**Universidade do Minho**
Escola de Engenharia

Fábio Alexandre Marques Catalão

# Analysis of the influence of stress on the interaction with the computer

Junho de 2013

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Departamento de Informática

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Dissertação de Mestrado
Mestrado em Engenharia Informática

Trabalho realizado sob orientação de

**Paulo Novais**
**Davide Carneiro**

Junho de 2013

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This work was developed in the context of the project CAMCoF - Context-aware Multimodal Communication Framework funded by ERDF - European Regional Development Fund through the COMPETE Programme (operational programme for competitiveness) and by National Funds through the FCT - Fundação para a Ciência e a Tecnologia (Portuguese Foundation for Science and Technology) within project FCOMP-01-0124-FEDER-028980.

## Acknowledgments

Working on this project was a wonderful experience. However, it has revealed itself to be a true mountain climb that was only possible due to the support of many people to whom I am grateful.

First and foremost, I would like to express my gratitude to my supervisors, Paulo Novais and Davide Carneiro. Their expertise, understanding, and patience, inspired me to work harder and better in this project, and have set an example I hope to match someday.

Furthermore, I am very grateful to the ISLab members, to the University of Minho climbing team, to my housemates, and to my close friends, for the exchanges of knowledge in so diverse areas, the skills and the encouragement they gave me during the deployment of this project, which, in the overall, helped enrich it.

Finally, I am very grateful to my parents Ana Maria and Manuel, my brother Pedro, my girlfriend Rita, and all my family, who have always supported and encouraged me in the advance of this project.

## Título

Análise da influência do *stress* na interação com o computador

## Resumo

A monitorização das diferentes funções físicas e cognitivas do ser humano tem sido alvo de numerosas ações ao longo dos últimos anos. Acontece que grande parte desses sistemas de monitorização utiliza técnicas invasivas e bastante dispendiosas. Existem já alguns estudos que têm tentado obter dados relevantes a partir de dispositivos comuns como por exemplo computadores, ou *smartphones*, mas trata-se de uma área que ainda não se encontra bem explorada.

Neste projeto de investigação procedeu-se a uma análise da interação dos utilizadores com o computador através do uso do rato e teclado de forma a obter conclusões relevantes sobre os efeitos do *stress*. A hipótese aqui apresentada revela-se interessante em virtude de utilizar técnicas de recolha de dados não invasivas, assim como o facto de não requerer a utilização de qualquer *hardware* adicional, e ter um custo de produção baixo.

## Title

Analysis of the influence of stress on the interaction with the computer

## Abstract

The monitoring of different physical and cognitive functions of the human being has been the subject of numerous studies in recent years. However, most of these monitoring systems use invasive and very expensive techniques, which complicate its use in research projects and real scenarios alike. Some studies are trying to obtain relevant data from common devices like personal computers or Smartphones, but this area has not been properly explored yet.

In this project, it was proposed to perform an analysis of the interaction of the users with a computer using the mouse and the keyboard in order to obtain relevant conclusions about the effects of stress on the individual. The hypothesis presented here is interesting due to the use of non-invasive techniques to retrieve data as well as the use of common and inexpensive hardware instead of specific and expensive one.

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# 1 Introduction

## 1.1 Motivation

Nowadays, people's life is becoming more and more stressful. According to the European Agency for Safety and Health at Work, work-related stress is one of the most significant health and safety challenges that Europe faces. Nearly one in four workers is affected by stress, and between 50% and 60% of lost working days are related to it [1], [2].

Thus being, stress at work is nowadays a reality that most employees are subjected to. According to an American Psychological Association' study, 69% of the employees report that work is a significant source of stress, and 41% reported they feel stress during the workday [3][4]. The same study says that 51% of the employees reported they were less productive at work as a result of stress.

Job stress is estimated to cost U.S. industry more than $300 billion a year. Among these costs are absenteeism, turnover, diminished productivity, medical, legal and insurance costs [5].

There is thus the need to try to identify the way different levels of stress affect employees' productivity. Several studies tried to achieve it, however all of them have some disadvantages. In order to execute a correct analysis of the influence of stress on productivity, employees' actions must be monitored. According to a study performed in 1995, traditional monitoring systems could influence the way employees do their job, and consequently their productivity [6].

The monitoring of different physical and cognitive functions of human beings has been subject of studies in recent years. However, most of these monitoring systems use invasive and very expensive techniques, which complicates its use in research projects and real applications alike. Some studies are trying to obtain relevant data from common devices like personal computers or Smartphones, but this area has not been properly explored yet [7].

At urge to solve this problem, in this project it is proposed a system to analyze the users' stress levels from data about their interaction with computer using mouse and keyboard, common and non-invasive devices.

## 1.2 Scope of the dissertation

This project proposes to perform an analysis of the interaction of the users with a computer using the mouse and the keyboard in order to obtain relevant conclusions about the effects of stress on the individuals. The hypothesis presented here results interesting due to the use of non-invasive techniques to retrieve data as well as the use of common and inexpensive hardware instead of specific and expensive one. This research took as a starting point the work already developed by the research group in which this project is inserted [8].

Initially, it was made a collection of data about the user's interaction with the computer using the mouse and the keyboard. This collection was possible due to the development, in this project, of an application to monitor the user's interaction with the computer.

From the mouse, it was collected data such as its velocity or acceleration, number of clicks and click precision. On the other hand, from the keyboard it was collected data such as writing speed, key pressure time, writing mistakes or key usage statistics. Stress was induced on users in order to detect changes in their behaviors.

After its collection, data was analyzed using different statistical and data-mining techniques in order to identify different patterns of user interaction with computer. This analysis revealed differences on users' interaction patterns due to their stress level.

## 1.3 ISLab Project

The work presented in this document is integrated in project CAMCoF - Context-aware Multimodal Communication Framework [8], [39], being developed at the Intelligent Systems Laboratory (ISLab) at the University of Minho (UM).

The main objective of this project is to develop a framework to model the users' context, focusing on stress, and to provide this information to a Virtual Environment (VE) so that richer communication processes can be developed. These communication processes will allow users to communicate in ways that are closer to face-to-face communication. The framework will be non-intrusive in order to facilitate more accurate and frequent monitoring. So, the estimation of stress will be based on the transparent analysis of the users' behavior and interaction patterns.

The proposal of this project is supported by previous work in which a group of ISLab members successfully measured changes in a non-intrusive way using motion detection and smartphones equipped with basic sensors. From this hardware, they were able to extract features such as touch patterns, touch duration, touch intensity, and touch accuracy, acceleration on the handheld device, amount of movement and a measure of cognitive performance. During preliminary tests, nearly 20 volunteers (students and teachers from the university) were requested to play a game that required them to perform mental calculations in a calm and in stressed state. In average, each participant showed significant differences in half of the parameters studied when comparing calm and stressed measurements.

Sustained by the preliminary results, the group now aims to acquire more appropriate and precise sensors that will allow them to develop a more accurate framework for modeling stress. This approach will provide meaningful context information to the users of a VE in the form of simple emotional avatars that can complement hat is being said using non-verbal information. It will result in more efficient communication processes that will more accurately resemble the context richness of face-to-face communication.

## 1.4 Objectives

The main objective of this work was to detect changes in the users' patterns of interaction with the computer due to stress. As stress depends on the individual it was also expected that different interaction patterns appeared due to the user-centric context.

In order to allow the detection of these patterns it was needed the development of a system that would allow the collection and treatment of the collected data. So, the following objectives were set:

- Development of an application to collect data about users' interaction with the computer:
    - Detection of mouse inputs: mouse movement, click precision, number of clicks, etc.;
    - Detection of keyboard inputs: key usage, key pressure time, number of errors, etc.
- Analysis of the collected data:
    - Development an application to process the collected data;
    - Perform a statistical analysis of the collected data;
    - Use of data mining and statistical tools in order to detect users' interaction patterns;
    - Development of an application responsible for a real time stress classification.
- Analysis and dissemination of the results achieved.

## 1.5 Research Methodology

This work was developed according to the Action-Research methodology. This method is suitable for solving a problem that seeks to obtain information leading to its resolution through an iterative and recurrent process. It assumes the cooperative involvement of several participants involved in the problem or in its resolution [9].

The methodology followed starts with the identification of the problem in order to allow the formalization of a hypothesis in which development work is based. Subsequently,

the information is recompiled, organized and analyzed, continuously developing a proposal to solve the identified problem. In the end, one can make conclusions based on the results obtained during the investigation.

Using this research model, six complementary steps were defined to achieve the planned objectives:

- Specification of the problem and its characteristics;
- Constant and incremental update and review of the state of the art;
- Idealization and gradual and iterative development of the proposed model;
- Experimentation and implementation of the solution during the development of a prototype;
- Results analysis and conclusion formulation;
- Constant diffusion of knowledge, obtained results and experiences with the scientific community.

## 1.6 Structure of the document

This document starts with the introductory chapter (Chapter 1). In this chapter it is presented the motivation, the scope and objectives of the project. It is also shown the research methodology followed during the progress of this project.

Chapter 2 starts with a detailed description of Stress, which starts by emphasizing historical descriptions of stress. Later, some aspects of stress such as stress types or the influence of external factors are presented. At the end, it presents and analyses some related projects.

Later, still on chapter 2, it will be introduced the concept of Ambient Intelligence. It starts with a brief description of the concept. Next, it presents some other concepts such as Ambient Assisted Living.

Chapter 3 will be dedicated to the presentation of a few related projects. In addition, analysis of the presented projects is also done.

Chapter 4 describes the process of data collection. This chapter starts with the explanation of the tasks users had to perform and the way data was collected. Afterwards, the way stress was induced in the users is explained, and finally, the data collection procedure is explained.

On chapter 4.5, the way that the collected data was analyzed is detailed. This chapter presents the way information was extracted from users' interaction logs, and the way data was analyzed in order to obtain valuable conclusions.

Finally, on chapter 6 some conclusions about the project are presented. It also presents the relevant work developed during the undertaking of this project and some work that will be done in the future and a brief description of the project.

# 2 Stress and Ambient Intelligence

## 2.1 Stress

One of the first definitions of stress was proposed in 1956 by Selye. Stress was then defined as a non-specific response of the body to external demands. These demands (the load or stimulus that triggered a response) are called stressors while internal body changes produced by them are called reactions to stress. Selye was also the first to document changes and hormonal chemicals in the body due to exposure to stress [8], [10].

Nowadays, the definition of stress is still under discussion and is not consensual in the scientific community. The various factors involved in stress factors, combined with the fact that many of them are subjective, lead to numerous interpretations that make it difficult to define. While some researchers argue that stress is seen nondescript because it is poorly defined, others choose not to provide a current definition until the achievement of a more accurate and consensual view of stress.

Attempting to resolve this question, researchers started to deal with stress from an empirical point of view. Therefore, they focused on the analysis of the cognitive and behavior effects and they started to view stress as a mind-body, psychomatic or psychophysiologic phenomenon. In this line of analysis, a more recent view of stress looks at it as a psycho-physiologic arousal response that occurs in the body as a result of stimuli. This view also considers that the stress effects of stimuli depend on cognitive interpretation of the individual. In this work, it will be adopted this interpretation of stress.

Based on the multiplicity of factors which influence stress and the different behavior and cognitive aspects that are affected, it was concluded that there was a need of a multimodal approach to allow a sufficiently precise and accurate measurement of stress [11].

From a high level point of view, two types of stress can be identified: acute and chronic stress. Acute stress results from recent demands as well as from the anticipation of demands in the near future. On the other hand, there is the chronic stress, a long-term on. This type of stress results, for example, from social conditions, health conditions, dysfunctional families, among many other issues.

