Universidade do Minho
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Effects of music preference and selection on stress management

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Trabalho realizado sob orientação de

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Declaração

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É AUTORIZADA A REPRODUÇÃO INTEGRAL DESTA TESE/TRABALHO APENAS PARA EFEITOS DE INVESTIGAÇÃO, MEDIANTE DECLARAÇÃO ESCRITA DO INTERESSADO, QUE A TAL SE COMPROMETE;.

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ABSTRACT

In this busy society of ours, people push their limits to work better and harder/longer in order to remain competitive with their peers. The activities of the working population have increased daily which have, in turn, created more stressful situations and conditioned the welfare as well as the physical and mental abilities of the person. Nonetheless, working longer hours does not necessarily improve productivity nor performance. In order to prevent the negative consequences of this increasing trend, the evolution of performance throughout the day of work should be more closely monitored.

It is acknowledged that, during the day, the user is subjected to various factors that can affect his performance, such as stress. Stress is an ever-present factor these days and can be considered a problem. However, there also positives aspects, and this has made it an increasingly interesting topic of study in the scientific community. In this work, the study carried out will focus on the interaction of stress with music, a broad phenomenon which is present in all societies. More specifically, we will study the effects of music on human stress levels and emotions while performing daily activities.

RESUMO

Na sociedade atual as pessoas são cada mais vezes testadas até aos seus limites para poderem trabalhar mais e melhor, a fim de manter a competitividade ao máximo nível. As atividades do dia a dia da população continuam aumentar, o que cria situações de mais stress condicionando o bem-estar, bem como as capacidades físicas e mentais da pessoa. No entanto, trabalhar mais horas não significa necessariamente uma melhora da produtividade ou performance. A fim de evitar as consequências negativas desta tendência crescente, a evolução da performance ao longo de um dia de trabalho deve ser acompanhado mais de perto.

É importante perceber que durante o dia as pessoas estão sujeitas a vários factores que podem afetar a sua performance, como o stress. O stress é um factor cada vez mais presente nos dias de hoje e pode ser considerado um problema. No entanto, há também aspectos positivos, tornando-se um tema cada vez mais interessante de estudo na comunidade científica. Neste trabalho, será realizado um estudo, que terá como objectivo perceber a interação do stress com a música, um fenómeno presente em todas as sociedades. Especificamente, irá ser estudado os efeitos da música a nível de stress e emoções durante a execução das atividades diárias.

CONTENTS

LIST OF FIGURES

LIST OF EQUATIONS

ACRONYMS

Aml - Ambient Inteligent

bmp - heart beats per minute

BVP - Blood Volume Pulse

CAMCoF - Context-aware Multimodal Communication Framework

EEG - electroencephalogram

ISLab - Intelligent Systems Laboratory

ISTAG - IST Advisory Group

GSR - Galvanic Skin Response

MIREX - Music Information Retrieval Evaluation eXchange

ISMIR - Music Information Retrieval

SSL - Secure Socket Layers

VE - Virtual Environment

UM - University of Minho

Aml - Ambient Inteligent

1

INTRODUCTION

The human being is currently under an increasing demand to perform, fruit of a competitive society in which the scarcity of resources drives individuals into harsher conditions. Workplaces are particularly "good" examples of this reality. The lack of jobs, decreasing wages, increasing working hours, working in shifts, competitiveness or unrealistic productivity goals result in constant and increasing pressure on the individual. These situations can lead to problems such as stress, which can produce negative or positive results in overall performance. In this chapter we present our motivation to withstand these problems, the forms of combat, such as the use of music, which constitute the objectives and scope of this work.

1.1 MOTIVATION

Stress is considered to be one of the major health problems nowadays, with a tendency to worsen. Thus, special attention to this matter is necessary and important. As mentioned, stress can condition the individual's physical and mental abilities.

According to the European Agency for Safety and Health at Work in 2005, stress compromises workplace safety and contributes to other work-related health problems, such as musculoskeletal disorders. Nearly one in four workers is affected by stress and between 50% and 60% of missed working days are related to it. The experience of stress can alter the way a person feels, thinks and behaves[13]. The symptoms range from reduced productivity to emotional reactions (sleep problems, depression)[14].

Given the symptoms, described above, it is necessary to understand how stress affects the human body from a physical to psychological state. In this work we will thus consider the possibility of monitoring the pulse rate levels, galvanic response and body temperature. Such parameters are very interesting to consider in other studies, such as finding differences between driving in a normal situation or driving under stress.

Over the years, many scientists have studied ways to combat and influence stress, for example the effects of color or music on people. In this work, one decided to study the influence of music. Why did we decide to study music? Because music is present everywhere, everybody likes music and music has a form of expression that cannot be put into words. Over the years music has always been connected to us, in many areas ranging from entertainment to war or religion, serving a myriad of purposes both socially and individually. Given the major importance of music in all human societies throughout history, and particularly in digital society, music plays a relevant role in world economy[25].

Why do people like music and why does it play with our emotions? Because when people hear music, the brain tries to predict what sound they will hear next. Usually these predictions are met as the "thing" we call music and it has to have some kind of structure or sound pattern. However, sometimes those predictions are violated and we hear something unexpected. These surprises keep our mind interested in the given music[23]. Music distracts people from pain and fatigue, elevates mood, increases endurance, reduces perceived effort and may even promote metabolic efficiency. With so much of our work now being done on computers, music has become an important way to "optimize the boring". Music has increasingly become apart of the modern-day work session[31].

Furthermore, in the perspective of user performance during daily tasks (e.g. work), which will be evaluated in this work, stress and music can affect performance positively or negatively. In addition, if the user is affected by stress, or some other factor, music could be a way of being able to calm down, as will be demonstrated in this dissertation. Does music actually make you more productive? More focused? More creative? Or is it a form of distraction (loose focus)?. These many questions are raised and will be analyzed in our study, regarding the user's performance. With the increasing importance of music in our society, and considering a wide range of musical styles and user preferences, one will study how music influences the user's stress level while he/she performs daily tasks and activities.

1.2 SCOPE OF THE DISSERTATION

Following the facts described in the previous sub-section, and in order to answer the question that was raised "How does music influence the level of stress on the user while performing daily tasks and activities ?", the main aim and motivation of the study is to create a music recommendation system. The system will monitor the user's stress level and performance in real time, combined with with the possibility to change the style of the music being played in order to control his/her stress level or to help control performance.

A possible application scenario is the system recognizing that the user is experiencing a high stress level and recommending a pause in the activity being performed, changing the music style to one that generally calms the user down. This kind of tool can contribute to a better quality of life, guiding and helping the user to remain calm, make better decisions and perform better in daily activities such as work tasks.

1.3 ISLAB PROJECT

The work presented in this document is integrated in the project CAMCoF - Context-aware Multimodal Communication Framework, being developed at the Intelligent Systems Laboratory (ISLab) at the University of Minho (UM)[7].

The main objective of this project is to develop a framework to model the users' context, focusing on stress, and to provide this information for 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. Thus, 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, the 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 then in a stressed state. On 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 of information to the users of a VE in the form of simple emotional avatars that can complement what is being said by using non-verbal information. It will result in more efficient communication processes, which will more accurately resemble the context of the richness of face-to-face communication.

1.4 OBJECTIVES

The main goal of this study is to create a music recommendation system based on the user's stress level and performance level acquired, through data collected by the keyboard and mouse, and aimed at managing the user's stress. In the pursuit for a better system, this system will inform the user of the dangers of being under stress for prolonged periods, and how it may lead to bad choices in very different situations (e.g. driving, taking binding decision in interpersonal relationships). This system will allow the user to analyze his/her potentially unhealthy behaviours thus enabling a possible personal reflection. Through that change in behaviours, the aim of improving life quality is achieved. Another objective of the system is to learn the user's personal musical preferences in order to improve the efficiency of the recommendation mechanism.
The objectives for the dissertation are:

- The analysis of the state of the art concerning the following sensors: Heart Beat, Skin Response and Body Temperature. Specifically, one will study (in a preliminary validation of the approach) the standard values of these sensors in the human body when the user listens to randomly selected music and songs and try to understand if this affects the user (when calm or under stress);
- The definition of a dynamic system to classify a user's level of stress and performance through the sensors mentioned, keyboard and mouse;
- The presentation of a questionnaire to the participants of the study in order to understand their musical preferences and how they perceive the effects of music in their daily lives;
- The development of a study to understand the effects of different types of music on the user in the workplace, while performing regular tasks, or in a similar simulated environment (this study will be conducted in the Intelligent Systems Lab);
- The use of machine learning tools for the data collected in the study described above in order to build a personalized model for each user;
- The development of develop a recommendation system based on this model;

1.5 METHODOLOGY OF WORK / RESEARCH

To accomplish the previously mentioned objectives, an Action - Research methodology will be followed. This methodology starts by identifying the problem so that a hypothesis can be formulated, and on which the development will be based. Subsequently, the information is recompiled, organized and analysed, continuously building a proposal for solving the identified problem. Finally, one can reach conclusions based on the results obtained during the investigation. For this research model to be followed, six complementary stages were defined to achieve the planned objectives. The stages defined are described ahead:

- The specification of the problem and its characteristics;
- A constant and incremental update and review of the state of the art;
- The idealization, and gradual and interactive development of the proposed model;
- The experimentation and implementation of the solution for the development of a prototype;
- A result analysis and the formulation of conclusions;
- A constant diffusion of the knowledge and results obtained, as well as of the experiments, to the scientific community;

1.6 STRUCTURE OF THE DOCUMENT

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

Chapter 2 will introduce the concept of Ambient Intelligence. It starts with a brief description of the concept. Next, it presents some other concepts such as that of the recommendation system and a brief explanation of intelligent components and sensor environments.

Chapter 3 presents a detailed description of stress, which starts by emphasising historical descriptions of stress. Later, some aspects of stress, such as stress types or the influence of external factors, are presented. Afterwards, there is a brief explanation of music and the relationship between performance, stress and music, as well as the effects of these on the user's performance. Finally , this section presents and analyses some related projects.

Chapter 4 describes the process of data collection. This chapter begins with an explanation of the preliminary validation of the approach (motivation); this comprises a test, by using sensors, to prove that music affects people in different ways. Afterwards, the study in this dissertation is described, from the methodology and collection of information to the presentation of results.

In Chapter 5, the Recommendation and Monitoring System developed is presented. Initially, the objectives, architecture and the communication used is presented for development. It also presents the implementation decisions, as well as the final system developed.

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

2

AMBIENT INTELLIGENCE

This section presents the definition of Ambient Intelligence (*AmI*), it details the main components behind in *AmI*,which is the main concept on which this work is grounded, so that it is important to explain and understand it.

2.1 WHAT IS AMBIENT INTELLIGENCE?

Ambient Intelligence (*AmI*) refers to a seamless and invisible computing environment that is “aware” of our presence and context, and which is sensitive, adaptive and responsive to our needs [21]. The concept was introduced by the IST Advisory Group (ISTAG),and is defined by a new paradigm, this emerged as a result of three new key technologies: Ubiquitous Computing [41], Ubiquitous Communication [28] and Intelligent User Interfaces [29], this is starting to change the way we see computers.

AmI is comparable to a large computer with other tools, where these tools communicate amongst themselves, with the ability to automatically adapt to the users' daily tasks and activities. In intelligent environments, computers are tools that learn what we like, what we do, our habits and our preferences, so they can simplify our lives. Moreover, they are shrinking in size and have now been hidden in common devices so that we do not notice them at all. AmI environments can be found in diverse places, such as homes, offices, meeting rooms, schools, hospitals, control centres, transports, tourist attractions, stores, sports facilities, music devices or others. In these environments one finds devices, which are currently commonplace items: mobile phones, air conditioning systems, laptops, media servers, PDAs or others. Similar, these devices are connected through a control network so that they can be controlled or control other devices from any point of the network.

In AmI it is important to mention that components are as hidden as possible (Figure 1). The ideal intelligent environment should appear to be a perfectly normal environment, embedding its

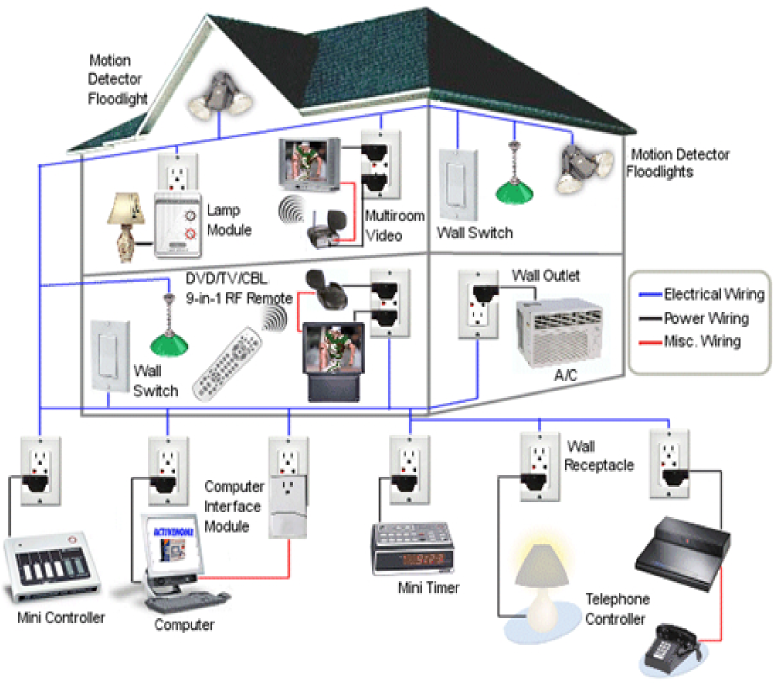


Figure 1: Example of Ambient Intelligence - SmartHome[33].

components in common devices, noticeable only through its actions. In AmI, each component has its functions and, together, their job is to ensure people's well-being and safety. For this this to be done (efficiently?), the users' preferences must be known, which constitutes one of the important characteristics of AmI. It learns preferences by interacting with the user: it studies one's behaviours, learns what one usually does and when one usually does something. Therefore, if the system learns the user's habits, that's mean that environment will be unique, depending on the people who interact with the system. We can thus say that another important characteristic of AmI is that it is personalized [6].

Nowadays, technological devices have more capabilities, especially those which are mobile. Theses devices can obtain data from the environment such as location, temperature, user movements and user habits. These devices include the already commonplace smartphones, as well as more innovative alternatives such as Google Glass. These allow for the implementation of AmI systems which have the capacity to adapt to the user's preferences and are thus personalized and sensitive .

2.2 SENSING

In the previous section Ambient Intelligence was described as a system that learns our behaviors, adapts to us, hides in common devices, is aware of our context and is able to predict our actions. It is important now to describe the components that make it possible for AmI to perform correctly.

AmI really depends on the sensors, for correctly reading as much data about the environment or users as possible, as this data is the basic information for any decision from the system. Nowadays, these sensors are more hidden as possible, from common flood detectors, alarms, gas detectors as sensors luminosity to temperature and humidity, making it possible to read the environmental parameters. With this the environment can be monitored in order to maintain the preferences, the needs or the safety of the person. The knowledge about environment and user is very important for the performance of the service provided.

