



## Methodological Review

## Towards an automatic early stress recognition system for office environments based on multimodal measurements: A review

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## ABSTRACT

Stress is a major problem of our society, as it is the cause of many health problems and huge economic losses in companies. Continuous high mental workloads and non-stop technological development, which leads to constant change and need for adaptation, makes the problem increasingly serious for office workers. To prevent stress from becoming chronic and provoking irreversible damages, it is necessary to detect it in its early stages. Unfortunately, an automatic, continuous and unobtrusive early stress detection method does not exist yet. The multimodal nature of stress and the research conducted in this area suggest that the developed method will depend on several modalities. Thus, this work reviews and brings together the recent works carried out in the automatic stress detection looking over the measurements executed along the three main modalities, namely, psychological, physiological and behavioural modalities, along with contextual measurements, in order to give hints about the most appropriate techniques to be used and thereby, to facilitate the development of such a holistic system.

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## 1. Introduction

Stress is a growing problem in our society. It is part of our daily life and many people suffer from it. We spend most of our time in the workplace, often with high workloads and time pressure, which contributes to increase our stress levels.

Stress is the second most frequent work-related health problem in Europe [1], preceded by musculoskeletal disorders which may also be a stress symptom in some cases [2]. In 2002, work-related stress cost € 20 billion to the enterprises of EU15<sup>1</sup>[3] and in 2005, 22% of working Europeans suffered from it [4]. According to a recent opinion poll [5], 51% of European workers confess that stress is common in their workplace and it is estimated that 50–60% of all lost working days in European enterprises are due to work-related stress and psychosocial risks [1].

## 1.1. Definition

Hans Selye defined stress as “the non-specific response of the body to any demand for change” [6]. Thenceforth, other definitions

that take into account the coping abilities of each individual have been exposed [7], including the one of McEwen [8] that defines stress as “events, that are threatening to an individual, and which elicit physiological and behavioural responses”. Regarding the occupational environment, work-related stress has been defined as “the emotional, cognitive, behavioural and physiological reaction to aversive and noxious aspects of work, work environments and work organisations. It is a state characterised by high levels of arousal and distress and often by feelings of not coping” [9]. “Work-related stress is experienced when the demands of the work environment exceed the employees’ ability to cope with (or control) them” [1]. These demands are not only related to high workload or long working hours, but also to high perceived stress, low social support from colleagues and managers, or to the individual characteristics of each one like the education and competitiveness [10,11].

Therefore, work-related stress, which refers to the stress that has been caused by work, or at least, made worse due to work, [12] can be understood as a particular example of stress. It follows the same characteristics as general stress and its response patterns and effects can be evidenced, and accordingly, measured, in the same way.

## 1.2. Stress types and levels

Selye [6] distinguished the concepts “eustress” and “distress”, as a positive and negative stress, respectively. Eustress appears

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with positive changes or demands that don't pose a problem for coping with or to adapt ourselves to the new situation. It can help us meet our goals and increase productivity [2]. Distress can be really harmful and can carry negative consequences. It is the most investigated aspect of stress and it is what in general terms, as well as throughout this paper, is understood by "stress".

Besides, three levels of stress can be distinguished depending on the time of exposure to stressors. Acute stress is the innate "flight-or-fight" response in face of short lasting exposure to stressors and it is not considered harmful [13]. Episodic stress appears when stressful situations occur more frequently, but they cease from time to time. It is associated with a very stressful and chaotic life [13]. Finally, chronic stress, which is the most harmful, takes place when stressors are persistent and long-standing, such as family problems, job strain or poverty [2].

In order to avoid stress to reach the highest level and help diminishing the risks [14], it is necessary to detect and treat it in its earlier stages, i.e. when it is still acute or episodic stress.

### 1.3. Long-term consequences

When work-related stress arises and it is not treated, it can cause big long-term physical and mental problems on the worker [4], but also economic losses in the companies.

Musculoskeletal disorders, depression, anxiety, increased probability of infections [15], chronic fatigue syndrome, digestive problems, diabetes, osteoporosis, stomach ulcers [3,16,17] and coronary heart disease are only some examples of chronic stress' long-term consequences.