Also, chronic stress can bring nefarious effects on the body and mind of the individual, slowly wearing him over time. On the other hand, acute stress, the short term one, won't do the same extensive damage on the individual as chronic stress but will instantly influence the performance of the actions being performed by the him [8].

## 2.2 Stressors

Stress can be influenced by a large multiplicity of factors. They can be divided into two main categories according to the source of contextual information: the user-centric context and environmental context [8].

User-centric information is composed of two categories: the background and the dynamic behavior. The background is composed by several attributes that can be extracted from the user's profile such as age, gender, working area, social status, personality traits, among others. In other hand, the dynamic behavior reflects the contextual attributes related to the activity being performed by the user.

The environmental information fuses the characteristics of the physical environment, social environment and computational environment. Inside physical environment we have attributes such as time, temperature, location, noise level, and luminance. High levels of noise, extreme temperatures and extreme levels of luminance are well known stressors. Social environment include attributes such as population density around the user or role, affinity and hierarchical position of the surrounding people. Finally, com-

puter environment can be characterized by the measurement of the electromagnetic field or the number of surrounding electronic devices.

## 2.3 Virtual environments and stress

In order to get better remote communication frameworks our society relies more and more in Virtual Environments (VE). According to Blascovich and Loomis (2002) VEs can be described as synthetic sensory information that lead to perceptions of environments and their contents as if they were not synthetic. VEs may be seen as simulated environments that try to look like the real simulated environments with the objective of implementation of some kind of interaction scenarios [8], [12].

Typical fields of use of VEs include teach learning in classrooms, distance learning, informal learning, business, e-commerce, real-life simulation, gaming or conflict resolution. However, VEs, as they are seen nowadays, are still not a proper replacement for old-style face-to-face communication. VEs are frequently described as "cold", without any role played by emotions and other traces of our complex interaction modalities. According to Mehrabian (1980) in face-to-face communication there are three elements: the words, the tone of voice and the non-verbal behavior. The way words are said is more important than the words themselves [13].

Another important part of communication is the affective aspect. Emotions appear in almost all models of human communication such as facial expression, voice tone, respiration, skin temperature, or gestures [13], [14].

The importance of stress must be also considered in VEs. Stress, as it is in most of aspects of human lives, is a very important factor in interpersonal communication. However, current approaches on VEs lack stress models that can support it which constitute an obstacle to effective communication between the participants.

When communicating online, people are prone to forget that behind the screen there is another person on the other side. People forget about the others' feelings and simply don't worry about the consequences of the words they say when communicating online.

## 2.4 Computer-related stress

The widespread introduction of information technology at work has produced a profound impact on the design of work processes. In some cases, computerized jobs have become more complex and require greater skill. On the other hand, for the majority of computer workers, jobs have become simpler and less challenging, and this has led to increased stress [15]. Computers produce efficiencies, competitive advantages and the ability to carry out work processes that would not be possible without their use.

Computerized jobs require little physical effort, tend to be sedentary and require substantial cognitive processing and mental attention. However, the production demands can be high with constant work pressure and with limited decision-making possibilities. The combination of these conditions have been reported to produce occupational stress [16].

The allegations that working at computer creates psychological distress are not new. Negative psychological perceptions can lead to stress reactions that may lead to adverse health outcomes. According to Smith et al., work system factors such as organization or technology have the potential to produce acute stress reactions which are modified by workers' personal characteristics and susceptibilities. If this short term stress becomes chronic, it can lead to significant adverse health outcomes such as coronary heart and artery disease or mental health disorders [17], [18].

## 2.5 Ambient Intelligence

At the beginning, computers were very expensive as well as very difficult to understand and use. They were rare and precious resources, and each one would typically be used by many users. Sometime later, users gained the chance to access the same computer, at same time, without the need of take turns to use computer. In the 80's a technological revolution that made possible took place that each user could use his own computer. With the progresses in computer industry and the drop of costs, users started to be able to access more than one computer. Nowadays we have dramatically more varied computational resources than a few decades ago [19], [20].

Nowadays, access to multiple computers does not mean each user own more than one PC or laptop. Microprocessors are now embedded in familiar devices such as home appliances, mobile or smart phones, and guidance systems.

Even with these advances in the last decades, computation has been centered on machines rather than on people. Purposing to serve us, computers have actually forced people to serve them. They have required people to speak their languages, and manipulate their devices. Computers have not been aware of our needs or their surroundings.

In the future, computation will be human-centered. It will be available everywhere, entering peoples' world, handling their goals and needs and helping humans to do more and better. Instead of the need to carry devices, configurable generic devices will bring computation to people whenever and wherever they might need it. As people interact with anonymous devices, they will adopt peoples' information personalities, and respect peoples' desires for privacy and security. People won't have to use keyboard, mouse, or learn how to use a computer. Communication will be done naturally, using speech and gestures that describe peoples' intent and computer will perform people's wills. Systems will help people boost their productivity. They will help people automating repetitive tasks, finding the information people need without need to examine thousands of search-engines hits, and it will enable people to work together with other people over space and time.

## 2.6 Ambient Assisted Living

Most of the developed countries of the world are suffering a deep demographic change. These demographical issues combined with structural and social trends tend in the direction of more and more elderly people and single households, which have intense effects on public healthcare, emergency medical services and the individuals. Humans are nowadays living longer, because of progress in medical care and pharmacy areas. This increase on the average area of the total population and the consequent rise of chronic diseases will result in dramatic increase of emergency situations within the coming years [21], [22].

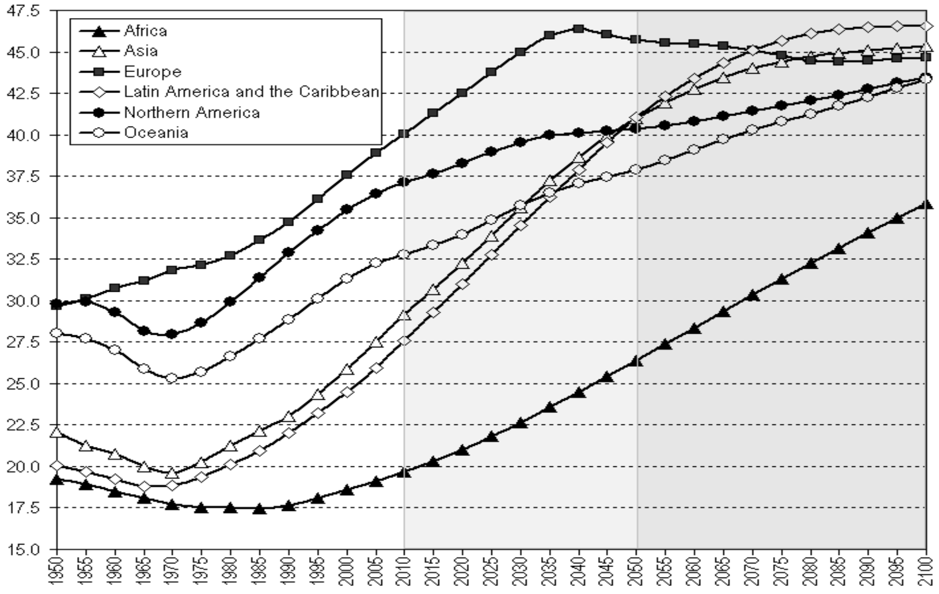


Figure 1 - Median age of the population by major region (years)[1]

This demographic change implies not only challenges but also opportunities for the citizens, and the social and healthcare systems. A study performed in Germany shows that 44% of Emergency Medical Services are dedicated to patients older than 70 years of age. It will result in even higher costs for health care services or in a decrease of service quality [23].

The post-1945 baby-boomers are changing their lives from full-time workers to full-time pensioners, sometimes adopting part-time or flexible work as a transition life style.

Until recently, most discussion gave emphasis to the negative effects of ageing such as a healthcare budget increase and the prediction of a deteriorating quality of life for the rapidly rising number of older people. However, this situation also presents opportunities.

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[1] According to United Nations, Department of Economic and Social Affairs, Population Division (2011): World Population Prospects: The 2010 Revision. New York, http://esa.un.org/wpp/, last access (30-01-2013).

New forms of social innovation such as creative ways for the elderly themselves to use and benefit from their experience and talent and their participation in re-organizing the services they need can help alleviate many of the problems. One of this ways is ambient assisted living.

The main goal of ambient assisted livings solutions is to apply ambient intelligence technology to enable people with specific demands, such as handicapped or elderly, to live in their preferred environment longer [22].

Assisted living solutions for elderly people using ambient intelligence can help to cope with this demographic trend providing some proactive and situation-aware assistance to sustain elderlies' autonomy. These solutions try to enable elderly people to live longer and better in their preferred environments as well as reduce costs for society and public health systems.

## 2.7 Synthesis

In this chapter it was shown an overview of the scientific areas this project is related to. It started with an introduction to stress and then it described some aspects associated with it such as stressors and virtual environments. After that, a description of the Ambient Intelligence was shown and, to end, it was presented the concept of Ambient Assisted Living.

# 3 Related Projects

A few projects in related fields have been analyzed during this research work. Bellow, some of them are presented, showing the work developed in this field of research by peers. Afterwards, it will be presented a brief analysis of the presented projects and a comparison with the project showed here.

## 3.1 Projects

### 3.1.1 Stress Monitoring in Conflict Resolution Situations

This work is part of a project being developed by researchers of Department of Informatics/CCTC of University of Minho. The purpose of the project is to develop an Online Dispute Resolution (ODR) framework which takes into account information about the users' context. [7], [8], [24].

Online Dispute Resolution is growing to become the major alternative to litigation in court. Given the characteristics of current disputes, technology-based conflict resolution may be a quite effective approach although in this shift of paradigm there are some threats that should be considered.

A particular part of this project deals with the problem of the lack of important context information when parties communicate in a virtual environment. In this project, researchers propose the addition of a monitoring framework capable of measuring the level of stress of the parties in a noninvasive way.

The collected information will be used by the platform and the mediator along the complete conflict process to adapt strategies in real-time, resulting in a context-aware and more efficient approach.

### 3.1.2 PokerMetrics

PokerMetrics - Stress and Lie Detection through Non-Invasive Physiological Sensing was a project developed by MIT Media Laboratory. In this study, researchers show how simple non-invasive psychological features such as voice pitch variation, skin conductance peaks, and heart rate variability are correlated to various stressful events in Hold'em Poker tournaments. With these collected features, researchers developed simple linear models that can be used to identify stress and lying/bluffing within the context of poker settings [25].

### 3.1.3 Electronic Performance Monitoring and Social Context: Impact on Productivity and Stress

This study was developed by The State University of New Jersey researchers in 1995. The purpose of this project was to analyze the impact of electronic performance monitoring and social context on productivity and stress of employees [6].

Electronic performance monitoring (EPM) systems is one of the many technological inventions employees face in today's workplaces. These systems provide managers a lot of information about employees' routines. They provide managers real time information such as the pace of employees' work, their degree of accuracy, log-in and log-off times, and even the amount of time spent on bathroom breaks. This study examined how productivity and subjective experiences are affected by EPM systems and how work social context moderates that influence.

In a survey of monitored workers, 81% of the respondents declared that electronic observation made their jobs more stressful [26]. Other study, from 1986 compared the behavior of monitored and no monitored workers who performed similar jobs, and found that monitored workers reported more stressful [27].

The changes in job design introduced concurrently with electronic monitoring have been attributed as the cause of the increase of stress associated with the introduction of EPM systems. The introduction of EPM systems could transform ordinary jobs into high-stress jobs. It can also reduce the opportunities for employees to socialize with each other's at work, what could lead to a loss of social support partially responsible for the stress associated with EPM. [28], [29]

Another study demonstrated that employees working on a simple data-entry had better productivity rates when they believed their work was monitored. Also, this study shows that complex-task performance has been shown to suffer among monitored workers.