In smart environments, the perfect scenario is one where all components are as invisible as possible, where the user does not perceive anything about the data collection regarding the environment and himself. These sensors collect data in a non-intrusive way. In this work, information was collected concerning users during activities: the user's performance in terms of features extracted from the use of the keyboard and the mouse, whether the user was or was not under stress or listening to some music. This information will be described in the study relating to Music interaction for this work.

When information about the user or his environments is necessary and there are no non-intrusive sensors, which collect necessary information such as the number of times the user's heart beats per minute (bpm), intrusive sensors must be used. For this work and for the scope of work in ISLab described above, one needs to use these types of sensors to monitor the user's vital signs during the study (preliminary validation of the approach) One can thus better understand how music influences the user's performance during activities. Over the course of the exercise, the participant is connected to the biofeedback unit. This consists of :

- A blood Volume Pulse (BVP) – The blood volume pulse refers to the amount of blood contained in an area. By indexing rapid changes in blood flow, the BVP meter indicates one's level of psychophysiological relaxation or arousal. These sensors provide information in different forms. For this work, one has highlighted the Heart Rate, the numbers of times the heart beats per minute. This value is 75 beats/min for a resting young, adult male. Resting rates slower than 60 beats/minute (bradycardia) and faster than 100 beats/min (tachycardia) may indicate cardiovascular disorder. Another element of information is the Stress Index where, if the values are between 1 and 3, the user is unstressed and, if they range between 4 and 6, the user is very stressed[40].

More light/higher BVP signal = blood volume is increasing and so is relaxation.
Less light/lower BVP signal = blood volume is decreasing;
Relaxation is decreasing and arousal is increasing [40].

Figure 2: Sensor for measuring the heartbeat - Blood Volume Pulse (BVP)[40].

- The Galvanic Skin Response (GSR) - Taped to the index and middle fingers,these electrodes produce a tiny current across the skin to measure sweat gland activity and, thus, psychophysical relaxation and arousal[40].

  High sweat gland activity and high electrical skin conductance = psychophysical arousal, tension, and stress OR possible arousal of the autonomic nervous system by gamma brainwaves

  Low sweat gland activity = low arousal/relaxation [40]

- Skin Temperature - is often measured at the fingertips and is a lagging indicator of arousal or relaxation in that it changes less quickly than other physiological measures. This sensor transmits the temperature of the user's body and it is interesting to see and analyze temperature when the user is under stress and not stressed[40].

This work will attempt to measure stress, through sensors that allow us to observe important values in the human body during an activity. These sensors will activate when touched and

Figure 3: Example of Sensor for measure sweat gland activity - Galvanic Skin Response[40].

Figure 4: Sensor to measuring body temperature - Skin Temperature[40].

will allow one to acquire information about the heartbeat rate (through variations in the finger's luminosity due to the arrival of blood), as well as the amount of skin moisture (by measuring its electrical conductance) [7]. These two parameters are directly related to stress and are definitely extremely clear. Body temperature will also be considered as it is also directly related to stress.

There are many types of sensors one can use to enrich the information that a system can acquire from the environment. A final example can reside outside weather stations which, when connected to the system, provide information about outdoor environment. This may be important, not only to inform the user, but also to make recommendations regarding what to wear or what to do on this day, according to the weather conditions[6].

2.3 RECOMMENDATION SYSTEMS

Increasingly, people have access to diverse sources of information, they also provide more information about themselves through the web and other systems. An example is the purchase of a product on a web site, where there are varieties of that product, sometimes the user needs to make choices without much (or any) sufficient personal experience of the alternatives. There is an extensive class of Web applications that involve predicting user responses to the options. Such a facility is called a Recommendation system. The goal of a Recommender System is to generate meaningful recommendations to a collection of users for items or products which might interest them. This recommendation system can prove to be important in a smart environment. For example, the user's behaviors can be analyzed and it also recommends that the user listen to a song to relax or feel more active.

Recommendation systems can recommend through two techniques[27]:

- Content-based systems: the Recommender System analyzes the characteristics of the item (keywords are used to describe the items) and the user profile . Through other users who possess items with the same characteristics, it suggests these similar items. For example, the system observes the bands that the user hears often on a music website and, through other users, it will recommend bands of the same genre of music which do not appear in the user's library.
- Collaborative filtering systems: the Recommender System recommends some items through a user profile. This profile is created by user feedback, for example when a user likes a particular song or not, information on the user's behaviors, activities or preferences. Through that profile, the system recommendeds items with the same characteristics due to their similarity to other users' items.

However, these technologies alone are insufficient and combining collaborative filtering and content-based filtering could be more effective in some cases. These systems are called Hybrid Recommender Systems. The Recommender System is built depending on the domain of the data characteristics that have to be analyzed and recommended. For example, the Netflix user frequently provides ratings on a scale of 1 to 5 (likes). In recent years, the Recommender System has emerged in several areas in our society and has become increasingly important. These systems are applied in various areas ranging from movies, music, news, books, health and financial services, among others[24].

In our work, the recommendation system developed will be based on the Collaborative filtering technique since, during the learning period of the system, all users will answer short questionnaires. These will indicate, for example, if you like the songs/music on/for that day, which will help the system to recommend other songs/styles of music. These recommendations may also be evaluated by the user.

3

STRESS AND MUSIC

After introducing the concept of Ambient Intelligence as seamless and invisible computing environments, the tools used to measure and evaluate the user (sensors) and the systems that analyze the data collected and subsequently advise/recommend these to the user (Recommendation System), we must more thoroughly understand which environmental factors can affect the user, for example stress.

This section describes Stress and Music, due to the fact that they constitute central topics for this work. Furthermore, one must understand the relation between them, as well as prior work undertaken in this area. Since we are analyzing the the user's performance at work on a daily basis, it is also important to understand how stress affects the day-to-day work level. We will try to understand the effects of music on stress levels, with a subsequent evaluation of performance.

3.1 DEFINITION OF STRESS

"Everyone knows what stress is, but nobody really knows"
Hans Selye

The definition of stress is still not consensual in the scientific community, remaining as an open topic of discussion. In fact, stress involves a multiplicity of factors, many of them subjective, leading to multiple interpretations that make it difficult to be objectively defined. Thus, some researchers argue that such a concept is elusive because it is poorly defined (Cox, 1985)[8] while others prefer not to provide an actual definition of the concept until a more accurate and consensual view of the phenomenon is reached.

One of the first definitions of stress was proposed by Selye[32]. According to this author, stress can be seen as a non-specific response of the body to external demands. These demands (the load or stimulus that triggered a response) are denominated stressors while the internal body changes that they produce constitute the actual stress response. Selye was also the first to document the chemical and hormonal changes which occur in the body due to stress[7].

Stress constitutes a response to various situations and this response can be emotional,physiological or both for example, increased blood pressure, and increased stomach acid. Stress can also affect the mind, with occasional nightmares, negativity and impaired judgment. Behaviours, such as more drinking and smoking are affected too, which is also the case for emotions like the loss of confidence and, ultimately, depression. However, stress can produce positive effects: for example, when a person is in danger, stress can prepare us to take defensive action, it also fuels creativity and motivates us to achieve.

From a point of view of high levels of stress, two types 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. Acute stress is thrilling and exciting in small doses, but too much is exhausting. A fast run down a challenging ski slope, for example, is exhilarating early in the day. That same ski run late in the day is taxing and wearing. Acute stress symptoms are perceived by most people. It constitutes a laundry list of what has gone awry in their lives: the auto accident that crumpled the car fender, the loss of an important contract, a deadline they are rushing to meet, their child's occasional problems at school and so on. Most common symptoms are Emotional distress, Muscular problems, etc[4].

On the other hand, there is long-term chronic stress. This type of stress results, for example, from social and health conditions, dysfunctional families, among many other issues [7]. This is the grinding stress that wears people away day after day, year after year. Chronic stress destroys bodies, minds and lives. It wreaks havoc through long-term attrition. It is the stress generated by poverty, dysfunctional families, being trapped in an unhappy marriage or in a despised job or career. Chronic stress occurs when a person never sees a way out of a miserable situation [4] . This type of stress appears for an undetermined time, and when people reach their limit and then go over the edge, the consequences/solutions are suicide, violence, heart attacks, strokes, and perhaps cancer.

Reducing your stress levels can not only make you feel better immediately, but will also protect your health long-term. Various exit strategies for reducing stress can be used, such as trying to identify the root of stress and attempting to register the causes, thoughts and moods. If one is able to understand these, then a plan to address these issues can be established. One should also set reasonable expectations for oneself and draw up a list of all one's commitments, assessing priorities and then eliminating any tasks that are not absolutely essential. Another possible solution is to get help, if you continue to feel overwhelmed, consulting a psychologist or another licensed mental health professional can help you to learn how to manage stress effectively[3].

3.2 STRESSORS

After describing “what stress is”, it is important to understand which factors cause stress. These causes are called stressors.

> ”A stressor is a chemical or biological event, environmental condition, external stimulus and event that causes stress to an organism.“[2]

As the previous sentences states, stressors create physical, chemical and mental responses within the body. The internal body changes that they produce constitute the actual stress response. Stressors may be different from person to person. The effects on users can be both physiological and physical. These stressors are present everywhere, it is not easy to work with them since each person will react differently to various situations. One can observe these stressors from one’s point of view and classify them as being positive or negative stressors. Positive stressors are characterized as those which motivate, excite, or improve people’s performance. A list of possible stressors are: starting a new job, marriage, taking a vacation, retiring, learning a new hobby or the birth of a child. On the other hand, the so-called negative stressors cause anxiety, are associated with unpleasant feelings and can lead to mental and physical problems. Examples of negative stressors include the death of a relative, unemployment, sleep problems, legal problems, financial problems [17].

Another way to classify stressors is through events or experiences, such as environmental stressors, crises/catastrophes, major life events, daily troubles/microstressors. Examples of environmental stressors include loud sound levels and over-illumination. Workplace stressors are also common and include deadlines, work competition, schedules or the lack of security. A good example of how stressors affect us daily is provided by the observation of our daily activities, such as when people are late for work and on the way to work, they get caught in traffic, thus feeling stress and this is aggravated by the possible negative consequences of arriving late at work. There are, of course, a number of other sources of stress in our lives, but these and their effects will always be different from person to person[17].

3.3 WHAT IS MUSIC?

Music constitutes a predominant worldwide art. From the times of Indian tribes to the rise of modern societies, music has had a particularly strong artistic presence in our culture. Several biochemical processes are involved in the process of attributing a feeling or an emotion to each single chord.

Music is used in many activities in our society, from a simple sportsman training for a competition to a doctor performing surgery [36]. It is used in various medical areas to control emotions and reduce anxiety and stress (see Standley, 1986)[36]. Miluk-Kolasa, Matejek and Stupnicki (1996)[36]. Miluk-Kolasa, Matejek and Stupnicki (1996) [36] examined the reduction of pre-surgical anxiety using an individually designed music program (IDMP) [19]. Since patients who heard music showed lower systolic blood pressure, heart rate, cardiac volume, blood glucose and high skin temperature, it was concluded that music had the effect of reducing pre-surgical anxiety [19]. This supports the main idea and motivation of this (Silva) work [36], using music to influence the level of stress level of the human body.

Among many other areas, music is used in many of modern-day workplaces (e.g. shopping malls, individual stores, surgery rooms, collective transportation). Even if music is not playing openly through installed sound systems, workers are often allowed to work while listening to their personal music by using headphones, which happens frequently in software development companies.

Especially in commercial environments, such as shopping stores or malls, the strategies for selecting music are often driven by the objective of activating people, inducing heightened shopping behavior. Moreover, [Yalch 1990][42] concludes that specific types of music should be used in particular areas of the store so as to appeal to different types of consumers.

In a 2012 study by C. J. Bacon of Sheffield Hallam University, Karageorghis and their colleagues, participants who cycled in time to music required 7 percent less oxygen to do the same work as cyclists who did not synchronize their movements with background music[35].

The human body is constantly monitoring itself. After a certain period of exercise and the exact duration varies from person to person—physical fatigue begins to set in. The body recognizes signs of extreme exertion, rising levels of lactate in the muscles, a thrumming heart, increased sweat production and decides it needs a break. Music competes with this physiological feedback for the brain's conscious attention [31].

Music has many positive aspects, which have already been described above, but one might also acknowledge the negative side of music. Many people prefer to work in their jobs without music, or with the normal noise produced by the environment. Researchers have shown that a moderate noise level can really get creative juices flowing, yet, too much noise has the opposite effect[38]. Certain types of music can totally destroy some people's focus on work.

3.4 PERFORMANCE VS STRESS AND MUSIC

Numerous studies have highlighted the negative effects of this lifestyle. [37] shows positive mean correlations between overall health symptoms, physiological and psychological health symptoms, and hours of work. [10] analyzes the impact of overtime and long work hours on occupational injuries and illnesses, thus concluding that these variables depend more on the amount of time worked rather than on the risk level of the job. In [16],the effects of shift work and extended work hours are analysed at different levels, including family and social life, performance, fatigue, productivity and health, among others.

As addressed in detail in [5], there is currently an overwork culture, which is further encouraged by greedy management techniques and job insecurity. While the main objective of management is to increase production, this does not necessarily happen, nor will it increase productivity. There is thus the need to improve performance or productivity by other means that do not generate such negative effects. This dissertation presents such an approach through the use of music. Indeed, musical selection affects many different aspects of one's life , including one's physiology, mood or motivation. This performance can be affected due to various reasons, for example pressure (life stressors), which causes stress. As already described above, stress can be both positive or negative, and can thus affect performance differently. Figure 5 [15] presents a possible relationship of stress with performance (the Yerkes-Dobson principle). According to this principle, stress will in- crease one's performance and even one's health and, as it rises, it is referred to as "eustress". When stress reaches a certain point, however, performance and well being suffer, and this is called "distress" [15].

The center zone is the area of best performance and, in order to keep one's performance at optimal levels, this depends largely on how well you take care of your body, mind and spirit, how far you are able to control your emotions, attitudes and how well you manage all of the demands made by life. During one's day, it is always difficult to maintain control over oneself because unpredictable situations happen all the time, there are mood changes, and one remains under stress (unconsciously). Many people try to control these mood states or reduce factors like stress, through music. Thus, after having described music and stress, it is important to understand the relation that exists between them. Both music and stress affect the body in many ways. So,

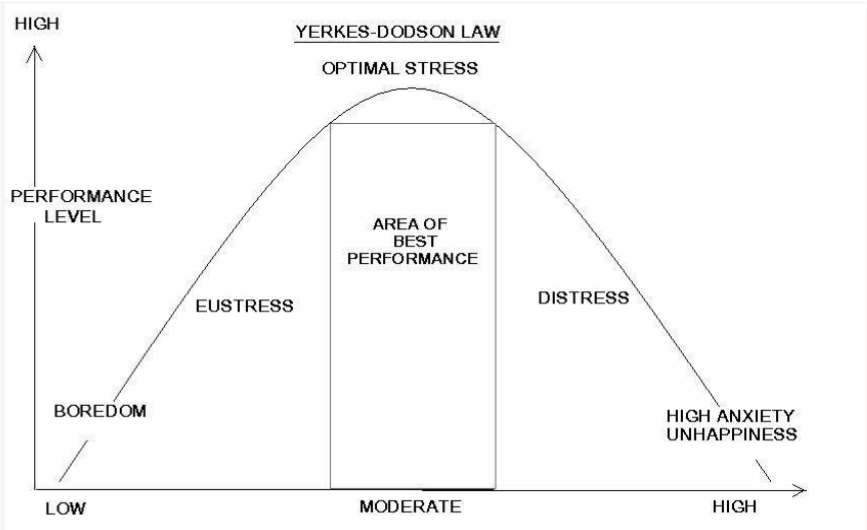


Figure 5: Stress vs Performance[15].

why not use music as a stress relief tool? In this dissertation, one of the main objectives is to prove that it is possible to relieve stress in many situations through music and thus decrease or increase performance as desired.

