpha wave and which is observed when a person is in the relaxed state of mind [44]. To the contrary, the higher frequency range 13-30Hz is associated with beta wave reveals the active state of mind of the human being.

Table 3: EEG features used in human stress detection

EEG Feature	Research of study
Delta wave	L. M. Gatzke-Kopp et al. (2014) G. Giannakakis et al. (2015)
Theta wave	G. Giannakakis et al. (2015) L. M. Gatzke-Kopp et al. (2014) T. Hayashi et al. (2009) J. Alonso et al. (2015) F. Al-shargie et al. (2015)
Alpha wave	G. Giannakakis et al. (2015) L. M. Gatzke-Kopp et al. (2014) T. Hayashi et al. (2009) J. Alonso et al. (2015) F. Al-shargie et al. (2015)
Beta wave	G. Giannakakis et al. (2015) L. M. Gatzke-Kopp et al. (2014) T. Hayashi et al. (2009) J. Alonso et al. (2015) F. Al-shargie et al. (2015)
Gamma wave	J. Minguillon et al. (2016)
Beta/Alpha wave	S. Seo et al. (2008)
AS value	G. Giannakakis et al. (2015) L. M. Gatzke-Kopp et al. (2014) T. Hayashi et al. (2009) J. Alonso et al. (2015) F. Al-shargie et al. (2015)
Beta coherence	J. Alonso et al. (2015)
Alpha coherence	J. Alonso et al. (2015)
Coherence	G. Giannakakis et al. (2015)
Brain load index	S. Tiinanen et al. (2011)
ApEn	J. Alonso et al. (2015)
Linear CMIF	J. Alonso et al. (2015)
Non- Linear CMIF	J. Alonso et al. (2015)

It has been observed during extensive literature survey and while performing actual experimentation on stress data and features, the alpha decreases while the beta value increases in stress condition [45]. The human emotional state with greater arousal level which can be assumed as anxiety correlated with the beta wave. The research study shows that the ratio of alpha and beta value is very important type of feature in the experimental study of stress recognition [46, 47]. The gamma wave is the extreme high frequency range signal in EEG, it is correlated to myogenic activity in emotional state. Another important EEG feature in stress recognition called coherence which varies when effective stimuli is applied and changes its frequency range between 23-36Hz which is quiet close to beta wave. Similar to this cross mutual information function and approximate entropy are also the important EEG features in human stress recognition.

SPEECH SIGNAL

The input signal for stress recognition system can be multiple signal, hence speech signal is one of the mode of the human stress recognition system. The research on speech Signal for stress recognition shows the variations in speech signals when a subject or person is in stress condition than the normal condition. In view of this, to discriminate stress condition in human being and to identify stress condition through the speech a very popular analysis method suggested known as voice stress analysis. In the human speech reproduction system input, noise removal block and output blocks are very prominently used for the production of human speech [48]. In this mechanism the source in association with noise removal block some time call it as filter system is used to produce speech signal. It has been observed in the literature survey that, during the stress situation the expansion and contraction in the interior muscle of vocal cord may affect the source. Moreover, due to the shifting the location of vocal cord affects the filter the noise removal component [49, 50]. Hence due to the contraction of muscles and position change of source and

vocal cord affects the speech signal [51]. The various feature set proposed in the different research on the stress situation is presented here in table 3. The feature set summarized in the table such as pitch, formant 1 and 2, spectral slope, utterance, glottal pulse, duration of word & vowels, intensity and finally jitter are very important features to distinguish the stressed and neutral speech. Moreover, the wavelet based analysis, HMM and muscle tension ratio based study are proposed for identifying stressed speech signal.

TYPES OF STRESS ELICITATION

The unexpected situations and events likely to be the reason of stress in human day to day life. Moreover, the stress situation occurred in the real life when a person is in controlled environment. The methods for inducing stress are focused in this section. In human stress recognition system the various stressor used to induce appropriate stress, one of the way for inducing stress is a picture system over the scale of valence and arousal dimension. The multidimensional picture system called international affective picture system is the appropriate tool for inducing human stress in stress recognition system. One another reliable stressor is a color identification test to identify the color of word this is called stroop color word test (SCWT). During extensive literature survey it has been observed that, researchers proposed various stress inducing methods as a stressors in their study. The author suggested an arithmetic test based on the mental ability. In addition to this, a neuro test based on successive addition called PASAT is also suggested in research study on stress detection as a stressor [52, 53].