### 3.1.4 Work Environments, Stress, and Productivity: An Examination Using ASSET

This project was developed by some researchers from School of Psychology of University of Liverpool. In this project researchers tried to find a correlation between work environments, stress and productivity. The researchers investigated the predictors of productivity with A Shortened Stress Evaluation tool (ASSET). [30]

A study of 1999 estimated that each worker, in terms of depression, experienced a month productivity loss of approximately $200 to $400. [31] By other side, other study of 1993 estimated that lost productivity due to depression cost American corporation $12.1 billion in 1990 alone. [32]

There is clear recognition by psychologist community of an evidence for the existence of a relationship between workspace stressors and mental and physical health outcomes. However, little research examines the effects of stressors and health outcomes, and their impact on productivity. This research study begins to address this by presenting the results of a large-scale study with a focus in the factors associated with productivity.

Albeit sparse, there are some evidences that establish an association between stress and productivity. In 1986, Yeh, Lester, and Tauber published a study on real estate agents that revealed a negative relationship between stress and productivity. [33] In 1992, Jamal and Baba, using data collected from blue-collar, managerial and nursing employ-

ees showed a direct, linear and negative stress-productivity relationship: the greater the stress was, the less productive the workforce was. [34]

### 3.1.5 MIT Project Oxygen

Project Oxygen is a project being developed at the Massachusetts Institute of Technology's Computer Science and Artificial Intelligence Laboratory. Its purpose is to develop pervasive, human-centered computing. Its architecture consists of handheld terminals; computers embedded in environment, and dynamically configured networks which connect these devices. [20]

The Oxygen team describes their project purpose as «Bringing abundant computation and communication, as pervasive and free as air, naturally into people's lives». Since the emergence of computers, people have been required to learn how to interact with computer using their language and manipulating keyboard or mouse. This project tries to make computation human-centered. Instead of force users to use their language, in the future computers will be human centered. Instead of the need of carry devices, configurable generic devices will bring computation to people whenever and wherever they might need it. As people interact with anonymous devices, they will adopt peoples' information personalities, and respect peoples' desires for privacy and security.

Computers will be available everywhere, handling peoples' goals and needs helping humans to do more and better. This project purpose that in the future, people will interact with computers naturally, using speech and gestures to describe their intent. They will be able to do automate repetitive tasks, find the information people's need without need to examine thousands of search-engines hits, and they will enable people to work together with other people over space and time.

To support highly dynamic and varied human activities, the Oxygen system must fulfill a lot of technical challenges. This system must be:

- Pervasive: it must be everywhere, with a sharing of information between all devices;
- Embedded: it must be present in peoples' world, sensing and effecting it;

- Nomadic: it most allow people to move around freely around to their needs;
- Adaptable: it must provide flexibility and spontaneity, in response to changes in user requirements and operating conditions;
- Powerful, yet efficient: it must be free from constraints imposed by hardware resources;
- Intentional: it must allow people to name services by intent, for example "the nearest TV", as opposed to by address;
- Eternal: it must never shutdown or reboot; components may come and go, but the whole system must be available all the time.

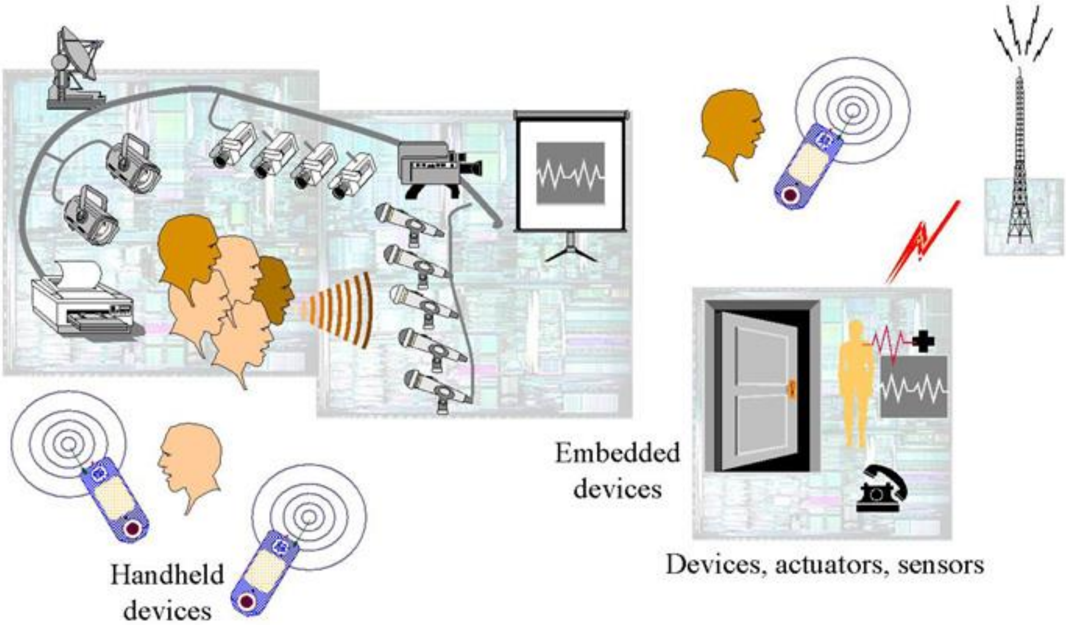


Figure 2 - Oxygen project architecture[2]

Oxygen, through a combination of specific user and system technologies, enables pervasive, human-centered computing. Speech and vision technologies enable people to

[2] . Source: http://www.oxygen.lcs.mit.edu (Accessed 25-01-2013)

communicate with Oxygen as if they are communicating with other people, saving much time and effort.

### 3.1.6 I.L.S.A. – The Independent Lifestyle Assistant

This initiative from University of Minnesota is an agent-based monitoring and support system to help elderly people to live longer in their homes by reducing caregiver weight [35]. This project has as main objective to study the response of elderly to a monitoring computer system inside their houses and determine how such systems can help this people.

They not only determined which are the main problems of elder people living alone, but they also performed some testes with parts of monitoring system in some houses in real conditions. This application is also good for elderlies' caregivers as everyone maintains its autonomy.

This system is a multi-agent one that incorporates a unified sensing model, situation assessments, response planning, real-time responses and machine learning.

A group of sensors was placed in each house according to what is being monitored. When this information was read it was sent to a central that studied it. If the person in question did not take the medication or if the behavior was very unusual, alerts were emitted.

The main features implemented in this project included passive monitoring, cognitive support, alerts and notifications, reports and controlling remote access to information. Clients had a portable device from where they could check their agenda, change some parameters and communicate with their caregivers.

## 3.2 Analysis of the related projects

A few projects related to the monitoring of different physical and cognitive functions of human beings have been developed in the last years. Previously, some of them were presented, showing their objectives, challenges, and some results obtained at the end.

As reported before, stress is nowadays one of the most widespread problems in the developed countries. Electronic Performance Monitoring and Social Context: Impact on Productivity and Stress study showed some very interesting results of the influence of stress on productivity. It also studied the impact of work environment on it. The solution presented in this document does a similar study although more focused on the effects of stress on performance of computer users. It will certainly result interesting as there is evidence that computer workers are very susceptible to stress and, this way, it will be possible to detect the influence of stress on their performance.

A very important conclusion that should be taken from the analysis of some previous work is the possibility of the interference of monitoring systems on analyzed people's behavior. As reported in the study Electronic Performance Monitoring and Social Context: Impact on Productivity and Stress, EPM systems can have a very negative impact in the validity of the final results.

The approach followed in this research work takes this into consideration in order to avoid this undesired interference. It uses common devices such as mouse or keyboard in their normal use. During the study, participants use the computer the same way they use it at other times which would reduce their perception of being monitored. Also, the use of these devices results very interesting because there is no need to use very expansive devices as in other projects.

Other advantage of the work proposed in this document is its narrow scope. It deals with a very specific problem in contrast with very broad projects such as MIT Project Oxygen. Instead of the need of a very large and long research, the project presented here is expected to have interesting results in the short term.

# 4 Data Collection

In order to collect users' interaction with computer using mouse and keyboard, a software application was developed. On one side, the developed application registers all the users' interaction data with computer from the use of the mouse and the keyboard. On the other side, this application includes some stress measuring tasks to collect data about users' interaction when performing particular tasks.

In order to analyze the users' interaction patterns, in both normal and stressed state, stress was induced to the participants of the study. This process is further detailed in section 4.3 Stress Induction.

## 4.1 Stress measuring exercises

The study implemented to collect participants' interaction data is composed by four different tasks. Each of these tasks requires participants to accomplish different actions in order to allow the motorization of their performance. These tasks are explained in the following sections.

### 4.1.1 Text Typing

The text typing task consists in transcribing a small excerpt of text. Participants read the text presented in a box and type them in a different box. They are not allowed to see the text in both boxes simultaneously.

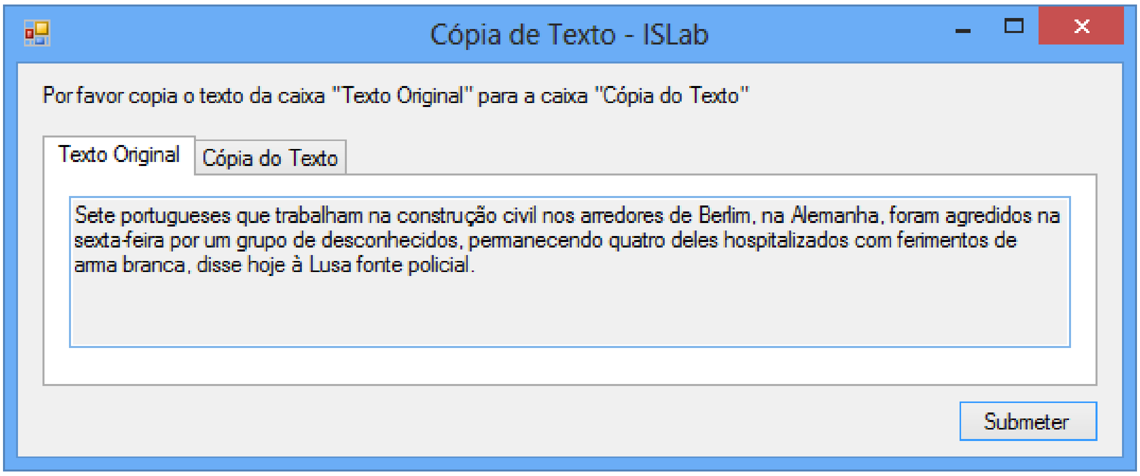


Figure 3 - Stress measuring exercises - Text Typing

As can be seen in Figure 1 there are two tabs in this exercise application form. In the selected tab (named "Texto Original"), users can see the original text which they have to copy. The other tab (named Cópia do Texto"), is where participants have to type the excerpt present on the original tab. This way, the task of copying text require more attention from the participants since it requires them to memorize the text they have to copy.

This task aim is to detect some users' interaction features such as typing speed, typing mistakes or the amount of text users are able to memorize each time they change tabs.

### 4.1.2 Maze

A maze is defined as a tour puzzle in the form of a complex branching passage through which the participant must find the route. Since solving a maze requires a lot of concentration from participants, it is an interesting exercise to subject the participants to, in order to analyze their performance.