Over the years, many studies have found that music encompasses many benefits, this is a key idea for this dissertation. Music lowers blood pressure (which also reduces the risk of stroke) and eases muscle tension, among other positive effects [12]. With all the benefits that music can produce, it is no surprise that music therapy has been growing in popularity. Many hospitals are using music therapists for pain management and other uses.

In order to determine if music relieves stress in certain situations, one must first consider which situations these are. For example, when people need to finish a work-related task that they are not enjoying by the end of the day, listening to appropriate music may make the task more bearable and even increase the quality of the product. Another example occurs when people are eating, music can also be a helper in this situation because the body can respond with relaxation, lowering cortisol levels (stress) and making it easier to digest food.

After explaining how performance can be altered by the stress of everyday life and how music can influence stress, this dissertation will determine the potential effect of music on the natural deterioration of performance that occurs during the workday. Specifically, we want to determine if particular types of music can decrease this natural degradation, contributing to the individual's higher overall performance.

3.5 RELATED PROJECTS

Several projects in related fields have been analyzed during this research work. Presented below are some of these, showing work developed in this field of research by our peers. A brief analysis of the presented projects follows, comparing these with the project shown here. Particular attention has been given to the first project presented, since we have used its proposed music classification method in our study.

Music Emotion Classification

This study was developed by the University of Pompeu Fabra, in 2007. The purpose of this study is to describe the MIREX Audio Music Mood Classification [22]and the Music Information Retrieval Evaluation eXchange (MIREX), an annual evaluation campaign for Music Information Retrieval (MIR) algorithms, joined to the International Society (and Conference) for Music Information Retrieval (ISMIR).

The same type of music may evoke different emotions in different humans, so it is a challenging task to assign a kind of emotion to a particular song/type of music. One of the main problems in this matter is the lack of a standard and good quality dataset with audio clips and emotional information. Due to this fact, each author has to gather his own data-set and present results based on it, making it impossible to compare the results of different studies. This problem was studied more actively in the 20th century, when several researchers investigated the relationship between emotions and particular musical attributes such as mode, harmony, time, rhythm and dynamics. Mood classification of audio music is one of the tasks included in MIREX, where re- searchers can submit their classification systems to be tested and ranked. In this study they described how a content-based similarity measure can help to classify a collection of music files according to mood.

Most studies in music emotion classification are based on datasets collected by the authors on the Internet. These datasets are usually pre-classified with emotions, through tags, taken for instance from sites. This study helped us during our work, since we used the Mirex Audio Music Classification for the music selected for the study. This classification creates groups of music styles that evoke similar emotions in people. Therefore, our first goal was to create a similar dataset with the same organization described above, because the MIREX dataset is secret and exclusive, and thus not available to everyone. In order to define the music dataset, we collected music from ALLMUSIC [1]. This website contains digital music repositories, which are subdivided into moods and classified with tags by users.

Modeling a stress signal

The main objective of this initiative from Australia National University in Canberra is to estimate an objective stress signal for an observer of a real-world environment stimulated by meditation. To achieve this aim, they proposed creating a computational stress signal which was developed from, and based on, a support vector machine, genetic algorithm and an artificial neural network to predict stress signals from a real-world data set [34].

During this work they analyzed the effect of a real life environment using an observer, which is an interesting perspective.. The observer‘s job is to see the real-life setting that the stressor has caused on someone. This means that the observer does not have any influence on the environment, but is likely to engage emotionally and intellectually with the events in which they are present, albeit passively [34].

The other interesting aspect of this work is how it analyzes the physiological signals of response when the user is under stress The signals used for stress analysis include the electroencephalogram (EEG), galvanic skin response (GSR), the electrocardiogram and blood pressure. These sensors are similar to those used in our work (section 2.2).

Physiological stress response to video-game playing: the contribution of built-in music

The main objective of this initiative from the University of Montréal in 2004 the study of physiological stress response to video-game playing, in order to study the influence of the music present in video games on players' stress levels [30].

Other studies about the effects of different types of music did not take into account the types of music that are 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 the organism's physiological response when exposed to music of is different from the one produced when there is silence. In this study it is also shown that participants were unaware that they were under stress. In line with previous statements, and in order to induce stress on participants, hard rock music was used during the study.

The Effects of Different Types of Music on Perceived and Physiological Measures of Stress

A very interesting study was undertaken in 2002 and studied the effects of different types of music on perceived and physiological measures of stress [20]. This study was developed by the University of South Alabama. For this study, 31 males and 29 females rated their level of relaxation and completed the State-Trait Anxiety Inventory (STAI) after they were told that they would be taking a stressful, mental test. During the study, the contributor then listened to different types of music or was silent, the level of skin temperature, frontalis muscle activity and heart rate was recorded during this period. Participants subsequently rated their relaxation and anxiety levels after listening to music or in silence.

The results of the research suggest that music may have an effect on the cognitive component of stress response. In this study, it was hypothesized that individuals who listened to classical music, or music they believed was relaxing, perceived 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, since participants who listened to hard rock music reported that they were not more relaxed after listening to this genre of music.

Precategorized Stimulative and Sedative Music

In 1973, Dale Taylor studied the Subject Responses to Precategorized Stimulative and Sedative Music [39]. The purpose of this study was to determine the accuracy with which musical selection have been classified as being stimulative or sedative. This report remains pertinent today due to its categorization of some music into stimulative or sedative, which is used as a standard.

The Impact of Listening to Music on Cognitive Performance

This recent work by Arielle S. Dolegui aimed to study the impact of different genres of music, played at different volume levels, on the cognitive abilities of college students while they completed academic tasks. The study focused on two distinct music genres and their influence on performance, anxiety, and concentration. Participants had to indicate their preferred genre of music and were requested to repeat a set of numbers backwards while listening to either stimulative, sedative, or no music.

This study used five different arithmetic tests to measure cognitive performance. The tests consisted of 20 different operations: 5 multiplication, 5 division, 5 addition, and 5 subtraction problems. The order of operations was randomized throughout the tests. No question involved operations with more than a three-digit number. The five tests were similar in difficulty. Loud music was defined as heavy-rock metal music, and the song used in that condition was "Not Ready to Die". Soft music was defined as classical piano-only music, and the piece that was used in that condition was "Morning Light"[11].

The results of the research are interesting because we were able to compare them with the results of our study. It indicated that participants performed worse while listening to their preferred type of music (music can serve as a distracting factor) and that the best results were obtained when there was no music condition. The results also showed that participants who listened to sedative music performed better than those who listened to stimulative music (a stronger distractor, which then obstructs cognitive processing). The first group also performed better than than those who listened to no music at all. Interestingly, there was no difference when the scores from soft music played at high volume were compared to scores from loud music at high volume.

3.6 ANALYSIS OF THE RELATED PROJECTS

Many projects have been developed over the last years, revolving around the main themes described above, such as Music, Performance and Stress. Some of these have been presented here, showing their objectives, challenges, and some of the results obtained at the end. All these studies proved to be important, providing a greater understanding of the various factors involved and contributing to an optimized/in-depth study through the results observed.

Music Emotion Classification, described by Mirex, is a study that many researchers participate in each year. It essentially allows for a better understanding of the relationship between emotions and particular music attributes, such as mode. This study proved to be of great use to us, due to its method of classification of music into 5 clusters (like a folder with songs of different music styles). Through this, we were able to understand that there are similarities between clusters (how music affects us), which we had to bear in mind in our results.

All the studies referred above were important to understand various factors, which included evaluating the user's performance when he/she was subjected to factors such as stress and music. There are several ways to evaluate stress and evaluating vital signs is one of these. In Modeling a stress signal study, the values of the vital signals are checked through sensors. This allows us to realize how sensors are used in studies, so that we used similar sensors in our pre-tests.

Still reviewing the last referenced study (The Impact of Listening to Music on Cognitive Performance), the results are very interesting, for example, the fact that when the volume of music is lower or higher, this does not change the results. We did not highlight this detail in our study where each user listens to music at the volume he wishes through headphones. Yet, i may be interesting to note this study, because it is similar in many aspects to ours. On a closer analysis, the method of the study uses math exercises, however, the analysis lies in establishing if the music is effective in short spaces of time (if it takes more time). The repetition of exercises (even changing the exercises), has no reverse effects on results. Compared to our study, the participants perform their work, but listen to music for much longer periods of time (morning or afternoon). A very important conclusion reached after the analysis of some previous work is the possibility of monitoring systems interfering in the behavior of the people being analyzed.

4

DATA COLLECTION

Human-computer interaction is an increasingly interesting research field. As our interactions with technology grow, so does the knowledge that can be built about us by common devices such as Smartphones or computers (and their software).

In the last years, we have shown that particularly stressful periods or peaks of fatigue change our interaction with these devices. Specifically, they change the performance of this interaction. While short periods of stress might even improve it, prolonged periods or fatigue may significantly decrease it. In this context, the aim of this study is to establish if listening to specific types of music may contribute to further improve or worsen the performance of the computer user. With this research, we aim to develop music recommendation strategies that can improve the experience of the user while interacting with a computer, whether for work or leisure.

For the main goal of this dissertation, it is necessary to collect the user's interaction with a computer. By using mouse, keyboard and intrusive sensors, a software application was developed. In order to analyze the user's interaction patterns, in both a normal and stressed state, the participants of the study worked normally on their daily computer tasks while listening to music. In this dissertation we focused on the preliminary validation of the approach and study.

In the preliminary validation of the approach, we carried out tests to prove that music affects people in different ways By using the sensors described in the previous chapter, we were able to prove that this approach makes sense and demonstrated the motivation of our work in this area. The Long Duration Study was implemented, in which we used only non-intrusive sensors, mouse and keyboard, in order to collect the user's interaction with the computer in normal activities. During this study, the user listened to different types of music to determine if, during the activity, the user felt more or less stressed. In this study, the users had to answer questionnaires. In these , we created user profiles with the purpose of understanding if music produces particular feelings on the user during the activity, like fury, happiness, or others.

4.1 MOTIVATION

As has already been shown, there are several good reasons to study this area,several projects over the years have proven that music generates different effects on people. In the preliminary validation of the approach, we decided to use intrusive sensors, namely Galvanic Skin Response, Blood Volume Pulse and Skin Temperature. These sensors allowed us to measure the user's vital signs during the study, so as to better understand how music influences the user's performance during activities. These tests were carried out by people from the Intelligent Systems Lab at the University of Minho. The participants played four mental games, a Memory Game, a Reaction-time Game, a Concentration Game and an Accuracy Game. The purpose of these games was to test the user's cognitive abilities, such as memory, concentration and reaction[26].

These games were played twice by each participant (in 2 phases). In the first phase, each participant could choose one cluster from five clusters, in the second phase, this was accompanied by the participant's preferred music (participants played games while listening to the music). In two phases of the test, we measured the participant's vital signs through the 3 sensors. In Figure 6 presents the results of the participant Kevin both graphs reveal that there are differences when going from one phase to another, more or less starting from the seventh minute. In the upper graph, the results of Skin Conductance are presented (a method of measuring the electrical conductance of the skin), where the values in the first phase are low and showed the participant to be calm and apathetic, in line with the music he heard. In phase 2, the user began to listen to his favorite songs, which produced greater activation, this was demonstrated by the higher values of Skin Conductance, which means more excitement or stress. The lower graph presents the results of Resistance (Skin resistance, the inverse of Skin Conductance), when the values of Resistance are higher, this mean that the participant is calmer. There is a change in the values of Resistance when the second phase begins.

In the Blood Volume Pulse sensor, values were constant, between 60 and 85 beats per minute. The Skin Temperature sensor also consistently recorded normal values for the human body. The values of Skin Conductance and Resistance may indicate that the user has, in fact, become excited, but there might not have been enough time to notice obvious differences in these vital signs (Blood Volume and Skin Temperature). With feedback from the user, we observed that the user had been more excited in phase 2 and that the scores were better. Generally, all participants demonstrated that there were differences between phase1 and phase2 through the sensor values and feedback from each participant.

Figure 6: Results of the preliminary validation of the approach - Skin Conductance and Resistance

During the study, we were able to perceive the state of the participants in the proposed activities (mood). Most of the participants who chose a random cluster in the first phase, and who did not like the music style at all, showed discomfort, this even caused possible irritation over the course of a longer time period. We were able to observe that the preferred music in phase 2 affected each user differently. For some users, it had a relaxing effect while, for others, it had the opposite effect, arousing the person.

After this preliminary validation of the approach and the results obtained, we were more motivated to carry out the main study, observing the effects of music (music styles) on the user. In the main study the user was subjected to several different styles of music, ranging from quieter to more aggressive. Another important aspect was to maintain the repetition of the games, one of the significant factors, besides the excitement caused by the music, was that the participant could produce better scores by having to repeat the games. We can compare this aspect to that of a person's routine in a job. One must take into account that the user in the main study will be working and that a good performance over time may not be motivated by music in the same way However, one must also consider that repeating tasks or not having stressors are important aspects, too.

4.2 STUDY DESIGN

Specifically, one studied the influence of different types of music on two variables: the interaction patterns of the users with computers and the behaviors in the environment.