These health problems bring consequences to enterprises, where absenteeism, staff turnover [4] and tardiness increase, decreasing the production. The problem of "presenteeism" also arises, where employees attend their workplace, but they don't work at 100% of their capabilities. Recently, the annual cost of absenteeism and presenteeism has been estimated at € 272 billion and the annual cost for loss of productivity at € 242 billion [3].

Given the importance of stress' long term consequences, the need of avoiding it as much as possible becomes evident. It is of great significance to detect stress in its early stages, before damages being caused. The scientific community is aware of this and much progress has been done in the last years towards the development of an automatic stress measuring system. Nevertheless, a reliable real-time stress measuring system, which is unobtrusive and completely transparent for the user has not been still created. The objective of this paper is to review the research done in this area to ascertain the paths to be followed in the future in order to get such an unobtrusive real-time stress monitoring system. For this purpose, the stress measurement techniques that have been used or that could be used in an office environment are reviewed, as well as the detection results of the state of the art in order to help selecting the best signals and features, and the methodological techniques that should be used for creating a stress monitoring system based on these measurements. Sharma and Gedeon [18] published a survey in automatic stress detection in 2012, where objective ways for measuring stress using physiological and physical information were explained, as well as information about the published stress data sets, monitoring systems and stress scales used in the literature. Some of the feature extraction and computational techniques were also exposed. Nevertheless, stress' multimodal nature was not considered in all its fullness and relevant measurement techniques based on contextual and behavioural information were ignored. Herein, an upgrade of the state of the art since its publication is given, in addition to a broader view of the multimodal nature of stress, which provides a different point of view of stress measurements, giving a clue for overcoming nowadays' obstacles.

This paper is structured as follows. In Section 3 the multimodality of stress is introduced and state of the art stress measuring methods are explained for each modality. In Section 4, stress elicitation methods are briefly described. Farther, in Section 5, a framework for an ubiquitous stress monitoring system for office environments is proposed based on the current technology and in Section 6 the challenges that are still open for this purpose are reviewed. Finally, in Section 7 a conclusion about the state of the art is given along with clues for future work.

## 2. Methods

The following review of the state of knowledge concerning stress detection, and, in particular, mental stress detection, was undertaken to address three specific goals:

1. To review the signals or measurements, as well as the variety of features, that can currently be used in order to measure mental stress levels of individuals, starting from the most widely accepted methods, to the new emerging ways.
2. To compare the accuracies that can be achieved with each signal or measurement, so as to help to decide among the most suitable signals for each situation.
3. To highlight the steps that should be followed in order to achieve a ubiquitous stress detection system for office workers.

To attain these goals a simple literature review was performed, with the following search strategy and inclusion criteria.

### 2.1. Search strategy

Publications were retrieved by means of a computerised search of the Compendex and Inspec databases via Engineering Village [19] and of the PubMed database [20] in order to find relevant studies published in English from January 2004 to date.

The review was carried out in an iterative way: first, a global point of view of the current state in stress detection was searched. The search terms used for this step were: "stress" AND "detect" OR "diagnos" OR "measure" AND "survey" OR "review". Controlled terms were used in order to discard all the publications related to non-relevant domains. After removing duplicates, 101 results were achieved. Titles and abstracts of the remaining papers were reviewed, rejecting the ones that did not work with human beings or focused on aspects of stress other than the measurement. Only eight papers were considered for further reading.

Once identified and understood the main concepts in current stress detection, the search terms were refined so as to focus on and identify the several domains and modalities of the measurable stress responses. The search terms in this step included "multimodal" OR "multi-modal" OR "taxonomy" AND "stress" AND "detect" OR "diagnos" OR "measure" OR "anal" OR "identif" OR "model". The non-relevant and duplicated references were excluded and 64 articles were retrieved. After title and abstract analysis, 42 were selected for further reading where those that did not accomplish the inclusion criteria were discarded.

After identifying the main domains and modalities involved in the current state of stress detection, a more specific search was carried out for each one of the domains. The combination of search terms used were the following: "mental stress" OR "workload" AND "detect" OR "recogn" OR "identif" OR "model" OR "anal" OR "diagnos" AND "physiolog" OR "behavio" OR "psycholog" AND "accura". A first set of 1159 study abstracts was retrieved for assessment. Controlled vocabulary terms were used in order to exclude publications related to non-relevant research areas and duplicates were rejected. The bibliographies of

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