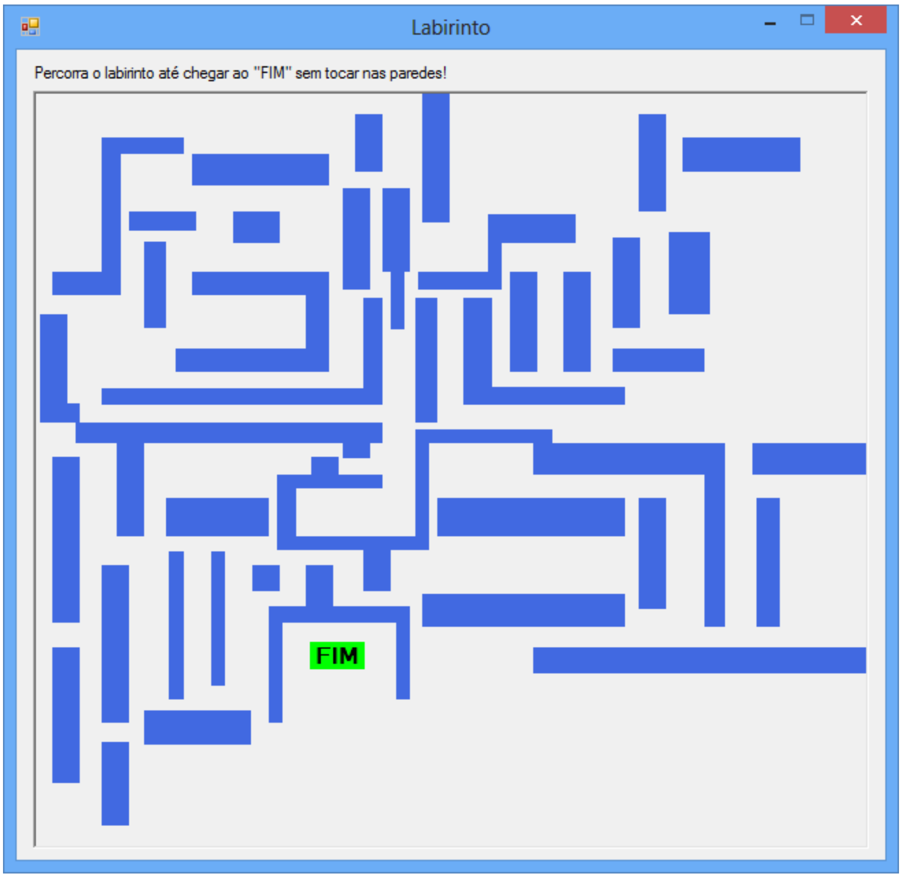


Figure 4 - Stress measuring exercises - Maze

The maze task present in the data collection application is static and must be solved using mouse movement. Participants must move the mouse from the start point to the end through paths with variable widths without hitting the walls. In doing so, some features such as mouse precision can be evaluated. A snapshot of the maze can be seen in Figure 4.

### 4.1.3 Connect the dots

Connect the dots is a well-known didactical game whose aim is to teach children to recognize and pronounce numbers and letters of alphabet in a children-friendly way. It is a form of puzzle containing a sequence of numbered dots. When a line is drawn connecting the dots the outline of an image is revealed. The use of numbers can be replaced with letters or other symbols. This game is traditionally played on paper but currently there are some computerized solutions that allow its practice on computers, smartphones or tablets.

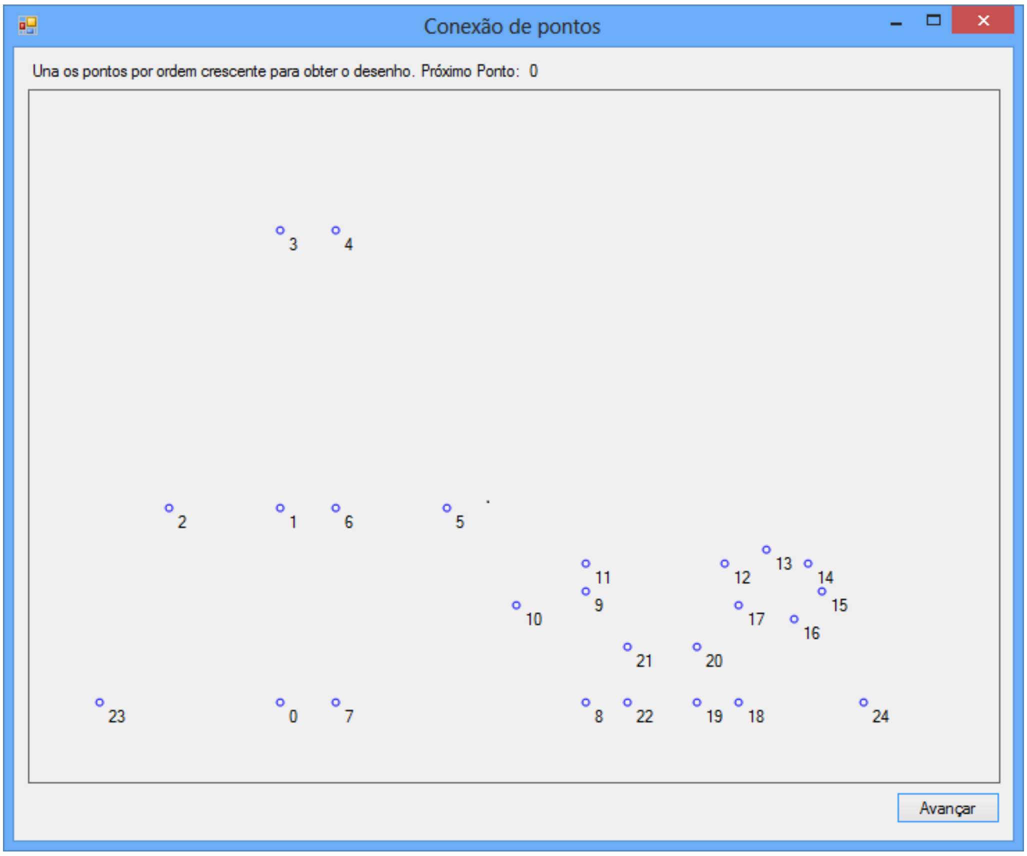


Figure 5 - Stress measuring exercises - Connect the dots, Start Screen

In the context of the developed application, this game was implemented in order to analyze the influence of stress on the participants' interaction with computer, specifically on the precision of their clicks and the path followed by participant to move from one dot to other.

When this exercise starts, a few numbered dots are visible for the participant to connect, as can be seen in Figure 5. While participants are connecting the dots the image will gradually appear as can be seen in Figure 6, leading to the final picture.

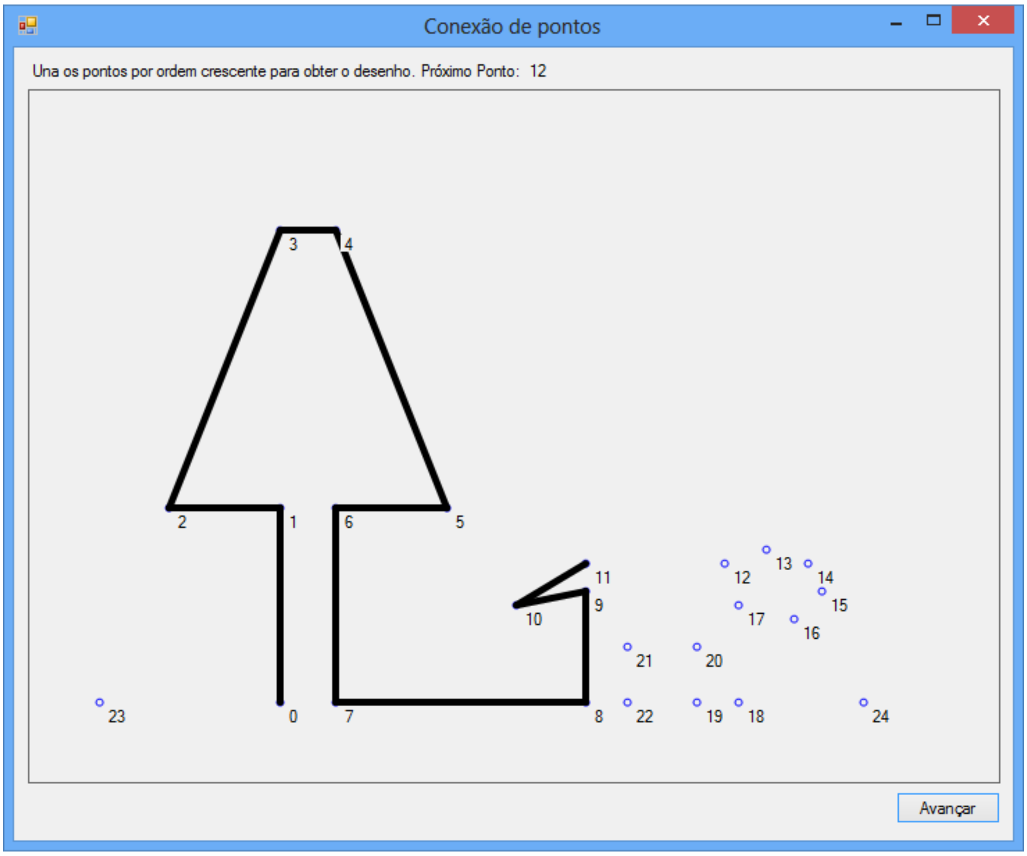


Figure 6 - Stress measuring exercises - Connect the dots, playing

### 4.1.4 Speed Hit

The Speed Hit task requires users to click on some boxes that appear on the screen. This task is used in order to analyze the participants' ability to move faster between different boxes and to analyze their precision when clicking.

Figure 7 depicts an example of a box in which participants must click. After a participant clicks on the presented box, another box will appear in a different place. It will force participants to move mouse and click on the new box. It allows to determine the path travelled by the mouse from one point to another which allows to analyze the differences in the path followed both stressed and non-stressed states.

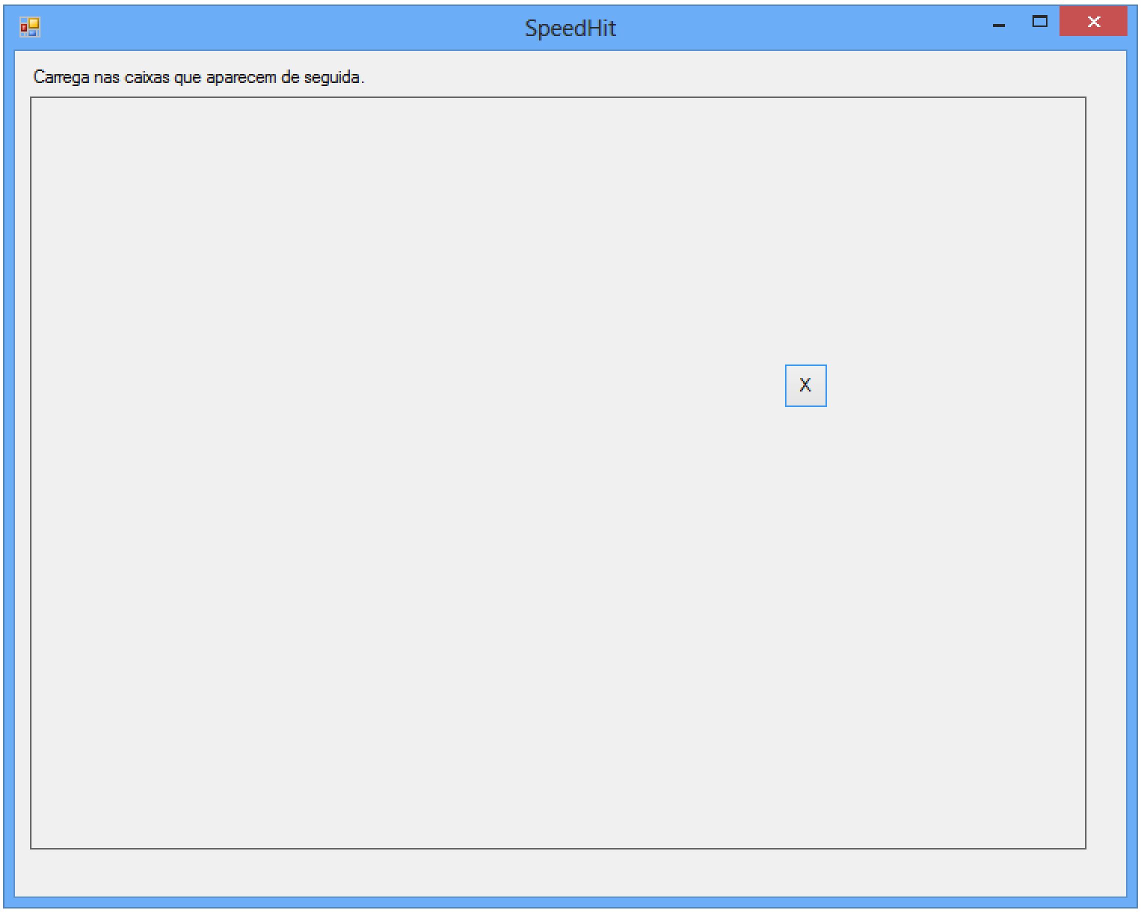


Figure 7 - Stress measuring exercises - Speed Hit

## 4.2 Activity logging

During the study, a background process logs all participants' interaction with computer using mouse or keyboard.