4.2.1 *Interaction Patterns*

Interaction patterns are described by a number of features, which are extracted from the log of activity of the mouse and the keyboard. This log contains particular events, issued by the Operating System, their timestamp and other important information such as coordinates, when applicable. The following events are considered:

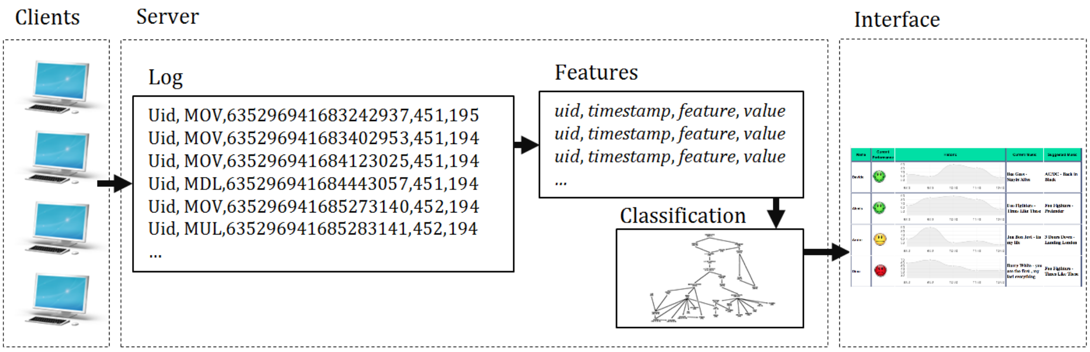


Figure 7: A high-level view of the architecture

- MOV, timestamp, posX, posY - an event describing the movement of the mouse, at a given time, to coordinates (posX, posY) in the screen;
- MOUSE_DOWN, timestamp, [Left|Right], posX, posY - this event describes the first half of a click (when the mouse button is pressed down), in a given time. It also describes which of the buttons was pressed (left or right) and the position of the mouse in that instant;
- MOUSE_UP, timestamp, [Left|Right], posX, posY - an event similar to the previous one but describing the second part of the click, when the mouse button is released;
- MOUSE_WHEEL, timestamp, dif - this event describes a mouse wheel scroll of amount dif, in a given time;
- KEY_DOWN, timestamp, key - identifies that given key from the keyboard was pressed down, at a given time;

- KEY_UP, timestamp, key - describes the release of at given key from the keyboard, in a given time;

These events were considered in order to build the following features, that describe the interaction patterns of the user with the computer:

- Velocity - The distance travelled by the mouse (in pixels) over the time (in milliseconds). The velocity is computed for each interval defined by two consecutive MOUSE_UP and MOUSE_DOWN events. Let us assume two consecutive MOUSE_UP and MOUSE-_DOWN events, mup and mdo, respectively in the coordinates (x_1,y_1) and (x_2,y_2), which occurred respectively at the moments time_1 and time_2. Let us also assume two vectors pos_x and pos_y, of size n,holding the coordinates of the consecutive MOUSE-_MOV events between mup and mdo. The velocity between the two clicks is given by $\frac{r\_dist}{(time\_2 - time\_1)}$, in which r_dist represents the distance travelled by the mouse and is given by equation 4.1:

$$r\_dist = \sum_{i=1}^{n-1} \sqrt{(posx_{i+1} - posx_i)^2 + (posy_{i+1} - posy_i)^2} \quad (1)$$

Equation 4.1: Velocity equation

- Acceleration - The velocity of the mouse (in pixels/milliseconds) over the time (in milliseconds). A value of acceleration is computed for each interval defined by two consecutive MOUSE_UP and MOUSE_DOWN events, using the intervals and data computed for the Velocity.
- Down Time - the timespan between two consecutive KEY_DOWN and KEY_UP events, i.e., for how long was a given key pressed.
- Time Between Keys - the timespan between two consecutive KEY_UP and KEY_DOWN events, i.e., how long did the individual took to press another key.
- Time Between Clicks - the timespan between two consecutive MOUSE_UP and MOUSE _DOWN events, i.e., how long did it took the individual to perform another click.
- Double Click Duration - the timespan between two consecutive MOUSE_UP events, whenever this time span is inferior to 200 milliseconds. Wider timespans are not considered double clicks.

- Average Excess of Distance - this feature measures the average excess of distance that the mouse travelled between each two consecutive MOUSE_UP and MOUSE_DOWN events. Let us assume two consecutive MOUSE_UP and MOUSE_DOWN events, mup and mdo, respectively in the coordinates (x_1,y_1) and (x_2,y_2). To compute this feature, first the distance is measured in a straight line between the coordinatesof mup and mdo as $sdist = sqrt(x_2 - x_1)^2 + (y_2 - y_1)^2$. Then, it is measured the distance actually travelled by the mouse by summing the distance between each two consecutive MOV events. Let us assume two vectors posx and posy, of size n, keeping the coordinates of the consecutive MOV events between mup and mdo. The distance actually travelled by the mouse, r_dist is given by equation 1. The average excess of distance between the two consecutive clicks is thus given by $\frac{rdist}{sdist}$.

- Average Distance of the Mouse to the Straight Line - in a few words, this feature measures the average distance of the mouse to the straight line defined between two consecutive clicks. Let us assume two consecutive MOUSE_UP and MOUSE_DOWN events, mup and mdo, respectively in the coordinates (x_1,y_1) and (x_2,y_2). Let us also assume two vectors posx and posy, of size n, holding the coordinates of the consecutive MOUSE_MOV events between mup and mdo. The sum of the distances between each position and the straight line defined by the points (x_1,y_1) and (x_2,y_2) is given by equation 2, in which ptLineDist returns the distance between the specified point and the closest point on the infinitely-extended line defined by (x_1,y_1) and (x_2,y_2). The average distance of the mouse to the straight line defined by two consecutive clicks is thus given by $\frac{sdist}{n}$.

$$s\_dist = \sum_{i=0}^{n-1} ptLinedist(posx_i, posy_i) \qquad (2)$$

Equation 4.2: Average distance of the mouse to the straight line equation

- Distance of the Mouse to the Straight Line - this feature is similar to the previous one in the sense that it will compute the s_dists between two consecutive MOUSE_UP and MOUSE_DOWN events, mup and mdo, according to equation 2. However, it returns this sum rather than the average value during the path.

- Signed Sum of Angles - with this feature the aim is to determine if the movement of the mouse tends to "turn" more to the right or to the left. Let us assume three consecutive MOV events, mov1, mov2 and mov3, respectively in the coordinates (x_1,y_1) , (x_2,y_2) and (x_3,y_3). The angle alpha between the first line (defined by (x_1,y_1) and (x_2,y_2)) and the second line (defined by (x_2,y_2) and (x_3,y_3)) is given by degree(x1,y1,x2,y2,x3,y3) = tan(y3-y2,x3-x2) - tan(y2-y1,x2-x1) . Let us now assume two consecutive MOUSE_UP and MOUSE_DOWN events, mup and mdo. Let us also assume two vectors posx and posy, of size n, holding the coordinates of the consecutive MOUSE_MOV events between mup and mdo. The signed sum of angles between these two clicks is given by equation 3.

$$s\_angle = \sum_{i=0}^{n-2} degree(posx_i, posy_i, posx_{i+1}, posy_{i+1}, posx_{i+2}, posy_{i+2}) \tag{3}$$

Equation 4.3: The Signed Sum of Angles equation

- The Absolute Sum of Angles - this feature is very similar to the previous one. However, it seeks to find only how much the mouse "turned", regardless of the direction towards which it turned. In that sense, the only difference is the use of the absolute of the value returned by function degree(x1,y1,x2,y2,x3,y3), as depicted in equation 4.

$$s\_angle = \sum_{i=0}^{n-2} |degree(posx_i, posy_i, posx_{i+1}, posy_{i+1}, posx_{i+2}, posy_{i+2})| \tag{4}$$

Equation 4.4: Absolute Sum of Angles equation

- Distance between clicks - represents the total distance travelled by the mouse between two consecutive clicks, i.e., between each two consecutive MOUSE_UP and MOUSE_DOWN events. Let us assume two consecutive MOUSE_UP and MOUSE_DOWN events, mup and mdo, respectively in the coordinates (x_1,y_1) and (x_2,y_2). Let us also assume two vectors posx and posy, of size n, holding the coordinates of the consecutive MOV events between mup and mdo. The total distance travelled by the mouse is given by equation 4.1 .

From these features, one can then obtain a measure of the user's performance (e.g. an increased distance between clicks, or sum of angles, represents decreased performance). As a result, a wide range of possibilities become real, such as the study of the effects of fatigue or stress on performance [11, 4] or, as in this case, the effects of musical selection.

4.3 LONG DURATION STUDY

4.3.1 *Goals and Objectives*

The main goal of this study is to determine the influence of music on the interaction of users with computers, as well as on their behavior within the environment. Determining the existence of these changes and measuring their magnitude will allow for the development of a recommendation system aimed at improving individual performance indicators.

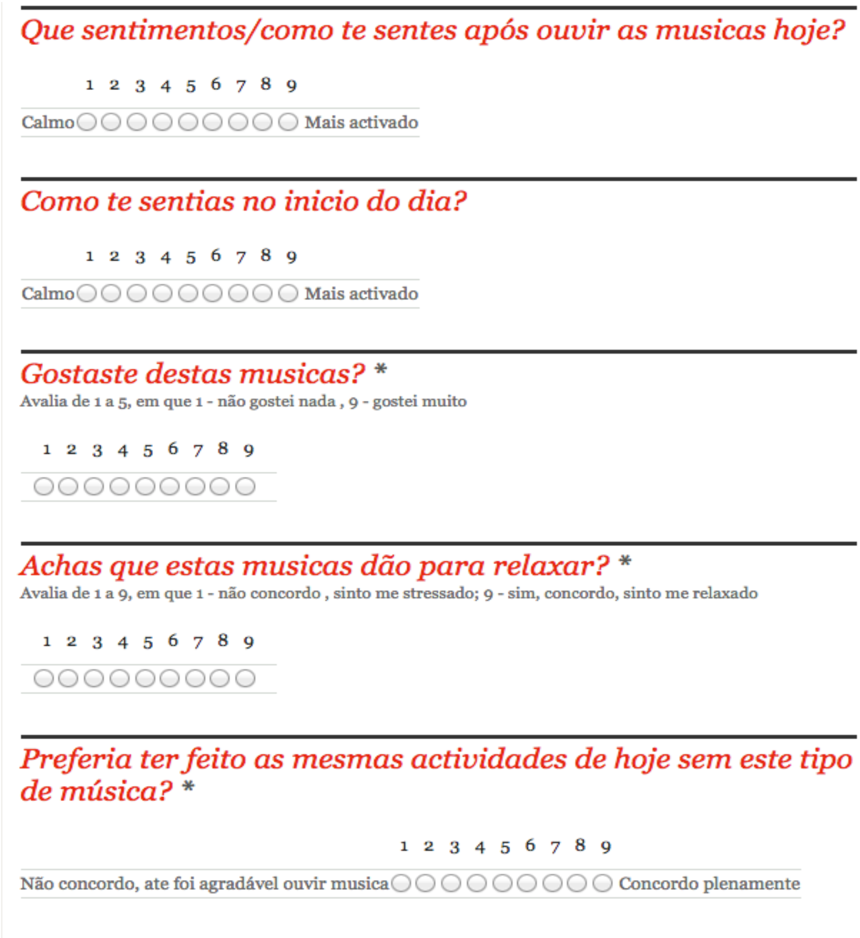
The main objectives of the study are:

- To determine if music produces an effect on the interaction patterns of the users with the computer;
- To determine if different types of music produce different effects on the variable;
- To study and quantify the effects of different types of music on the variable;
- To determine if users are conscious of the effects measured or, at least, of some effect at some level;
- To determine if the effects observed can be generalized to the population in general (e.g. type of music A affects 95% of the population in a similar way) or if only personalized models will be sufficiently accurate;

4.3.2 *Method*

This experimental study took place in the Intelligent Systems Lab at the University of Minho. In this lab, numerous students and researchers spend their day working with a specific computer and are allowed to listen to music using headphones. 12 participants were selected to take part in this study, aged between 20 and 28, with an average age of 24.3 . Prior to their participation in the study, each individual filled in a questionnaire aimed at determining their musical preferences. Moreover, at the end of each day, they also filled in another questionnaire to determine their subjective opinion about the musical selection of the day. With the help of psychologists from the School of Psychology at the University of Minho, these questionnaires were drawn up and grounded on affective standards such as valence, activation and dominance (Figure 9). Valence means that something caused positive or negative emotions in a participant, in this case, what kinds of emotions were provoked by the music in question. Activation relates to whether the participant feels more active or calmer after the study, in this case after hearing musics during daily work. Dominance is related to whether the participant lost control over the activity that was taking place due external factors (music) during the study.

These three affective norms are related, so that the questions were constructed in line with these principles. After carrying out a more critical analysis, these questionnaires allowed us to establish which of the participants' emotions were caused by music: fear, anger, surprise, sadness, and so forth.


Que sentimentos/como te sentes após ouvir as musicas hoje?

1 2 3 4 5 6 7 8 9

Calmo ○ ○ ○ ○ ○ ○ ○ ○ ○ Mais activado

Como te sentias no inicio do dia?

1 2 3 4 5 6 7 8 9

Calmo ○ ○ ○ ○ ○ ○ ○ ○ ○ Mais activado

Gostaste destas musicas? *

Avalia de 1 a 5, em que 1 - não gostei nada , 9 - gostei muito

1 2 3 4 5 6 7 8 9

○ ○ ○ ○ ○ ○ ○ ○ ○

Achas que estas musicas dão para relaxar? *

Avalia de 1 a 9, em que 1 - não concordo , sinto me stressado; 9 - sim, concordo, sinto me relaxado

1 2 3 4 5 6 7 8 9

○ ○ ○ ○ ○ ○ ○ ○ ○

Preferia ter feito as mesmas actividades de hoje sem este tipo de música? *

1 2 3 4 5 6 7 8 9

Não concordo, ate foi agradável ouvir musica ○ ○ ○ ○ ○ ○ ○ ○ ○ Concordo plenamente

Figure 8: Questionnaire to classify the musics/songs (clusters) at the end of each work day.

The selected individuals were requested to participate in the study for five days. During their participation, they did not need to change any of their routines: the only request was that they carried out their usual tasks while listening to the music provided, using their headphones. The recording of their performance indicators was carried out in the background, through a log application that required no interaction at all. The independent variable in this study was thus musical selection. Five different types of music were used, firstly, they were classified and then put forward by [18] in the form of five so-called mood clusters. Each cluster contained music classified as follows:

- Cluster 1: passionate, rousing, confident, boisterous, rowdy;
- Cluster 2: rollicking, cheerful, fun, sweet, amiable/good natured;
- Cluster 3: literate, poignant, wistful, bittersweet, autumnal, brooding;
- Cluster 4: humorous, silly, campy, quirky, whimsical, witty, wry;
- Cluster 5: aggressive, fiery, tense/anxious, intense, volatile, visceral;

The dependent variable was the performance of the participants, measured in terms of the features described above. Before the actual start of the data collection, each participant filled in a first questionnaire, meant to establish a profile for each participant. In this questionnaire, each participant provided some standard demographic data, rated some songs from the different clusters according to their level of activation or valence (from the participant's point of view) and answered some questions which would allow us to perceive their musical preferences. During the actual study, each participant took part in five different moments of data collection, each one on a different day. On each day, the participant heard music from one of the different clusters during the whole period of work, a minimum of 3 hours.

At the end of each day, each participant answered another questionnaire aimed at determining how the type of music made them feel, concerning their performance at work (e.g. was the participant consciously aware of some effect?). Moreover, it was also the aim of this questionnaire to determine if the music truly induced the desired state in the participant. The data collected, from both the questionnaires and the performance monitoring software, was analyzed using statistical software.The results are described further ahead in this work.

4.3.3 *Results*

Given the scope of the study, we will not delve very deeply into the results of the study: we will only focus on the most important aspects that allowed us to grasp the relationship between music and performance.

One of our objectives was to determine if the musical selection in each cluster would be experienced by the participants as expected, i.e., if the clusters we deemed to be calm would be considered calming by the participants. As Figure 9 shows, this did, in fact, happen. Cluster 3, containing music classified as autumnal, brooding or literate, was the one that relaxed participants the most. Cluster 5, on the other hand, containing music described as aggressive, fiery or tense/anxious, was the one that relaxed them the least.