Another very important and sophisticated stressor based on imaging called MIST is adopted in various research studies on stress detection. The author suggested card sorting based stressor called BCST for inducing acute stress in the subject. In addition, some unethical stressors like electric shocks, skydive and threats are used to induce acute stress for experimentation purpose in stress recognition system.

DISCUSSION

The term " Human stress" is a multidimensional because of the way of understanding and representing is different in all its type. In many situations a person under stress cannot understand the acuteness of the stress he is suffering from. Moreover, direct prediction of human stress without any clinical approach is not available which can evaluate stress state related to behavior and human feelings.

Table 4: Important feature set for stress detection from Speech signals

Feature Set	Research Study
Pitch	K. W. Godin and J. H. Hansen (2015), D. Gharavian (2012)
Jitter	Thiam, P, Kestler, H.A, Schwenker, F (2020)
Formant 1	I. Lefter, L. J. Rothkrantz, , P. Wiggers (2011)
Formant 2	I. Lefter, L. J. Rothkrantz, and P. Wiggers (2011)
Spectral pulse	Thiam, P, Kestler, H.A, Schwenker, F (2020)
Glottal pulse	A. Asif, M. Majid, and S. M. Anwar (2019)
Utterance	Franzoni, V, Biondi, G, Perri, D, Gervasi, O (2020)
Duration of words	Franzoni, V, Biondi, G, Perri, D, Gervasi, O (2020)
Duration of vowels	Franzoni, V, Biondi, G, Perri, D, Gervasi, O (2020)
Intensity	A. Asif, M. Majid, and S. M. Anwar (2019)

It has been observed in survey, few performance indicators are used by the researcher for evaluating the stress. The scores from the performance indicators like questionnaire and its association with stress levels helps to investigate the stress state. In addition to questionnaires clinical interview may also gives some score or rating for predicting the human stress. In many investigation studies on stress state, the experimental data are collected after the spiritual speech for evaluating the level of stress [54]. In line with this, many researchers performed experiment on the subject after an hour of meditation [55]. The comedy videos and pictures are also used by the author for the estimation of stress level. The human stress in real world situation is distinct from the

stress elicited by the stimuli of any type and estimation is also subjective [56]. The bottom line on this is that, the real life stress is far from the stress induced by stimuli.

The review presented in this paper is on the basis of the evidences collected through the experimental work. It has been observed that, the stress signal used in the experiments are collected after stressor applied. The study shows that the intensity level of induced stress is depends on the level of stressor used. In spite of that, the level of human stress in actual situation depends on many parameters such as his/her biological structure and way of handling situation. During survey it is also observed that many researchers focused on the subjective nature of this stress recognition system, it means the outcome of the system is not universal but varies with situation. Another important observation on the outcome of stress detection system is, the outcome of system may vary due to the contamination of the signal by various noise and artificats. The signals presented in various studies like, EEG, ECG, Speech, EMG are contaminated with noise. The well suited filers are used by the researchers for the removal of noise and artifacts. Although, the filter circuit are well designed and appropriate for noise removal still signal distortion may affect the information in stress detection. Similarly, the output signal elicit from human organs may also get affected due the change in environmental situation, such as brain, heart, skin and vocal cord. Hence, to improve the performance measure of stress detection system it is very important to maintain the stability in the environmental condition while collecting signals during experimentation. In the experimental set up of stress signal collection, it has been observed that the effect due to stressor can observed significantly at the start of experiment. However, the stressor effect diminishes over the period of time. Due to such reason to maintain the stability in the performance evaluation in such situation for different techniques is not possible.

The analysis bio-signals for early stage detection of human stress induced during day to day activity as well as due to some threats in a life and its assessment is very important in clinical study. In contravention of the subjective nature of human stress the efforts taken on the it's reliability to represent and assess are not possibly controllable. Inspite of having many research papers and information on stress detection using bio-signal, there is a lack of a clear distinction between the feature set used in the research for stress condition. In this review article the investigation on human stress is focused, the biosignal and its prominent feature used for the investigation of stress condition are HR, asymmetry index, R-R interval, frequency ratio LF/HF, voice pitch with its variable values. Most important part in this research is to select and make fusion of feature set for accurate stress detection. This article present here to share the technical overview of human stress and it's mechanism for understanding human stress and it is associated with bio-signal.

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