First, participants are required to introduce some personal information as a username, genre or age. Later, after submission of these data, the log of participants' activity starts.

During the execution of the activity logging procedures, all the participants' interaction using mouse or keyboard is logged. For all logged information a timestamp is added in order to allow determination of the time elapsed between two consecutive events.

Consequently, from the mouse, the following information is registered: mouse movements, mouse buttons pressed (right, left and center), mouse buttons released (right, left

and center), and mouse wheel movements. For each mouse event, information about the cursor position is also logged. From the keyboard it is registered information about which keys are pressed or released.

## 4.3 Stress Induction

In order to achieve the project aim, data collection for each participant took place in two different moments, according to the participants' stress levels. First, data was collected from participants without the use of stressors. After this first moment of data collection, and in order to collect data from stressed users, stress was induced in the participants.

Stress induction was done using different methods. Following, each of the methods used to induce stress on users is explained.

### 4.3.1 Music

During the second part of the data collection procedure, participants listened to some music in order to increase their stress levels.

There is a lot of research about the influence of music on users' stress levels. However, most of current studies consider the effects of music in order to induce relaxing effects in individuals, usually with classical music.

In 1973, Dale Taylor studied the Subject Responses to Precategorized Stimulative and Sedative Music [38]. The purpose of this study was to determine the accuracy with which musical selections have been classified as stimulative or sedative. This report is still very interesting nowadays due to its categorization of some music into stimulative or sedative that is used as a standard.

In 2002, a study from the University of South Alabama, analyzed the effects of the different types of music on perceived and physiological measures of stress [36]. The results of the research suggest that music may have an effect on the cognitive component of the stress response. In this study it was hypothesized that individuals who listened to classical music or music they believe was relaxing would perceive themselves to be more relaxed and less anxious than those who listened to hard rock music. The final

results of this study supported this hypothesis as participants who listened to hard rock music reported that they were not more relaxed after listening to this genre of music.

A very interesting study was done in 2004 and studied the physiological stress response to video-game playing: the contribution of built-in music [37]. In this study researchers studied the influence of the music present in video games on players stress levels. The other studies about effects of different types of music didn't take into attention the types of music usually present in video games: techno and rock music. This study's purpose was to examine the effects of built-in techno music on cortisol levels during video game playing. Their study provided the first empirical support for the informal idea that music is an integral part of the stress generated by video game playing. Their results proved that the physiological response under music in the organism is different from the one produced under silence. In this study it is also shown that participants were unaware that they were under stress.

According to previous statements, and in order to induce stress on participants, hard rock music was used during the study.

### 4.3.2 Heat

Another way of stress induction was the use of extreme temperatures, namely heat. An infrared heater was placed below the table where the study took place. During the phase in which the participants were expected to be stressed, the heater was turned on in order to subject users to an annoying heating wave.

### 4.3.3 Light

Annoying lights were also used to induce stress. Participants of the data study were subject to two different annoying lights near their face, in particular red and green. These lights were used just in the phase where users are expected to be stressed.

In addition, a strobe light was used in order to induce stress to the participants of the study. This light was positioned in a way that it can be perceived by users' vision and at the same time it allowed them to perform the computer tasks they has been requested to.

### 4.3.4 Chronometer

During all the data collection procedures a chronometer was made visible to the users in order to subject them to time pressure during the study. This was used in order to enforce participants to complete the requested tasks in a short time. It was said to the participants of the experimentation that their performance was evaluated and the time they take to complete the required tasks was used as an evaluation measure. This way, each participant tried to complete the requested tasks in the fastest time possible.

## 4.4 Data collection procedure

The data collection was conducted in a setting located inside the ISLab room at the Informatics Department on the University of Minho. A personal portable computer with a keyboard and a USB mouse, two different lamps, an infrared heater and a smartphone were the main items used in this study.

Sixteen subjects participated in individual sessions where they were requested to perform the tasks described at section Stress measuring exercises of this document. Firstly, the participants were requested to complete the described tasks without any addiction of stress while their inputs to computer using the keyboard and the mouse were being recorded. Afterwards, as can be seen on section Stress Induction, stress was induced into the users and they were requested to repeat the previous tasks. It was done in order to analyze the differences between their performances in their normal stress level, or stressed.

## 4.5 Data extraction

First, the data collected was parsed using a Java application. This application was developed to parse the collected data and to extract the required information for analysis.

The collected data contains records of the user's interaction during the execution of the experimentation, in both stress and non-stress states. So, one of the tasks this application had to do was analyzing data according to users' stress level. Later, taking this into

account, this application analyzed all the recorded events and calculated some measures from those records.

Following, the different measures that have been calculated from the collected data are presented:

- Mouse movements:
    - Duration of clicks: Time spent between each mouse button press and mouse button release;
    - Time between clicks: Time spent between each two consecutive clicks;
    - Double click speed: Time between the two clicks of a double click;
    - Number of double clicks: Total number of double clicks;
    - Distance between clicks: Distance traveled between two consecutive clicks;
    - Distance during clicks: Distance during clicks;
    - Sum of distances from pointer to line between clicks: Sums the distance from the pointer to the line defined by two consecutive clicks;
    - Average of distances from pointer to straight line between clicks: Average of distance that the pointer travels from the straight line that connects two consecutive points;
    - Total excess of distance traveled between each two clicks: Difference of distance between what the mouse traveled and the distance in straight line;
    - Average excess of distance traveled between each two clicks: Average difference of distance between what the mouse traveled and the distance in straight line (given in comparison with the distance between the two clicks);
    - Absolute sum of angles between each two clicks: Absolute sum of the angles between each two consecutive segments of line between two clicks (total of curve);
    - Signed sum of angles between each two clicks: Signed sum of the angles between each two consecutive segments of line between two clicks;

  - Velocity: Velocity of the mouse movement between two clicks;
  - Acceleration: Acceleration of the mouse movement between two clicks;
  - Movement Path: Movement followed by the mouse during the experimentation.
- Keyboard Usage:
  - Time during key down: Time elapsed while a key is pressed;
  - Time between keys pressed: Time between two keys pressed;
  - Errors per key pressed: Number of times the backspace key was pressed.

In the next section it is explained the way these measures were analyzed in order to detect which of them are related with stress levels.

# 5 Data analysis

In order to obtain valuable conclusions, after the collection of data, the data must be analyzed. A few tasks were performed in order to get interesting results from the collected data, which are explained in the following sections.

## 5.1 Statistical data analysis

After the data collection procedure, logs were analyzed and transformed using the developed Java application, and analyzed using Wolfram Mathematica 8. This was done in order to examine the reliability of each of the calculated measures in its relationship with the stress level felt by the participant. It has been done to ensure that in the next phase the appropriate measures were used.

A preliminary statistical analysis showed that most of the distributions of the collected data are not normally distributed. Therefore, the Mann-Whitney test was used to compare the collected data of two different samples, Normal and Stressed state.

The Mann-Whitney is a non-parametric test of the null hypothesis ($H_0$) that two independent populations are the same against an alternative hypothesis that states that a particular population tends to have larger values than the other. For each two distribution compared, the test returns a *p-value*. A small value suggests that it is improbable that $H_0$ is true. So, for every test whose $p - value < \alpha$, the difference between the two distributions is considered to be statically significant, in other words, $H_0$ is rejected.

In the context of this work, a statistically significant result between the distributions of the collected data in two different states (normal and stressed) suggests that the feature

being analyzed is influenced by stress. The null hypothesis set was that "Users' interaction with computer is unrelated to users' stress level".

$Null\ Hypothesis$: "Users' interaction with computer is unrelated to users' stress level"

So, for each participant, his collected data was analyzed in order to try to find these results. The standard value $\alpha = 0.05$ was used during all the Mann-Whitney tests performed during the data analysis.

In that way, from the mouse the following features were analyzed: duration of clicks, time between clicks, number of double clocks, distance between clicks, distance during clicks, sum of distances from pointer to line between clicks, average of distances from pointer to straight line between clicks, total excess of distance traveled between each two clicks, average excess of distance traveled between each two clicks, absolute sum of angles between each two clicks, signed sum of angles between each two clicks, velocity, acceleration and movement path. On the other hand, from the keyboard, the following features were analyzed: time during key down, time between keys pressed, and errors per key pressed.

This process started with the analysis of each user data records, individually. Following some of the analysis at which data were subject will be shown.

One of the analyzed features was Double Click Speed. In the chart present at Figure 8it is possible to analyze the distributions of double click speed for a specific user.

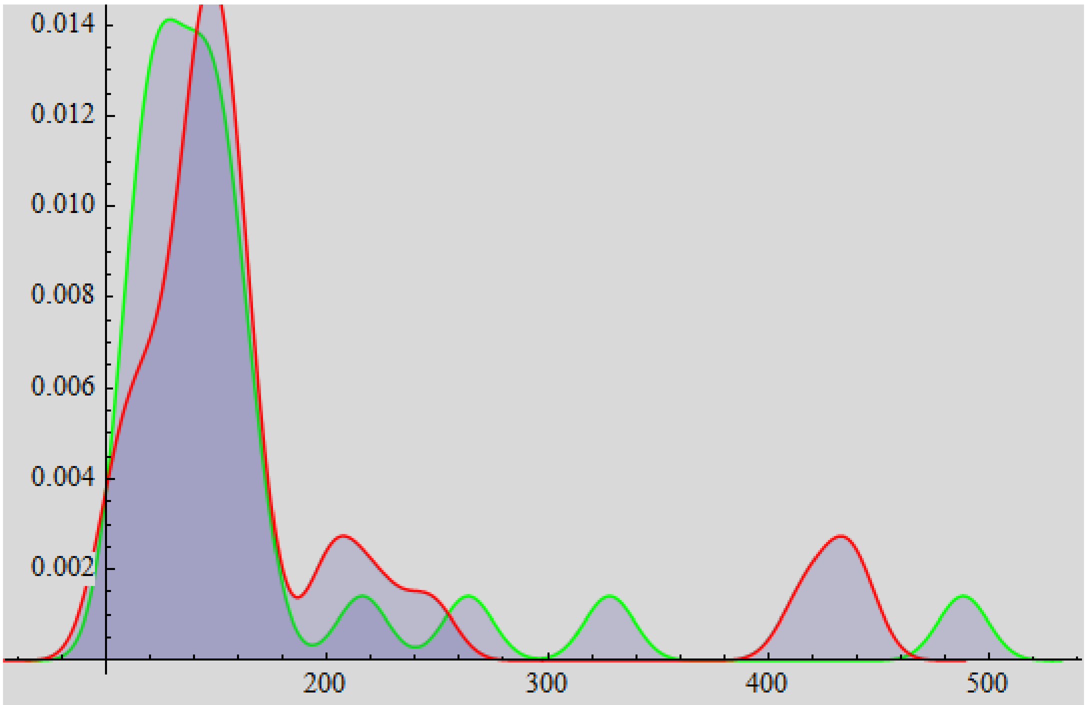


Figure 8 - Double click speed distributions: normal (green), stressed (red)

In order to test if double click speed is influenced by stress, Mann-Whitney test was performed. On Table 1 it is possible to check that $H_0$ for the data collected from that user is not reject, this feature was not significantly influenced by stress.