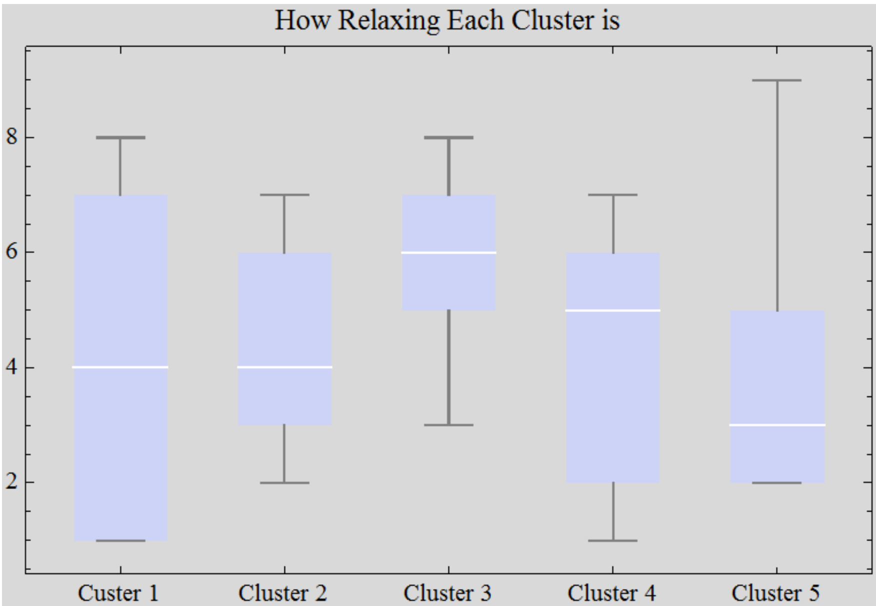


Figure 9: Distribution of the gradings, by the users, of how relaxing each Cluster is (1 - no at all relaxing, 9 - highly relaxing).

There is not necessarily a direct relationship between how relaxed you are and your performance. Indeed, this relationship is more complex than it may seem at first sight. In this study we found that one's performance does not depend solely on musical selection but also on the individual's musical profile. Indeed, if we consider Figure 10, we will observe that the Cluster which most attenuates fatigue over the day is Cluster 4, while those that most contribute to increasing the effects of fatigue are Clusters 2 and 5. This can be explained by the fact that Cluster 4 contains music that can be described as humorous and silly, contributing to the participant's good mood and motivation. Though somewhat similar, Cluster 2 is calmer and activates people less. Cluster 5 contains heavy music, which over longer periods, will wear the participants out, producing negative effects. These characteristics can help one to understand the observed differences. Although these differences are visible when observing the entire population, this is still more interesting when one considers individual participants and their musical profile. Indeed, we saw that people who enjoy heavy music more are positively affected and experience improved performance over a longer timespan with the heavier clusters. They are activated by this music in a positive manner and work more efficiently. These are also people who possess higher baseline activation, i.e., they are naturally more "stressed". People that are naturally calmer, on the other hand, find this music annoying and sometimes hurtful to the ear, as a result, they are unable to concentrate, which affects their performance. These individuals thus perform better at work when listening to calmer music.

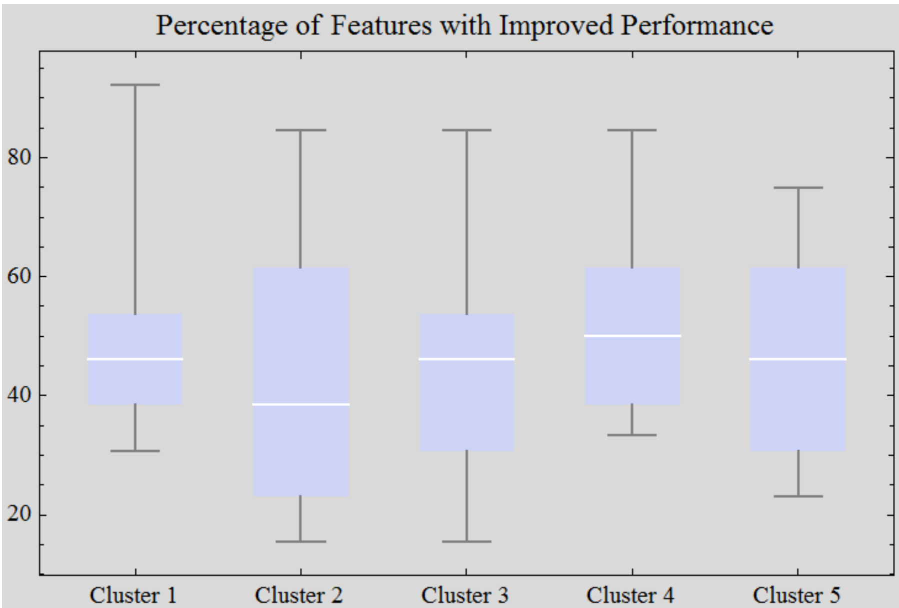


Figure 10: Distribution of the percentage of features in which each participant improved their performance over the day, for each Cluster.

On analyzing a case of 12 individuals who carried out this study, the participant "Davide" obtained the following performance classifications, represented in Figure 11. One can observe better ranking in Cluster 2, which means that over time the participant improved his performance. In Clusters 3 and 4, the participant obtained a lower classification. The data collected allows us to observe the metric values over time for each cluster, which changes to high and low values. On analyzing each day for each cluster, we can generally observe if each of the metric values rose or dropped. In Figure 11, the upper table presents the general assessments of the metric values, which are represented by "+" and "-". The symbol "+" means that the average values were positive in the aspect of performance (values may have increased or decreased over time), for example, if the KeyDown metric in a cluster has a "+", this means that the values over time dropped (there are a few exceptions where values rise, for example in a pause), thus contributing to increased performance. The symbol "-" means that the average values were negative in the aspect of performance, which could mean that over time, due to fatigue or stress, the user took longer to press the keys on the keyboard and the time of writing was therefore longer, which helps to reduce user performance. This form of representation allows one to calculate the value of overall performance (e.g. if all the metrics in the cluster had "+"), and the overall performance would then be 100%. The percentages shown in the lower table of Figure 11 are constructed by starting with the counting of "+", this means that, in thirteen metrics evaluated for example in cluster 2, 84% of these metrics had positive values that contributed to the increased performance on that day. Considering the performances below 50%, one can say that performance dropped over time, because the values of more than half of the metrics evolved negatively in terms of performance ("-").

	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5
KeydownTime	-	+	-	+	-
TimeBetweenKeys	-	+	-	+	-
Mouseacceleration	-	-	-	-	-
Mousevelocity	-	-	-	-	-
TimeBetweenClicks	-	+	+	-	-
AvaregeExcessOfDistance	+	+	+	-	+
TimeDoubleClicks	+	+	-	-	+
AvarageDistancePointline2clicks	+	+	+	+	+
TotalExcessDistance2Clicks	+	+	+	-	+
DistanceDuring2Clicks	-	+	-	+	+
DistanceBetweenClicks	+	+	+	-	+
SignedSumOfAngles	+	+	+	+	+
AbsoluteSumOfAngles	+	+	+	-	+

	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5
PerformanceDavide	46.1538	84.6154	46.1538	38.4615	61.5385

Figure 11: Classification of performances in each cluster. - Participant Davide.

In order to evaluate overall user performance, one needs to understand the values calculated by the metrics, since an increase in metric values does not always mean higher performance. In Figure 12, for example, if the TimeBetweenKeys metric values rise over time, this means the user takes longer to press between keys, which may signify a break in concentration or tiredness, and can thus not be related to increased performance. If one is conclude that there has been an increase in performance over time, all the metrics have to be calculated together and not individually.

	More performance	Less performance
KeydownTime	↓	↑
TimeBetweenKeys	↓	↑
Mouseacceleration	↑	↓
Mousevelocity	↑	↓
TimeBetweenClicks	↓	↑
AvaregeExcessOfDistance	↓	↑
TimeDoubleClicks	↓	↑
AvarageDistancePointline2clicks	↓	↑
TotalExcessDistance2Clicks	↓	↑
DistanceDuring2Clicks	↓	↑
DistanceBetweenClicks	↓	↑
SignedSumOfAngles	↓	↑
AbsoluteSumOfAngles	↓	↑

Figure 12: Relationship between metrics and performance. DownArrow means that the values fell. The UpperArrow indicates that the values rose

Through the graphs presented in Figure 13 we can obtain a better perception of the development of a metric value over time, and how this affects the user's overall performance . The graphics are a representation of the metric values over time (KeyDown and Average Distance of the Mouse to the Straight Line). Above each graphic, there is an equation of slope (y = mx + b), represented by a line on the graph. In the graph for metric AverageDistancePointLine in cluster 2, the slope is negative (-1.092099468x), so that the values of this metric dropped over time. In this case, it is positive for increased performance. One can also observe differences between clusters, in cluster 2 the values dropped, but in cluster 4 the values rose, which contributes to a drop in performance. The case of the analysis of the Metrics KeyDown graphs is the same. What is generally observed in these graphs, compared with the table in Figure 11, is that we can see why the participant Davide obtained a classification of low performance in clusters 3 and 4 and a higher classification in cluster 2.

The results of overall performance for each cluster, allows for a deeper analysis so that one can understand each user's personality type, from the calmer and more stressed user and what kind of music is best suited to these personalities. Good examples of this are participants "Davide" and "Vitor Neto" (Figure 14). Davide, who can be described as someone who regularly listens to heavy music, achieves the best performance results with Clusters 2 and 5. Vitor, on the other hand, a calmer person by nature, demonstrates better performance in Clusters 3 and 4. Indeed, the problem of determining the most appropriate style of music for an individual is a complex one and, as these results show, several variables must be taken into account, namely, and besides

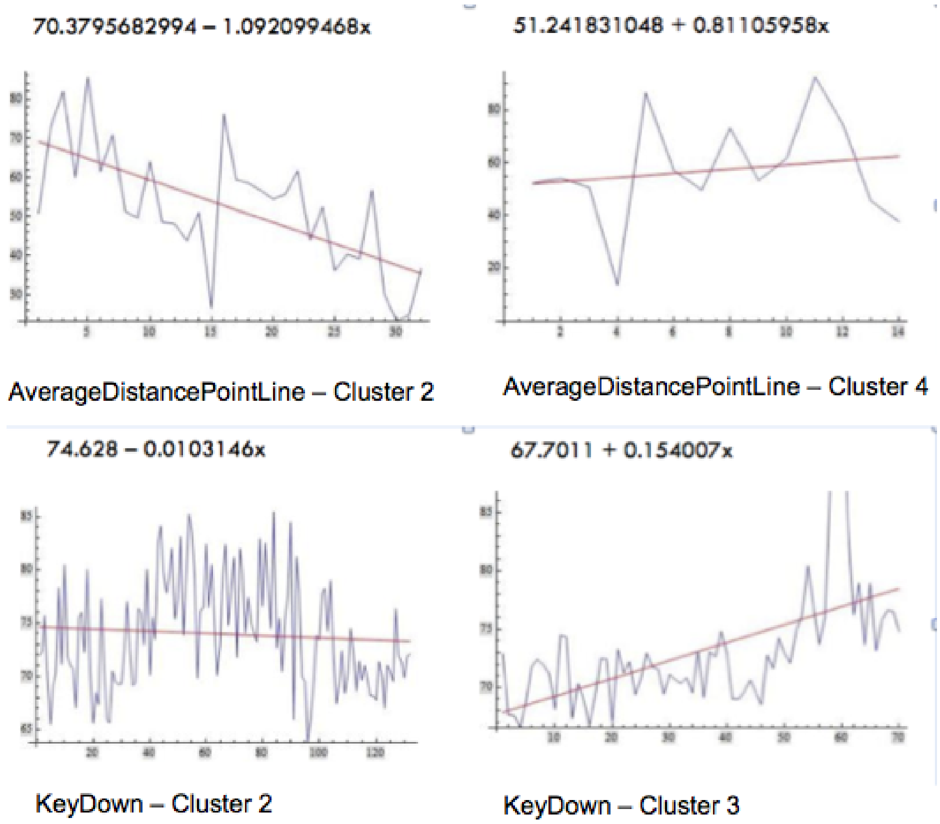


Figure 13: Graph metric of clusters - Participant Davide.

the type of music, the individual's musical profile . Moreover, the subject's objective l at the time (e.g. Does he need to complete a task quickly? Does he prefer to work calmly?), as well as the timespan (e.g. One tends to grow tired of a type of music if one listens to it for prolonged periods of time) should also be included in the future.

To supplement the results obtained, it is also important to note the answers to questionnaires. On observing Andre's responses (Figure 15) and the values of the general performances corresponding to Andre (Figure 14), the following questions were asked:

- a) - What feelings / how do you feel after hearing the songs?
- b) - How did you feel at the beginning of the day?
- c) - Did you like these songs?
- d) - Do you think these songs allowed you to relax?
- e) - Would you rather have done the same activities today, without this kind of music?

User	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Alexis	53.8462	23.0769	15.3846	38.4615	46.1538
Andre	38.4615	46.1538	53.8462	61.5385	69.2308
Angelo	53.8462	23.0769	84.6154	84.6154	61.5385
Claudia	30.7692	23.0769	46.1538	53.8462	46.1538
Davide	46.1538	84.6154	46.1538	38.4615	61.5385
Angelo	50	41.6667	33.3333	50	75
JosePacheco	61.5385	69.2308	53.8462	38.4615	23.0769
Kevin	41.6667	66.6667	33.3333	33.3333	25
Luis	61.5385	30.7692	69.2308	46.1538	61.5385
Ricardo	92.3077	61.5385	30.7692	61.5385	46.1538
VitorNeto	38.4615	38.4615	61.5385	76.9231	30.7692
Dino	38.4615	15.3846	30.7692	69.2308	30.7692

Figure 14: Percentage of features that improved over the day, for each user and each cluster.

- f) - Did hearing these songs affect the achievement of your normal activities?

Through the answers, we observed that when Andre hears music that adversely affects him or makes him more active/stressed (I don't like this music style), his performance is affected negatively. In cluster 1, Andre answered that these songs had jeopardised his work, he felt more active or stressed later than at the beginning of the day and was unable to relax. On analyzing the rest of the responses to the Clusters, we perceived that he had found many of the songs strange (maybe they were not familiar to him), but that he could perceive that the music allowed him to relax, he was feeling calmer (the difference between the subsequent order of the day and the beginning of the day) and obtained the best performances (Cluster 3,4,5). One aspect to notice is in cluster 5, in which Andre felt that the songs he had heard had not allow him to relax, yet he liked them. Additionally, one can see that his performance was not adversely affected. It is difficult for the participant to have a sense of his performance after finishing routine work and what the effects of the music was (subconsciously). As a result, sometimes the questionnaires answered by the participants do not fully correspond to the results.

	a)	b)	c)	d)	e)	f)
Cluster1	7.	4.	2.	1.	9.	7.
Cluster2	6.	4.	6.	6.	4.	3.
Cluster3	4.	5.	4.	6.	5.	4.
Cluster4	4.	5.	3.	6.	6.	7.
Cluster5	5.	6.	5.	4.	4.	3.

Figure 15: Answers from questionnaires at the end of each day - Participant Andre.

4.4 CONCLUSION AND CRITICAL ANALYSIS

Music is reflected in the people through emotions, ranging from fear and anger to happiness and well being. These states are represented in our music repository through the clusters. Emotions can be induced in people, as was demonstrated in this study.

After the preliminary validation of the approach and the main study, which was based on a study conducted regarding the effects of music in related projects, one can say that the results obtained were extremely satisfactory. They helped to comprehend various situations, with the purpose of trying to understand if the person has experienced an evolution of his performance over time in his daily work, if there has been an influence of stress factors on the person or if factors such as music help to improve performance, and so on.