Table 1 – Mann-Whitney Test – Double Click Speed

*Mann-Whitney Test – Double Click Speed*

| | p-value | Reject $H_0$ |
|---|---|---|
| *Normal VS Stress* | 0.335482 | False |

The statistical analysis presented above was performed for all the features under analysis, and for all users. Later in this report, on Table 4 it is possible to observe a synopsis of the analysis perform.

Interesting results were also found on the Maze game which was implemented in the data collector application in order to analyze users' ability to follow a path using mouse movements. This game provided a way to get some data such as mouse movement acceleration and velocity. However, while useless to a real time analysis during a comput-

er normal usage, the path followed in the Maze by the participants provided some interesting results. In the next picture is shown the path followed by a user in the resolution of the Maze without the use of stressors.

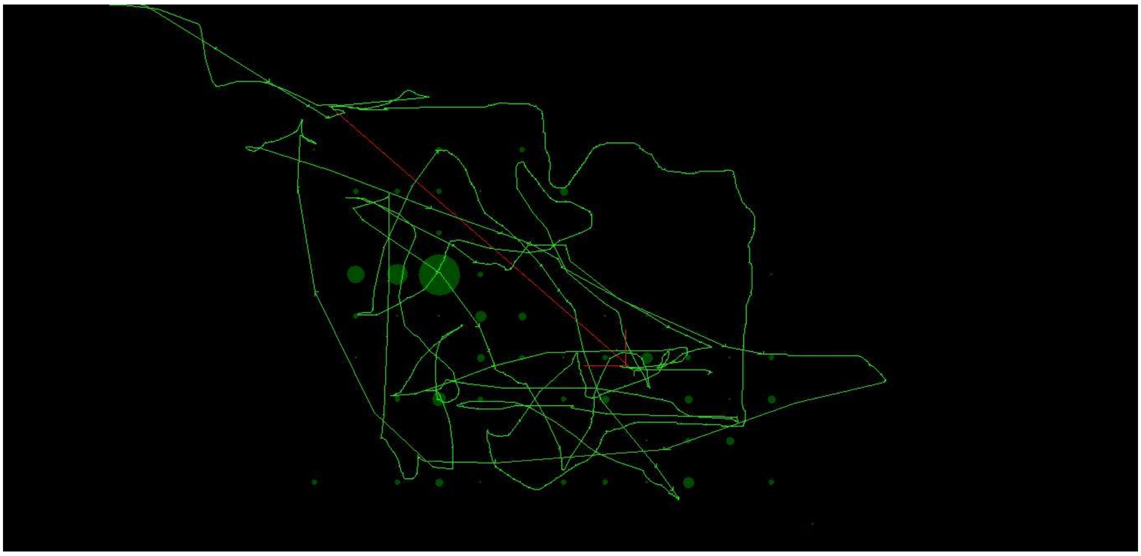

Figure 9 - Maze mouse path - Normal state

As participants were requested to resolve the Maze game in both stress levels, there are also results from stressed participants. In the next picture it is shown the path followed by the same user as the previous picture, but while under stress.

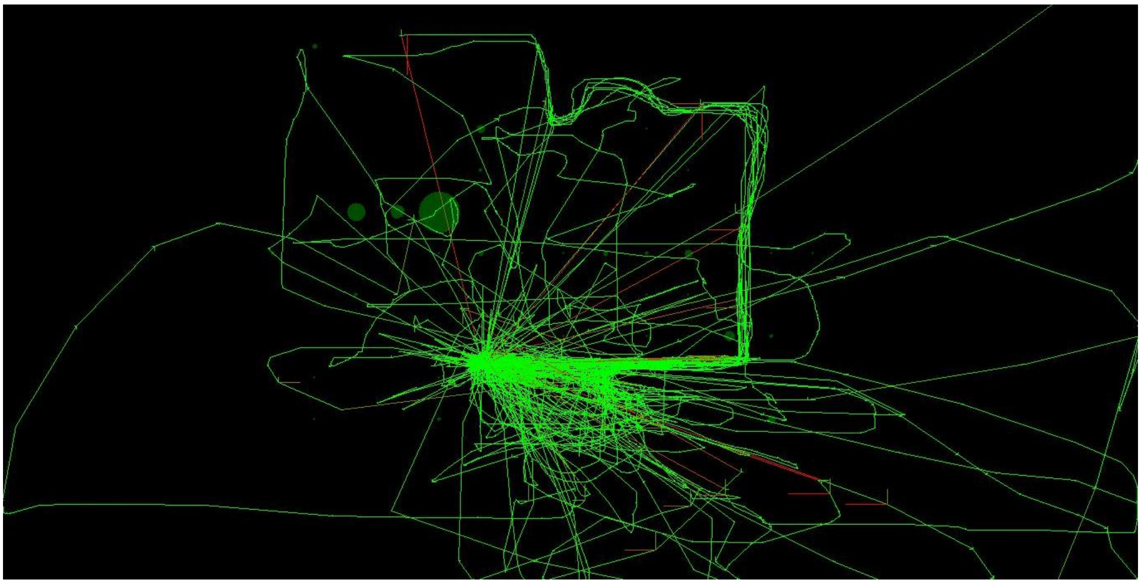

Figure 10 - Maze mouse path - Stressed state

From the pictures above it is possible to observe that the stress influences very effectively this participant's interaction with the computer. Thicker and brighter lines show that mouse walked over the same path several times.

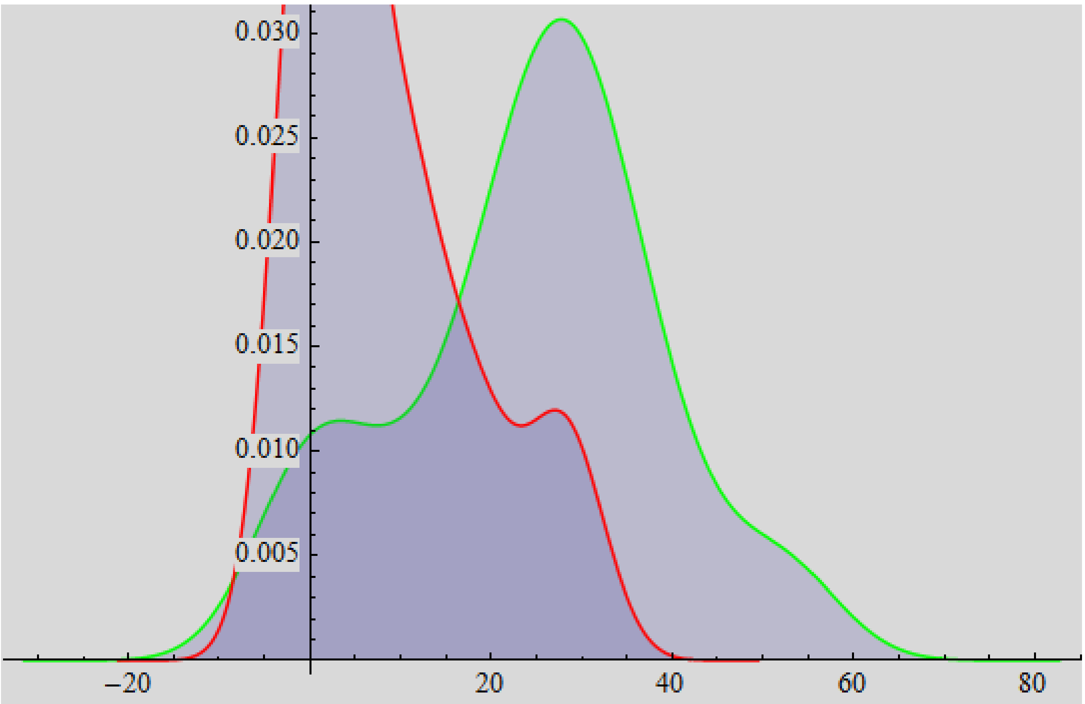


Figure 11 - Keys between tab change distribution: normal (green), stressed (red)

Other interesting result was obtained from the Text Typing exercise. Some users experienced significant different results while performing this exercise. The number of characters they were able to memorize and write without changing tab differed a lot in some users.

On Figure 11 and Table 2 it can be seen that, for the participant under analysis, there is a rich distinction between normal and stressed state which can lead to the hypothesis that stress also leads to a lower memorization capacity.

Table 2 - Keys between tab change

| | *Mean* | *Standard Deviation* | *Median* |
|---|---|---|---|
| *Normal State* | 24.3571 | 14.5423 | 26.5 |
| *Stress State* | 8.36364 | 9.47964 | 5 |

A similar analysis was performed to the time between each tab change. In this case, it was found that this participant changed between tabs quickly when under stress. The results presented on Table 2 were somewhat expected because users memorize less characters which makes them change between tabs faster. The values presented on the following table are in milliseconds.

Table 3 Time between time changes

| | *Mean* | *Standard Deviation* | *Median* |
|---|---|---|---|
| *Normal State* | 11200.8 | 5652.3 | 11081 |
| *Stress State* | 5766.27 | 3719.15 | 6164 |

With the analysis of the collected data from all users, significant differences were observed in most of the individuals in the distributions of the following features: Time between Keys, Mouse Acceleration and Mouse Velocity. It can be seen in the next table where the "T" (True) means that $H_0$ was rejected by the Mann Whitney and "F" (False) that it was not.

Table 4 - Results of the Mann Whitney test - Rejection of H0

| ***Individual:*** | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** | ***8*** | ***9*** | ***10*** | ***11*** | ***12*** | ***13*** | ***14*** | ***15*** | ***16*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Key Down Time* | F | F | F | T | F | F | F | F | F | F | T | T | F | T | F | F |
| *Time Between Keys* | T | T | T | F | F | T | F | T | T | T | T | F | T | F | F | F |
| *Mouse acceleration* | T | T | T | T | T | T | T | T | F | T | T | T | T | T | T | T |
| *Mouse velocity* | T | T | T | T | T | T | T | T | F | T | T | T | T | T | T | T |
| *Time Between Clicks* | F | F | F | F | F | F | F | F | F | F | F | F | T | T | F | F |
| *Double Click Speed* | F | F | T | F | F | F | F | F | T | F | F | F | T | T | F | F |
| *Average Excess Of Distance* | F | F | F | F | F | F | F | F | T | F | F | F | T | T | F | F |
| *Average Distance 2 clicks* | F | F | F | F | F | F | F | F | F | F | F | F | T | F | F | F |
| *Total Excess Distance 2 clicks* | F | F | F | F | F | F | F | F | F | F | F | F | T | F | F | F |
| *Time Per Tab Change* | F | F | F | F | T | F | T | F | T | F | T | F | T | T | F | F |
| *Keys Per Tab Change* | F | F | F | F | T | T | T | F | T | F | F | F | T | T | F | F |

After the determination of the features whose distributions were influenced by stress, a further statistical analysis was performed on the significant data. In this analysis, data from all the users was used in order to discover a common pattern to determine users' stress levels.