During our daily work, there have been always factors that are potentially stressful, such as time, our boss, work efficiency, amongst many more other factors. One might consider that music can be a way to combat this stress, helping the person to relax in a situation such as a meeting. It was important to realize that there are basically two types of personalities regarding the music factor. From the results,we can see that there are people who hear their favorite music and become relaxed, so that music works as a tranquilizer. It can also work as a stimulant, making the person more lively and can constitute an extra supplement of energy in some situations. Each cluster contains a list of music (style of music) that produced different effects on the participants, from feeling good while hearing the music to general discomfort. We may think that a cluster is comparable to the type of music lists that currently exist, such as the music list which encourages sport or study, amongst so many others. An important aspect observed is that for people who had musical training, the effect of music is not so obvious. This might be due to the fact that they have already heard numerous different styles of music and the brain has already been trained to appreciate or ignore some styles of music.

Overall performance was measured by using a set of calculations with sets of metric values, which may not be the correct path to follow, however, we believe that there is no more correct or more perfect form. Our way of observing performance over time was by calculating the metrics, but some contradictions could emerge. If the user pauses in his work this affects the metric values, which will then be higher or lower (depending on the metric) This will, in turn, affect the overall average of this metric and, consequently, the value for overall performance. Trying to solve this problem in the construction of our system proved to be complicated, but when overall user performance was built, we were able to produce a filter for the inapplicable values (user pauses at work), for example zero values. Another detail that should be seen in future work, is that of attributing more importance to some other metric. If one could assess the type of work the user is doing at the time, then one would be more certain of the performance. For example, if the user is working only with a keyboard (type text), the values for the mouse will be almost zero, which may greatly influence the evaluation of overall performance. Thus, the objective was to remove the metric values for the mouse when a performance evaluation takes place.

Finally, when evaluating the questionnaires, we noticed that it was rather difficult for the user to evaluate themselves. An important aspect that could have been evaluated was whether the user was experiencing an external factor on that day which might have affected his work, and then somehow try to evaluate this aspect when assessing overall performance. Our ideal, is to eventually try to eliminate questionnaires in the future, so that our system will automatically perceive various issues presented in the questionnaires.

The results of this study allowed us to realize various problems, which have already been described One of these was how difficult it can be to evaluate a user's performance, with both an external factor as well as music constituting an additional stress factor. Our recommendation system will be built on the basis of this result and on what we learned from this study. It will, thus, be possible to recommend specific music or styles of music for certain objectives (e.g. a meeting), depending on the person's personality. The recommendation system must be subjected to a period of learning, which will be described in the next chapter.

5

MONITOR AND RECOMMENDATION SYSTEM

Based on the study performed in this dissertation, and in order to try to understand the evolution of user performance in daily work, monitoring is necessary. All monitoring is based on observation and evaluation. The observation of this system in particular is carried out by recording the events caused the mouse and keyboard are handled by a user. These records are associated with the metrics described in the previous chapter. Associated with this observation, the system also has the ability to recommend styles of music based on user goals and performance in real time.

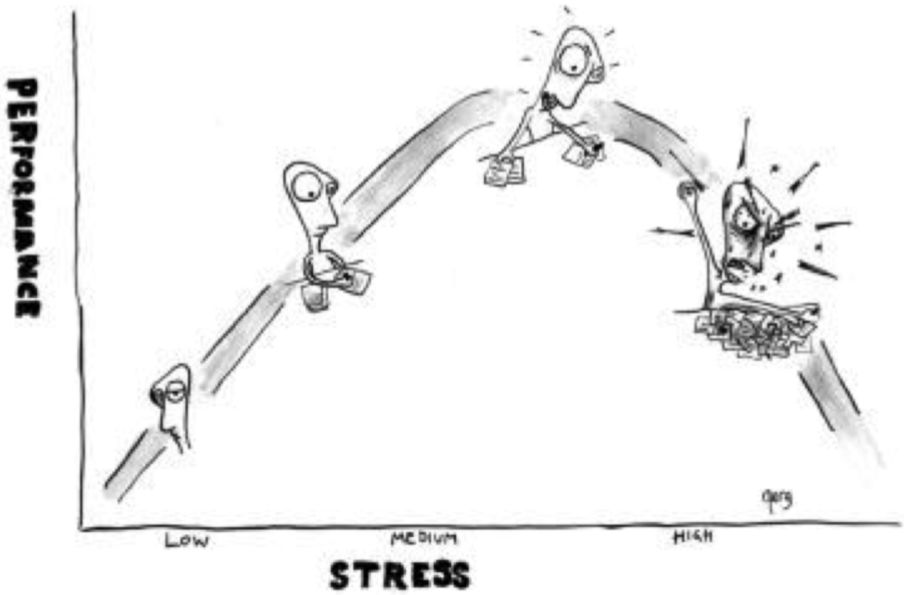


Figure 16: Stress vs Performance.

Over a working day, we are subject to various situations that influence our work rate. These situations can create stress, which influences the performance level of our work. There are users who respond well to stress, increasing their level of performance at work, while others react to stress in an adverse manner, which is harmful to their health. This tool allows the user to be able to evaluate and try to understand if he responds well to stress. He can then ask the system to recommend which music increases his performance or, in situations of stress which music allows him to relax. In this chapter, we will describe the objectives of the system, its architecture as well as how our monitoring and recommendation system was implemented.

5.1 DESCRIPTION

With the help of a service which calculates Metrics through behavioral biometrics, this recommendation and monitoring system has the ability to evaluate the user's performance. The recommendation and monitoring in our system was undertaken through an interface, where each module has one interface. To complete the monitoring of users, a web interface was developed, where it is possible to monitor performance and to observe the music style suggested for each user.

The architecture must respect the following features:

- The historical Performance module, which allows one to view and load previous performances. This information allows the system to create graphs for each metric (e.g.: Keydown) and also updates the historic performances of the user
- The on-line module, where users can see their performances in real time. When compared with the user's previous records, one canz analyse if performance has increased (acting) or decreased. This module still allows the user to hear music from the previously created repository
- The Music Recommendation System module is a simple interface, from which users can choose their current objectives at any moment (e.g.: to be able to relax for a creative task) and the system will recommend music to help with these objectives

5.2 OBJECTIVES

The main objective of this recommendation and monitoring system lies in the monitoring of the user's performance at work and the selection of the most appropriate style of music at a given time. In order for the system to be implemented successfully, the following objectives were set:

- To understand the effects of different kinds of music on the user, while in the workplace, while performing regular tasks or in a similar environment.

- The system will build a personalized model based on data collected from each user.
- Based on models for each user, the system must be able to suggest different types of music for different objectives (e.g. relaxing). Besides assigning an objective, the user can also assign a weight to Performance and Musical Preference. In other words, by placing a higher weight on Performance, this will result in music that will contribute more to the user's activation, despite his preferences. On the other hand, music that is more in line with the user's taste r will be selected, despite less effective results being expected with regard to performance.
- To analyze user performance in a selected environment, and with the objectives defined by the ambient manager, this system recommends a specific style of music (e.g. If there is a scheduled brainstorming session, the manager may decide to put on activating music in order to stimulate ideas and actions).

5.3 ARCHITECTURE

When designing a recommendation and monitoring system, one is confronted by some challenges. One of these is: how the system has collected information from the users and determines their performance over time. Using this information, this system has to be able to recommend a style of music to help improve or tone down the user's performance (relaxing or stressing). There are many important variables that were worked through in order to be able to make recommendations to the user. Indeed, different styles of music for each user may produce different results, for example, listening to rock music is relaxing for some people, while for others it can be stressful. To meet these challenges, the platform was built in a logical and simple way, from the moment of data collection to the recommendation service.

Figure 17 illustrates the architecture used for the platform, where different parts of the platform are connected by a network. On the left side of the figure one represented one user interface, whose data was collected. This interface was developed by investigation carried out by the ISLAB group, whom we integrated in this work. We opted for the development of the client (the computers used by the individuals in the environment) in C# using the KeyboardHook and MouseHook. These libraries allow access to all mouse events on any keyboard where the user performed the same task.

This user interface (C#) connects to the system which we developed in this work. It supplies the user's data in real time (keyboard and mouse) to the system, which contains a server (the

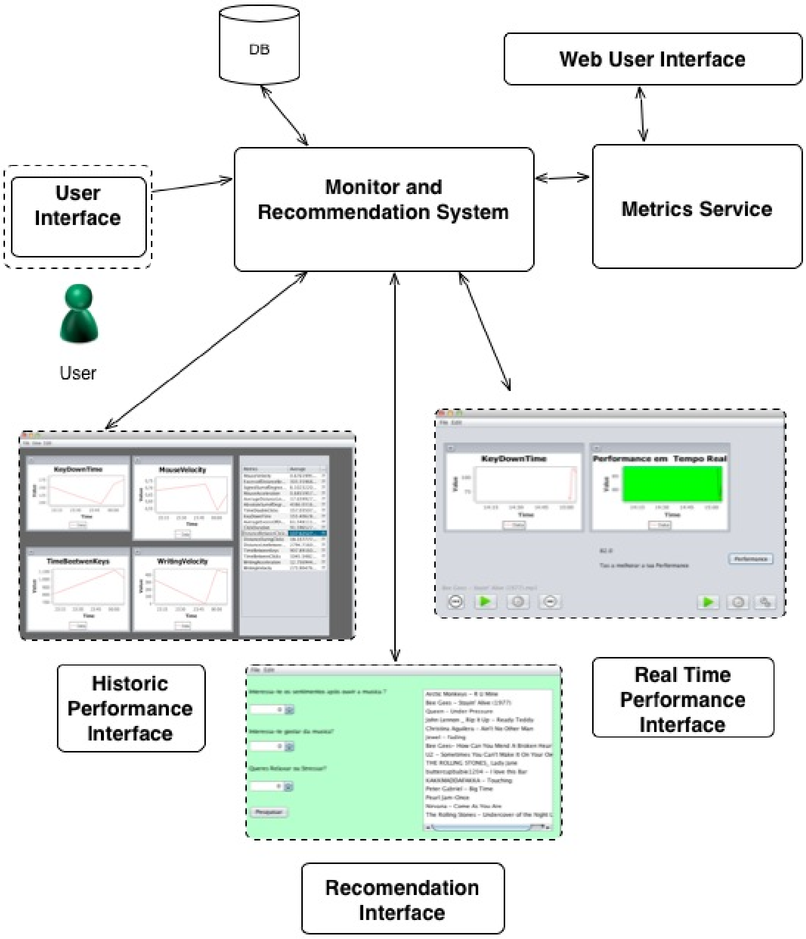


Figure 17: Architecture of the Recommendation and Monitoring System.

central part of the Figure - Monitoring and Recommendation System). Our system stores this information (it is received every x time) and, after receiving it, sends it to another server (Metrics Service) to process. Metrics Service was developed by the investigation of the ISLAB group and is a service that awaits requests from users and can respond or only save/manage the information, it also calculates metrics through behavioral biometrics services. In real time, this Metrics Service processes the data and responds with an object of metrics (averages of the values obtained through the user interface). In real time with the responses obtained at the Metrics Service, our system then stores and manages the data. This data is compared with the user's history , and it is possible to show if this performance increases or decreases, it further generates graphs, where the progress of metrics over time is shown. Our system allows the user to upload his performance and create a record (on offline mode). Data processing is equal to the real time of service.

Our system was also created to enable music recommendation, and to help the user in his objectives (Recommendation Interface). Using a minimalist interface, the users are able to assign their objectives (these can be calm or active), indicating if there are important feelings after listening to the music and if the user has any music preferences. To assist recommendation and link it to this information, an algorithm was created for this purpose, the user's recorded profile is then able to recommend appropriate music/songs from the repository.

Finally, in order for a normal user to see his own performance over time, or so that the user can see the music recommended by the system on any machine or anywhere else, the web interface was developed. It is still possible for an Ambient manager to control the workroom, if there is a scheduled brainstorming session, the manager may decide to put on activating music in order to stimulate ideas and actions. A distributed and accessible system was thus created, and any computer can access our system through the Internet. This web interface communicates with the Metrics service (which can be anywhere), every x time, and keeps updated information. The available and developed interfaces in our system and web interface will be explained further on.

5.3.1 *Communication*

Since information must be shared, all the modules of the system mentioned in the previous sections have to be connected.. In order to monitor a user, it is initially necessary to observe the user and his behavior, and then transform the observed data into useful information for the monitoring context. For this purpose, we built a model based on the client-server, where the client and server are separated by a network. It is important to realize that the Metrics service can be anywhere, and does not need to be on user's computers, the idea is for it to be accessible to any user through the Internet (server). The recommendation system and the user interface are usually on the user's computer (localhost/client), but one can include our system on another computer without the user. For the platform to work correctly, it is essential for the Metrics service and our recommendation system to be running. However, behind this model there is a dependence on Internet connection in order for the monitoring to be able to perform .

As can be seen in Figure 18, the Metrics service, our recommendation system and the user interface, all need to work in real time to begin to collect data. The data collected in the user interface (client) will be encrypted before sending it to the server. Using SSL (Secure Socket Layers), data will be encrypted and then sent to the server. The Data encryption is required for the registration of all user input personal data, so that passwords or other such personal information is protected and kept safe when collected. The communication between the interface and the

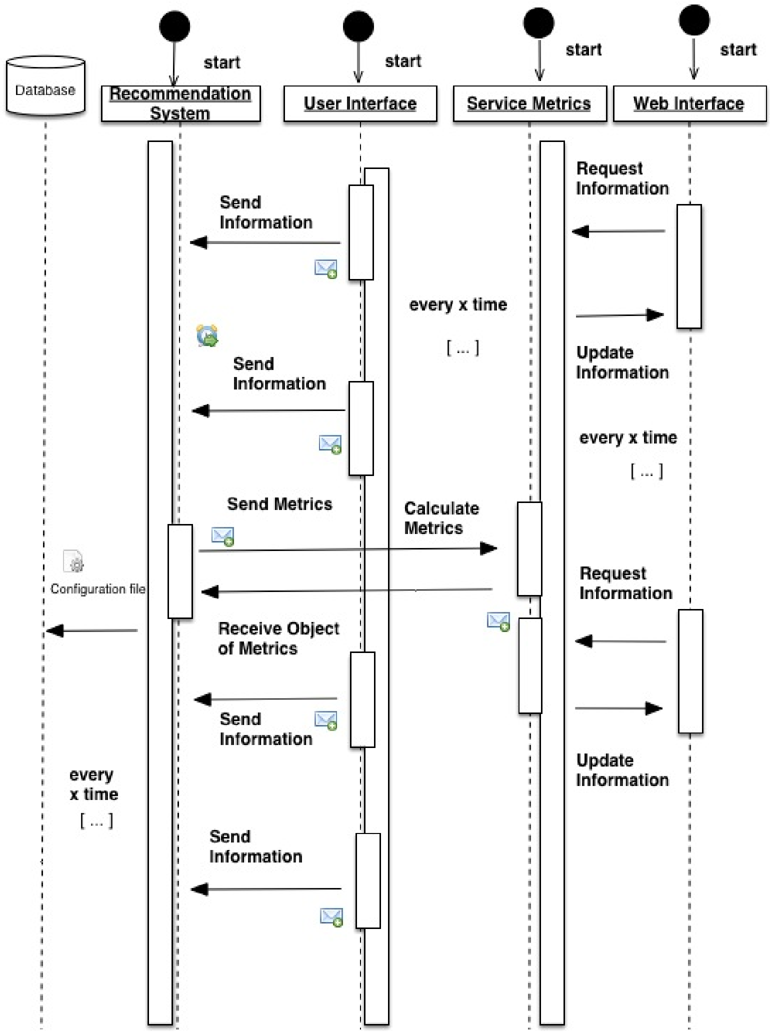


Figure 18: Communication between the plataform modules - Architecture.