Thus being, for each of the determined significant features, additional statistical analysis was performed. Next, some statistical results obtained will be presented.

Time between keys was one of the features where there were found significant differences between normal and stressed state in most of the users. So, in order to obtain interesting results from the entire participation group, data was merged and from it, some statistical job was performed. In Figure 12 - Time between keys distributions: normal (green), stressed (red), the distribution of the collected data about time between keys from all the users is shown. In this chart the differences between the data collected in normal and stressed states are easily observable.

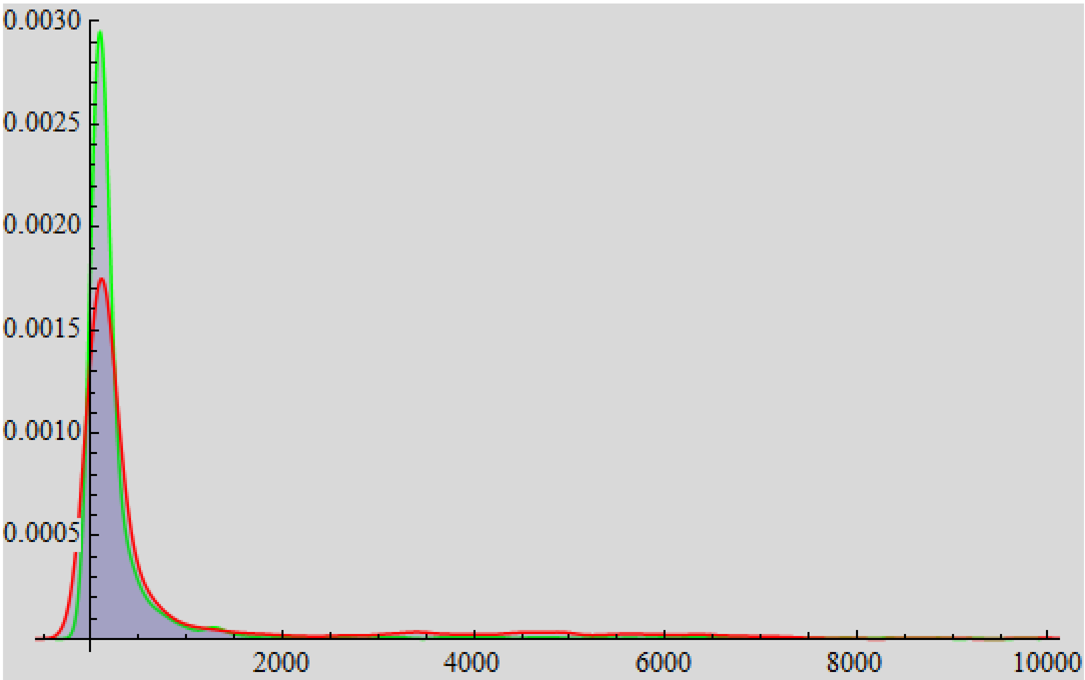


Figure 12 - Time between keys distributions: normal (green), stressed (red)

Also, from the collected data, some other statistics were calculated. In Table 4 it is possible to observe that in 87.5% of the analyzed users it was observed an increase in both mean and median from normal state to stressed state.

Table 5 - Significance - Time between keys

*Time Between Keys*

| | Normal | Stressed | Difference | Change of Average |
|---|---|---|---|---|
| *Mean* | 447.863 | 894.267 | 446.404 | Increases in Stress 87.5% |
| *Median* | 112.344 | 144.75 | 34.4063 | Increases in Stress 87.5% |
| *Significance* | Reject $H_0$ in 56.25 | | | |

An interesting statistical approach found to use in the context of this analysis was the calculation of confidence intervals. A confidence interval gives an estimated range of values which is likely to include an unknown population parameter, the estimated range being calculated from a given set of sample data. So, intervals were calculated for each of the significant features analyzed using a 95% confidence interval for the population mean in both normal and stressed levels. Regarding to Time between keys distribution the following confidence intervals were observed.

$$Confidence\ Interval\ Normal = [388.861, 518.267]$$

$$Confidence\ Interval\ Stressed = [847.045, 1033.29]$$

With the calculated confidence intervals for both normal and stressed states distributions, it is possible to observe a clear distinction between them which results very interesting in order to classify participant's stress states.

Next, some statistical results regarding mouse movement acceleration are shown. In Figure 13 the distributions of the mouse movement acceleration are shown.

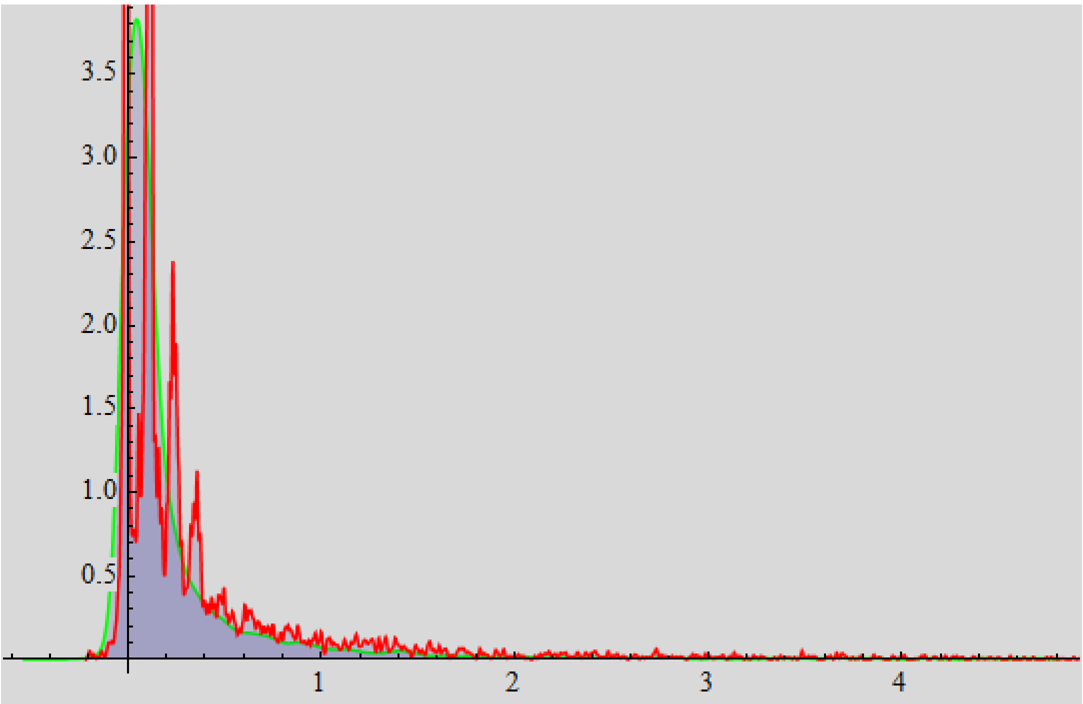


Figure 13 – Mouse acceleration distributions: normal (green), stressed (red)

As happened to the time between keys measures, here it is also observable that there is an increase in the mean and in median between normal and stressed state. It is also observed that a large majority of the users followed this trend, with 93.75% of them (15 users) having an increase on the measures of the mouse acceleration.

Table 6 - Significance - Mouse Acceleration

*Mouse Movement Acceleration*

| | Normal | Stressed | Difference | Change of Average |
|---|---|---|---|---|
| *Mean* | 0.261194 | 0.44124 | 0.180046 | Increases in Stress 87.5% |
| *Median* | 0.0831407 | 0.151919 | 0.0687786 | Increases in Stress 93.75% |
| *Significance* | Reject $H_0$ in 93.75 | | | |

Confidence intervals for normal and stressed states were also calculated for the mouse movement acceleration distribution. It is also possible to observe that there is a clear distinction between the two intervals.

$$Confidence\ Interval\ Normal = [0.26255, 0.27626]$$

$$Confidence\ Interval\ Stressed = [0.441237, 0.461778]$$

The last of the determined significant features was mouse velocity. In the chart present in Figure 14 it is possible to detect a large difference between normal and stressed states.

Table 7 - Significance - Mouse Velocity

*Mouse Movement Velocity*

| | Normal | Stressed | Difference | Change of Average |
|---|---|---|---|---|
| *Mean* | 0.287037 | 0.502527 | 0.21549 | Increases in Stress 87.5% |
| *Median* | 0.0922899 | 0.181224 | 0.0889339 | Increases in Stress 93.75% |
| *Significance* | Reject $H_0$ in 93.75% | | | |

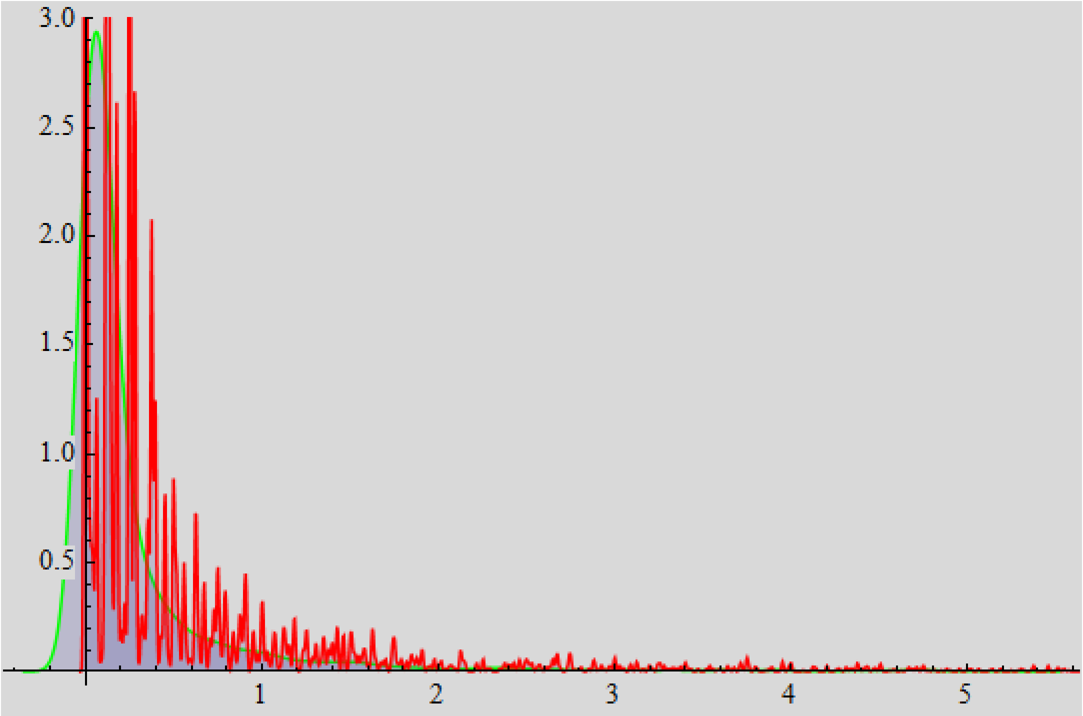


Figure 14 - Mouse velocity distributions: normal (green), stressed (red)

As happened with the other significant features some statistical analysis has been performed. In Table 7 it is possible to observe that substantial differences exists between normal and stress states' distributions. It is also possible to observe that the number of participants who evidenced mouse velocity changes between normal and stressed states is the same as from those who showed changes in mouse acceleration. Furthermore, the participants whose data revealed changes between normal and stress distributions of mouse velocity were the same who showed these changes about mouse acceleration.

Finally, for mouse velocity, confidence intervals were also calculated as presented below.

$$Confidence\ Interval\ Normal = [0.290174, 0.304738]$$

$$Confidence\ Interval\ Stressed = [0.503282, 0.524743]$$

From the information presented above, it is possible to conclude that there is a clear influence of stress on users' interaction with computer when using mouse and keyboard. While some of the analyzed features didn't show any changes, other clearly showed major differences from the two states: normal and stressed.

## 5.2 Real time analysis

An interesting component of this research work was the development of an application able to classify the users' stress levels in real time. In order to make it possible, this application takes advantage of the acquired knowledge in the data analysis process.

The real time analysis system is composed by an application responsible for the data collection during users' interaction with computer and an application responsible for the classification of the users' stress levels according to their interaction with computer.

The data collection application collects some data about users' interaction with computer and sends this information to the classification application. The classification application, based on the knowledge acquired from the statistical data analysis, proceeds to the evaluation of the data and then show users their stress levels while they are using the

computer. In Figure 15 it is possible to observe a screenshot taken during the execution of this application, where it is possible to check the evaluation of users stress levels.

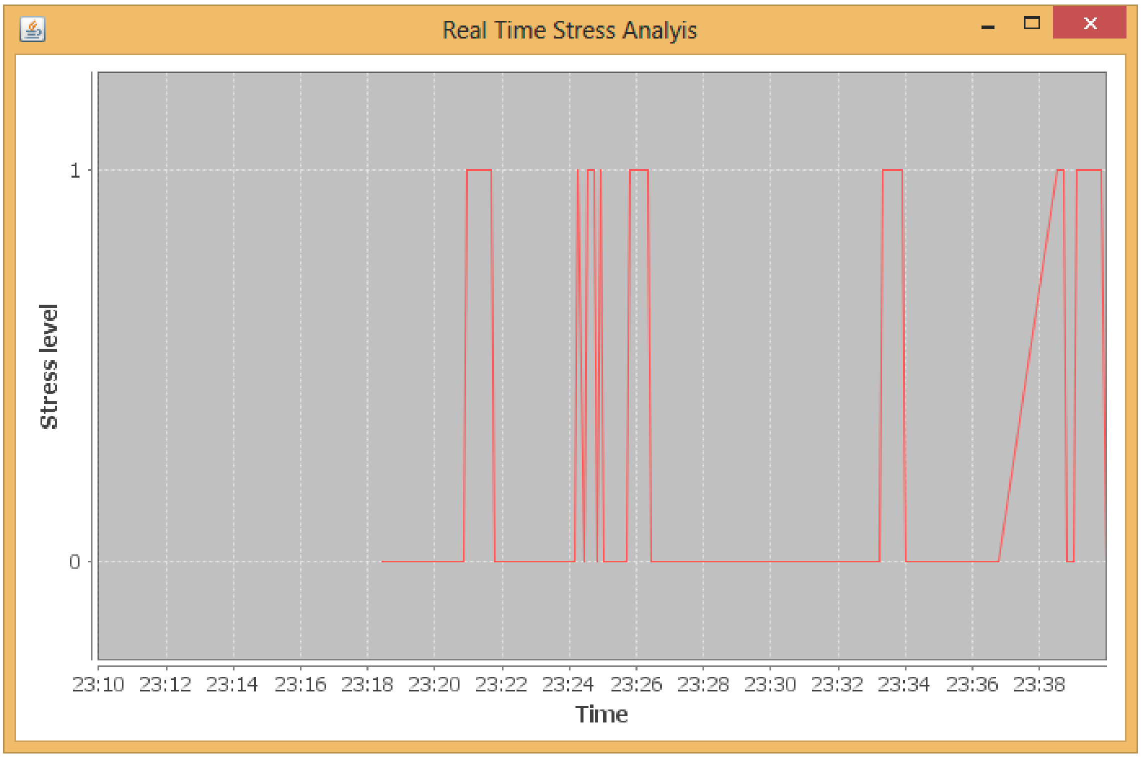


Figure 15 - Real Time Stress Analysis Application

This real time analysis reveals very interesting as it is a noninvasive way to classify stress levels on users with the use of common devices: keyboard and mouse.

## 5.3 Discussion

At the end of the analysis a few conclusions were taken. The analysis of the collected data proved that stress really influences the way users interact with computer using mouse and keyboard.

From the developed study results, it was found that most of the users revealed significant differences on the same three collected features: time between keys, mouse acceleration and mouse velocity. This assumption let it to assume that a system using computer devices such as mouse and keyboard can be used in order to classify users' stress levels.

There were also found other differences on some users' interaction between their normal and stressed states. This is an evidence that stress takes into account the personal individualities of each user, with each react in a differentiated way to stressors.

In order to allow the classification of the data from user interaction with computer using mouse and keyboard, confidence intervals from the collected data distributions for both normal and stressed states were calculated.

A system to classify users' stress from the collected interaction data was implemented using the retrieved knowledge, more specifically the confidence intervals calculated from the data collected in the study phase. This solution revealed itself very interesting as it allows the classification of users' stress levels in real time using noninvasive and common devices.

# 6 Conclusions and future work

Stress is maybe one of the biggest health and safety challenges that the developed world faces nowadays. People's life is becoming more and more stressful. According to some studies, a large number of workers are affected by stress and between 50% and 60% of the lost working days are related to stress, which implies a decrease on their productivity and causes large costs for employers.

In this report it was presented an approach to detect the level of stress on individuals using a computer and its standard devices of input: mouse and keyboard. The use of these two devices was based on their availability for most of people who use a computer. Also, the fact they are non-intrusive allows a more accurate and frequent monitoring of the users' interaction.

With this project it was concluded that it is possible to develop a stress level classification system using such common devices. The use of this kind of devices is what is believed to be the future of healthcare diagnostic methods.

The aim of creating a system to detect stress levels on the users' interaction with computer was accomplished. Therewith, this work contributed with a new way to solve one of the biggest health and safety challenges that developed countries are facing today.

## 6.1 Scheduling

This project followed a methodology that started with the identification of the problem in order to formulate a hypothesis from which the development of the work took place. In the following stage, it was developed an application to collect the necessary data to

the analysis. Then, data was analyzed using statistical and data mining techniques in order to the development of model. The next stage was dedicated to the writing of the thesis, based on the obtained conclusions. In this last stage, dissemination of results was also done. Below it is presented the schedule of activities that was proposed at the beginning of this project.

Table 8 - Initial task scheduling

| ID | Task | Start | End | 2012 | | | 2013 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
| 1 | State of the art | 01/11/2012 | 28/11/2012 | | | | | | | | | |
| 2 | Software development | 29/11/2012 | 12/12/2012 | | | | | | | | | |
| 3 | Experimentation | 13/12/2012 | 06/02/2013 | | | | | | | | | |
| 4 | Analysis of data | 07/02/2013 | 06/03/2013 | | | | | | | | | |
| 5 | Analysis of results | 07/03/2013 | 03/04/2013 | | | | | | | | | |
| 6 | Pre-dissertation report | 10/12/2012 | 01/02/2013 | | | | | | | | | |
| 7 | Writing of dissertation and dissemination of results | 04/03/2013 | 21/06/2013 | | | | | | | | | |

The preliminary task scheduling presented in the work plan was unfortunately too optimistic. The analysis of the state of the art took longer than expected which led to a delay in the experimentation. Also, the software developed needed to be changed during the study. Despite this fact, the submission of the thesis was not delayed. Bellow it is presented the way project has been developed.

Table 9 - Project progress

| ID | Task | Start | End | 2012 | | | 2013 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
| 1 | State of the art | 01/11/2012 | 28/11/2012 | | | | | | | | | |
| 2 | Software development | 29/11/2012 | 21/05/2013 | | | | | | | | | |
| 3 | Experimentation | 13/12/2012 | 03/04/2013 | | | | | | | | | |
| 4 | Analysis of data | 04/04/2013 | 01/05/2013 | | | | | | | | | |
| 5 | Analysis of results | 02/05/2013 | 29/05/2013 | | | | | | | | | |
| 6 | Pre-dissertation report | 10/12/2012 | 01/02/2013 | | | | | | | | | |
| 7 | Writing of dissertation and dissemination of results | 04/03/2013 | 21/06/2013 | | | | | | | | | |

## 6.2 Synthesis of the work done

During the deployment of this project, a wide variety of work was developed. The main contributions of this work are presented here.

- Data collection application: This application was developed in order to allow the collection of users' interaction to computer using computer and keyboard. It is composed by four different exercises which require users to accomplish different tasks. This way it is possible to collect data from the users while performing different type of exercises. Also, the induction of stress on users while they are using this application allows this application to collect data from users in different stress levels.
- Data analysis: Data collected in the previous phase was analyzed and some interesting results were obtained. It was found that stress influences users' interaction with computer according to some of the features being analyzed. The changes detected on these features allowed the development of an easy stress level classification system.
- Real time stress level classification: Based on the analysis of the data collected, a model to determine user stress level was implemented. Using this model, a so-

lution that allows the classification of the users stress level while they are using computer was implemented. Users can normally use their computer, and the developed solution can run in background and classify their stress level.

The work done on this project represents an advance on the field of stress detection, providing an easy and inexpensive way to detect stress on computer users who are using mouse and keyboard. This solution to detect stress is also an interesting approach as it does not require the use of very complex, expensive and intrusive systems.

## 6.3 Relevant Work

The work developed and documented in this dissertation was integrated in the CAMCoF - Context-aware Multimodal Communication Framework project which takes place at the Intelligent Systems Laboratory (ISLab) at the University of Minho (UM).

Part of the work presented in this dissertation was documented in the following publications, having been presented in the 4th ISAmI - International Symposium on Ambient Intelligence.

Carneiro D., Novais P., Catalão F., Marques J., Pimenta A., Neves J., Dynamically Improving Collective Environments through Mood Induction Procedures, Ambient Intelligence- Software and Applications – 4th International Symposium on Ambient Intelligence (ISAmI 2013), Ad van Berlo, Kasper Hallenborg, Juan M. Corchado, Dante I. Tapia, Paulo Novais (eds), Springer - Series Advances in Intelligent and Soft Computing, Vol 219, ISBN 978-3-319-00565-2, pp 33-40, 2013. http://dx.doi.org/10.1007/978-3-319-00566-9_5

And in the 10th International Conference DCAI - International Symposium on Distributed Computing and Artificial Intelligence.

Alves J., Rebelo A., Catalão F., Marreiros G., Analide C., Novais P., Neves J., Simulating the behavior of teams of Affective Agents using Robocode, Distributed Computing and Artificial Intelligence, 10th International Conference, Sigeru Omatu, José Neves, Juan M. Corchado, Juan F. De Paz Santana, Sara Rodríguez

González (eds), Springer - Series Advances in Intelligent and Soft Computing, Vol 217, ISBN 978-3-319-00550-8, pp 79-86, 2013. http://dx.doi.org/10.1007/978-3-319-00551-5_10

## 6.4 Future Work

The objectives of this work have been accomplished. However, some additional work must be done in order to increase the accuracy and validity of the developed system.

One of the most important tasks that remains to be done was the use of sensors to measure some vital parameters from users while they are being subjected to the experimentation. It should be interesting in order to prove in a more conventional way that users are really under stress, which would validate the exactitude of the results of the developed system. In order to perform these measurements from vital parameters, some sensors must be acquired.

Also, the improvement of the mechanism for stress levels classification could be done using an evaluation that takes into account the particularities of the users. This way, the classification system could be improved by adding to it of some users' particularities such as age, genre, job or ability on the use of the computer using mouse and keyboard.

Finally, the study of the advances in technologies that continuously happen as well as the possible advantages that they could provide to this project should be done.

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