Recommendation system is done through Sockets, the simplest, safest and most effective and path of communication between different parts. Our recommendation system was developed in Java, mainly because we developed these aspects in a different programming language. The sending of data between these parties always happens when a new event occurs on the part of the user, for example when touching the mouse or typing on the keyboard.

After receiving this data, our Recommendation system starts at x to x time, sending objects with this data to the Metrics Service. The Metrics Service returns the Metrics Objects with the value processing through biometric services. This communication between the services is carried out by using HTTP Methods. Our Metrics service was developed as RESTful Web services, so that it is always waiting for requests from any entity. In this way, our Metrics Service does not need to be in the same physical location as the users and can be accessed by more than one. This whole process of communication from the interface to the service is performed in real time.

Our recommendation system allows the users to upload their old performances and create their record (Record of Performances). The communication is equal to real time, but one need not be in communication with the user interface. The recommendation system loads the file, cuts the file and saves it into objects. After that, it is sent to the Metrics Service, which stores the responses.

As can also be observed in Figure 18, there is a web interface, which communicates in the same way as the recommendation system communicates with the Metrics Service, by using HTTP Methods. The web interface will make requests for information and will update the page, making it possible to visualize the environment in groups or for one particular user. All communication is undertaken in a simple and accessible manner, it is important to note that both the web interface and the Metrics Service can be accessed from anywhere.

5.4 RECOMMENDATION AND MONITORING SYSTEM

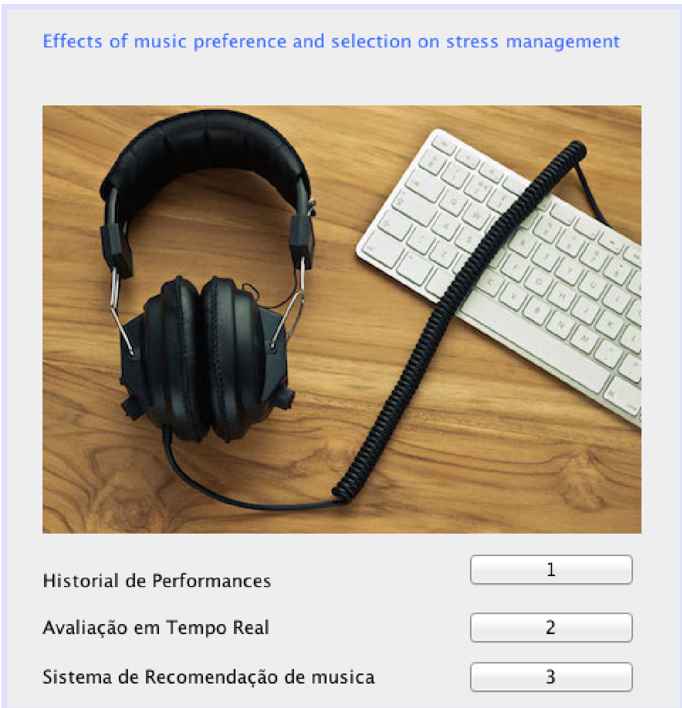


Figure 19: Menu - first interface seen by user.

In order to implement the Recommendation and monitoring system, some decisions were made in terms of the representation of strategic information and information storage (as mentioned in the previous sub- chapters). Our system was designed and built using minimal steps, so that the user has what he wants in a simple, logical and effective way. The system is fast to evaluate the user's performance, when compared to his recorded performance or what kind of music the user must hear to reach certain objectives. Through this simple interface, the user can choose what to do with a simple press of the button. Through this menu shown, users have access to three modules that will be explained in the following sub-chapters, in Figure 19.

5.4.1 *Historic Performance*

For this recommendation system to be able to recommend styles of music to the user and help him to achieve his objectives (e.g to relax), it has to learn more about the user, such as his previous performances, in order to create a record for the user. It is thus essential for the user to perceive, through graphs and other information, if he has had a good performance throughout the day and also try to understand what types of music affected his daily objectives.

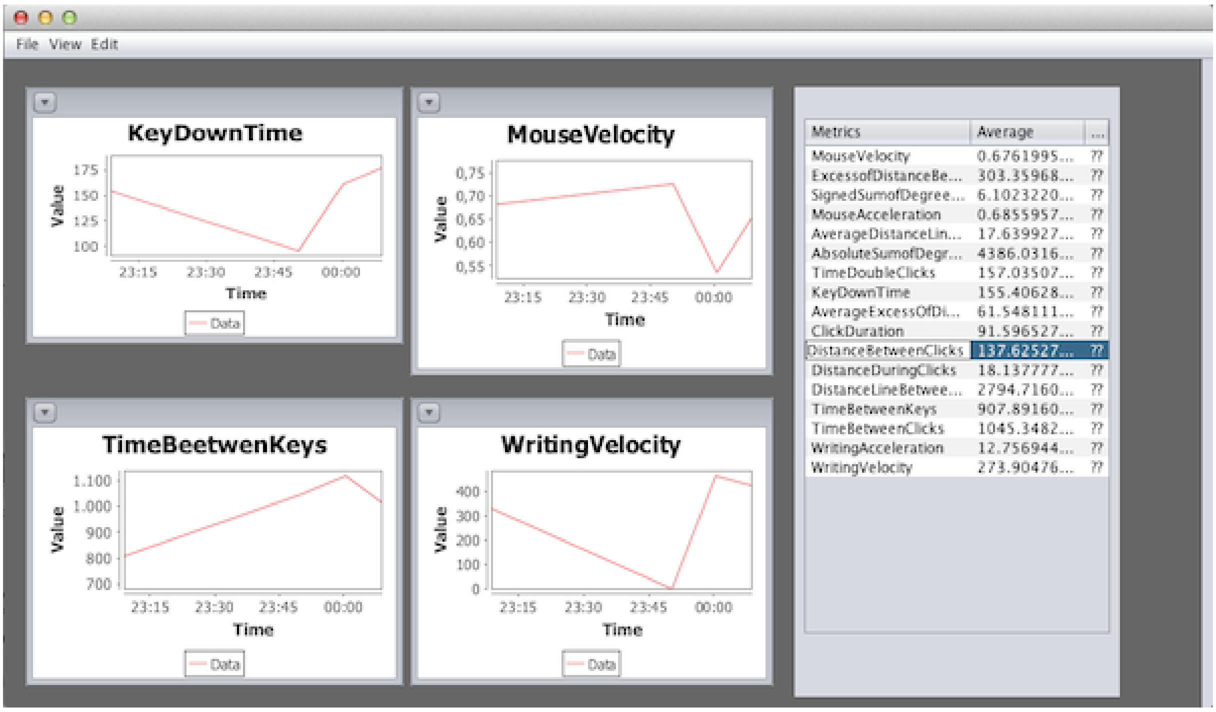


Figure 20: Interface of Registered/Recorded Performance - first option from the Main Menu.

This module has a simple interface, as can be seen in Figure 20, in which a user can view the uploaded information processed by metrics with a few clicks. In the study performed in this dissertation, and through interaction with the computer, users generate data files every day (during the morning or afternoon). These are processed by the Metrics Service, when we get the metrics to observe performance during this work. The system allows the user to upload these files, which will then be processed and stored. The system can create a history of performances and general performance. This overall performance is created by comparing all the performances, in particular the largest and smallest values of each metric. This overall performance will allow for a point of reference, in order to compare data recorded for the user in real time.

To better understand this information simply and quickly, the system creates graphs where the values of the metrics (it increases or decreases) are presented over time. The interface presents four graphs with the records of the most important metrics over time, but also presents a table with the averages of all the metrics. When the user clicks over each metric, he is presented with a graph showing values for that metric over time.

It is important to remember that, when most of the metrics are presented in a line graph, if the line is going up, this does not mean that there is improved performance, such as the case of the Keydown metric. The highest value in Keydown Metric simply means that the user is taking longer to write something. This aspect contributes to a decrease in performance .

This module is important for the creation of each user's history. However, by observing the data (data processed in metrics) from their days of work, users try to make a critical evaluation. Many questions arise, for example, if performance goes up or down during the day, if the user has to have more breaks during working hours, if certain styles of music make the user subconsciously relax or help to improve similar aspects. All the data generated and processed by this module is important for the next module, this will be explained in the following sub-chapter.

5.4.2 *Real Time Performance*

Following on from the explanation of theRecorded Performance module, and what we can expect from this module, such as the overall performance of each user, in this subchapter it is important to explain how the user can observe (in real time) his behaviour and realize if his performance has risen or dropped.

In our daily lives, there are moments of stress and moments to relax. During our work, consciously or subconsciously, we decrease or increase our work rate. Depending on the task to be achieved, we sometimes need to relax (e.g. a meeting) or increase performance. One possible way to achieve these objectives is to listen to certain music that can act as a stimulant or depressant. Through the interface, this module shows the user's performance in real-time during the day. Using this information, the user can then proceed with an analysis, for example, if the method of work is suited to his daily objectives or, for example, if he needs more breaks throughout the day.

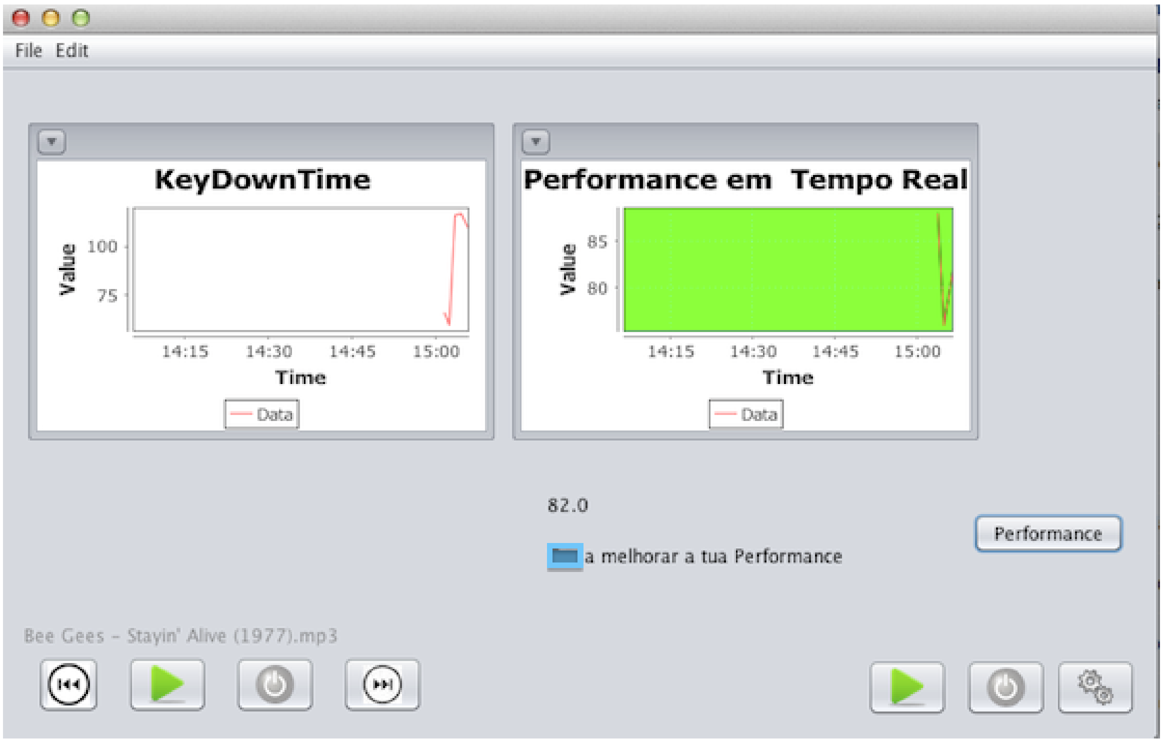


Figure 21: Interface of Real Time Performance - second option from the Main Menu.

When starting this module, a simple and fast interface is visible, and with few clicks one can quickly do what is intended. The interface presents two graphs: the graph on the left presents a metric that the user wants to view, and this graph changes when it receives new values from the user (interface C#). The graph on the right shows the calculated values of the user's performances. This chart will change the values calculated and, whenever the user clicks the performance button or every half hour, the system will update the values of the user's performances.

This module was developed with the intention of running in real time, so that an internal server was created for this purpose. The buttons in the lower right corner of the interface, allow one to start or shut down the server. A server only makes sense if users connect to it, then in this case, we consider that the user is our interface developed in C#, previously referred in this dissertation. Interface C# is a socket which connects to our server. The data received from this interface (user) is stored by our server and sent to the Metrics Service, it is subsequently processed and sent back to our server (identical to the Historic performance process). The user still has a button that allows him to select the type of metric. He can change the graph on the left - by default it displays the values of metric KeyDown - to another type of metric, such as mouse speed.

When the user starts the server, the system asks if he wants to hear the music/song. If the answer is yes, it asks for the user to choose one type of cluster (previously mentioned in this study) from the repository, and then the styles of music he wants to hear. The sets of buttons in the lower left corner of the interface, allow the user to control the music. Its functionality is similar to a classic media player. Each cluster contains music of different styles and each cluster is ranked according to feelings. The recommendation system will suggest different music and types of clusters for each user.

The system must learn about the user and only the stored the data received by the Metrics service is insufficient. The user needs to provide information for the system to know the user's type of personality, what the effects of certain music/songs or some music styles are, from anger to relaxation. For some people, Cluster1 contains music, which produces a calming and relaxing effect, while for others it has the reverse effect. For the five different clusters, and when beginning with the use of this platform, the system recommends that each cluster be heard on different days (5 days), while always doing the same work. When the user has finished his task and stops the system (server), the system shows a quick questionnaire to fill out (if the user has not filled in the questionnaire for that cluster).

The questionnaire that people answered in the study for this dissertation, is presented on this interface, Figure 22. Once has the user filled out the questionnaire, the system stores and processes this information. All this data will be weighed on the recommendation algorithm to suggest music or styles of music. After being saved on the system, the information generated in this module will be crossed with the previously stored information (Historic Performance). This data-crossing will create or update the user's historical performance, as well as the data for each cluster, relating to general performance. These questionnaires are based on the same principle as the questionnaire filled in during the study at the end of each session.

Thus, this real-time monitoring module, together with the Music Recommendation system, creates a powerful tool which has the ability to learn about the user and suggest, depending on the objectives. The next subchapter will explain the music/song recommendation model.

5.4.3 *Recommendation System*

One of the main objectives of this dissertation is to create a structure whose main objective is the selection of the most appropriate style of music at a given time. These recommendations will be based on the user's recorded/historical performance (created in the two modules described above) and the user's music profile, which was built by using the questionnaires during the period of

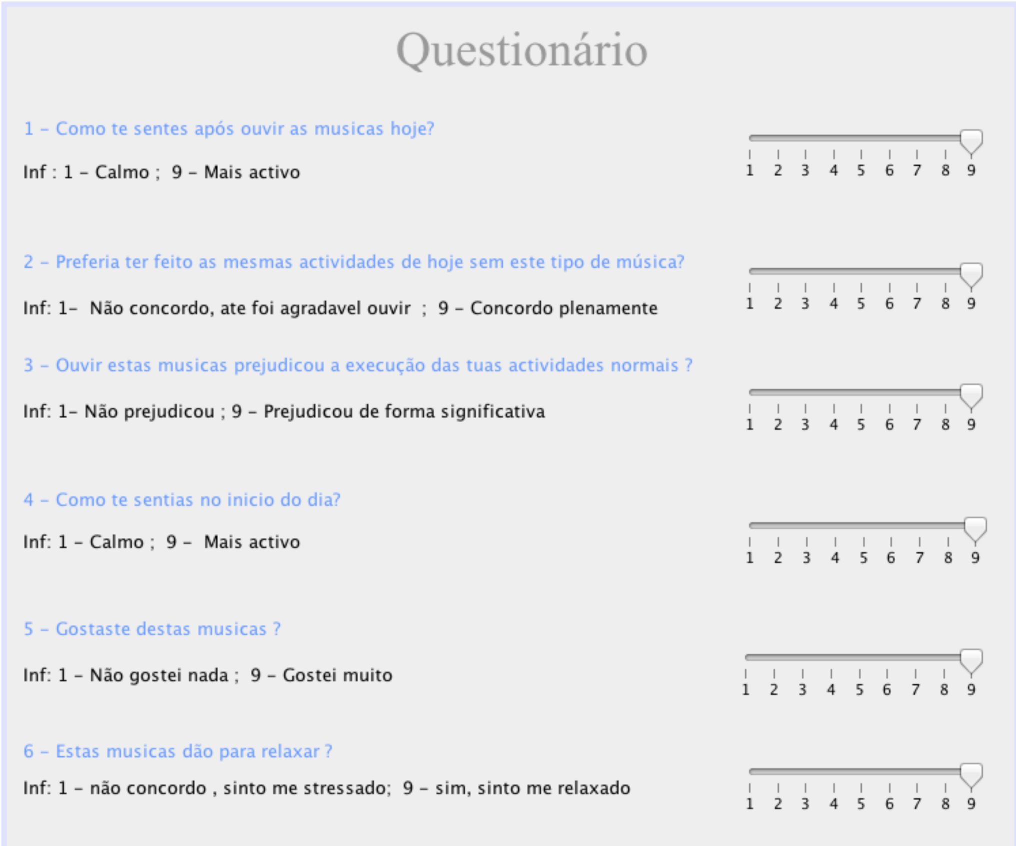


Figure 22: Questionnaires for users to fill out for each cluster.

learning the system. In order to be able to recommend, the system also has to know the user's objectives , for example if on a particular morning, at a specific time or at that very instant, the user wants to relax for some reason. The user can determine his objectives through the interface, Figure 23, simply by assigning the weights in question (0-100) through the algorithm to the system, so that this is able to recommend music.

This Recommendation system has a repository of music, which was created during our study. The repository contains five clusters, each cluster is classified according to the feelings caused by the music. When new music is added to the repository, the system administrator will classify it, providing the music with weights relating to each cluster. For example, cluster 2 is ranked as joyful music and cluster 4 is ranked as being funny music, so that there are similarities between the clusters. If song X belongs to cluster 2, it will have a greater weight in cluster 2, yet, it will also be attributed a great weight in cluster 4, while the other cluster will be given a small or zero weight. This method of classification can be considered a limitation, and possible future

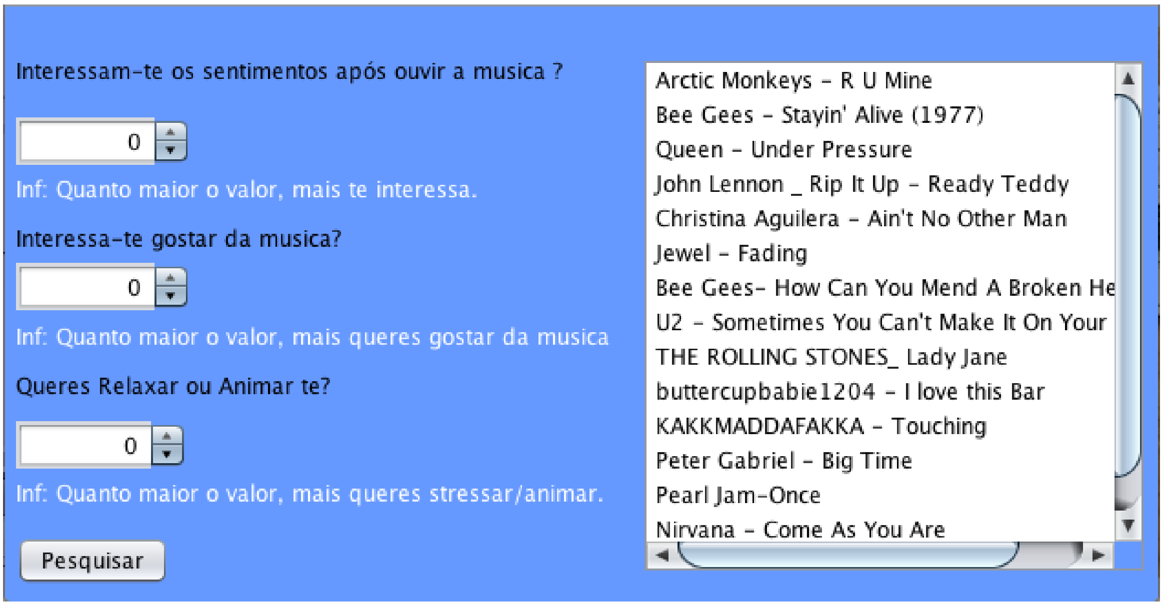


Figure 23: Interface of Recommendation System - third option from the Main Menu.

work will be to solve it. The songs present in the repository were previously classified, as was mentioned in the previous sub-chapter.

After this classification in our repository, the system must learn more details about the user. The questionnaires answered by the user provide di information, which helps to create a user profile. From these profiles, we know how each individual feels about each type of music, how much they like it, how relaxing/ activating they find it or to which extent they would have preferred to have carried out their activities without listening to this particular type of music. As demonstrated in this study, person X can feel relaxed when listening to music from cluster 1, while another person is extremely stressed by this style of music, proving that each person has a different personality in relation to music. Therefore, in order for the system to be able to suggest, it first has to learn what the user profile for that user is.

The recorded/Historic performances, the repository of music, the user profile and the ability of the system to learn over time are all important features, but the system must know what to recommend . To this end, users also provide their current objective by using a minimalist interface. At any moment, the objective can be ‘to relax’ (e.g. when the user is involved in a creative task), ‘to activate’ (e.g. when the user needs to complete a given task quickly) or, regardless of performance issues, simply to listen to their favorite songs . Besides assigning an objective, the user also assigns a weight to Performance and Musical Preference. That is, placing a bigger weight on Performance will result in songs that contribute more to the user’s activation, despite his preferences. On the other hand, songs that are more to the user's taste will be selected, despite less effective results being expected in relation to performance. These variables, as well as the weights assigned by the user, are used by optimization functions to attribute a score to each Cluster, at any moment, normalized in the interval [0,1]. To prevent people from getting tired of constantly listening to the same type of music, songs are then selected from all the five Clusters on a frequency that is proportional to these scores (e.g. if Cluster 1 has twice the score of Cluster 2, songs from Cluster 1 will be selected with twice the probability).

This system also has the capacity to autonomously suggest, for example if the user's performance has declined over time during the afternoon, it then suggests breaks or listening to a preferred style of music to change this state. In future work, it may be possible to adapt the system in order to try to understand other types of user behaviors in relation to stress and performance levels.

5.4.4 *Web Interface*

The modules described above, have the ability of allowing the user to observe his own performance, thus evaluating himself. Taking this into consideration, a web interface was developed at an industrial level. This web interface will communicate with our Metrics Service (which contains the updated user infor- mation) and will collate and provide information about users, such as their performances, the songs suggested, and so on.

It can do so at two different levels: the user-level (in which the system optimizes the musical selection for a given user) and the group-level (in which it does so for a group of people). The process is similar for both cases and the system is a distributed one. Each user interacts with a particular computer, which monitors his performance and the client himself.

In this group-level case, a selection of background music was selected, a similar process was used for the user-level. However, in this case,it is the ambient manager that determines the objective for the environment. If there is a scheduled brainstorming session, the manager may decide to put on activating music in order to stimulate ideas and actions. On the other hand, if the end of the day is approaching, the manager may decide to play more relaxing music as individuals are already tired and listening to activating music in this context may produce negative effects.

In the case of the user-level, if the user has a meeting at the end of the morning and observes, through the system, that his performance has dropped and feels increasingly stressed as a result, then he can determine by using the interface what music he wants to listen to in order to relax. Based on these objectives, the system crosses the data about the user and determines which style

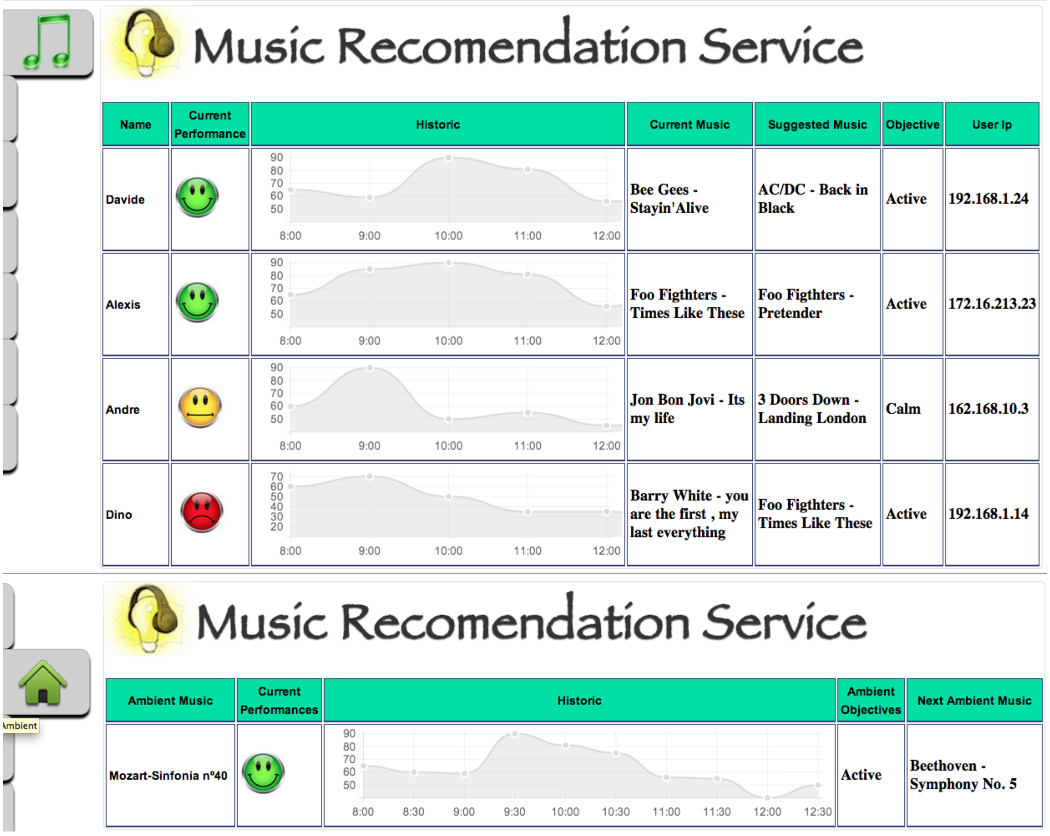


Figure 24: Detail of the interfaces of the Music Recomendation Service for individual users (upper image) and for the group of users (lower image).

of music will produce more relaxation and which he likes best. Through the web interface, the user can observe his performance and suggest songs in any part or device with Internet access. To do so, he will need to log in. .

5.4.5 *Conclusion*

In this chapter, we present the monitoring and recommendation systems on which this study is based. In addition, we describe the model and architecture of functioning, as well as the entire process and its objectives.

This system allows the user to observe his performance over days and carry out self-assessment. For example, it will try to understand if the user worked under too much stress or pressure during that day. Consequently, this system can prove to be very important. It may suggest certain songs or styles of music for the user to relieve pressure (relax) or even for a moment's pause. This system constantly learns and updates the user profile in terms of his performances (recorded/historical) and musical profile.

In future work on this platform, one could develop new techniques to try to understand other of the user's habits, such as pausing during work, so that the system may suggest shorter or longer breaks. The system will allow the user to introduce his music preferences in the repository and, after some sessions, it will automatically analyze the effects of this music on the user (possible elimination of the job of the administrator, which evaluates the new music/song by cluster). Another possible implementation is to create types of users, such as a profile. These profiles could be adapted to the user, such as a profile for meetings, a profile to animate, a profile to relax, and so on. For example, if the user has a meeting in half an hour, the profile changes to meeting, and the system will then recommend music that will produce calmness.

6

CONCLUSIONS AND FUTURE WORK

Stress and Fatigue, and their negative effects, are currently causing growing concern. These effects generate an impact not only at personal or health levels, but also at social (e.g. our reduced time for social and enjoyable activities) and economical ones (companies' costs with absenteeism and reduced productivity are on the rise). Given the current economic scenario, targeting the source of the problem (e.g. decreasing hours of work , imposing more favourable legislation) may not be the most realistic or time-efficient solution. In that sense, alternatives should be sought to minimize these negative effects.

In this dissertation, we looked at the possibility of using music to attenuate the negative effects of stress, fatigue or other negative factors on the individual. Specifically, we analyzed how performance, measured in terms of the interaction between the mouse and keyboard, decreases along the day and how different types of music affect this phenomenon. The aim of creating a music recommendation system based on the user's stress level and the user's performance, through the user's interaction with the computer, was accomplished. Thereby, this work contributed with a new way to solve one of the greatest health and safety challenges that developed countries are facing today. This system allows the user to analyze his potentially unhealthy behaviours for possible personal reflection, it also learns the user's personal musical preferences in order to improve the efficiency of the recommendation mechanism. This work is important in our community in that it obtains more user data in a simple way from various situations, which will improve and customize the ambient of intelligence (section 2.1).

We conclude that the relationship is a complex one, it involves variables other than the type of music, it includes the individual's objective at each moment, as well as his personal preferences regarding music. The collected data in the experimental study was used to define optimization functions that are used to maximize different aspects of this relationship: the selection of the user's favourite songs/music, the selection of the most active music for users or the selection of music that calms them the most. My goals in this work are different when compared to other similar studies. This work was not only about studying stress and music but also about the relationship between them and how they affect one's body. These effects were analyzed through different parameters such as the heartbeat, skin response, temperature, emotions and, most importantly, the interaction between the mouse and keyboard (for the analysis of performance during work).

6.1 SYNTHESIS OF THE WORK UNDERTAKEN

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: In this dissertation study, data was collected of the user's interaction with the computer using the mouse and keyboard. The application was developed for this purpose. This data relates to the user's interaction with the computer during daily tasks, for example in the workplace.
- Data analysis: This data collection can help us understand the effect of music on people and on their lives, more precisely in their work (different styles of music). With the data collected until now, and respecting the timetable set for this work, we can analyze and understand user behavior - if users' performance will decrease or increase over time, how many breaks that user takes (if he needs more breaks or not), if factors such as stress or music affect his work schedule (final questionnaires). We were also able to analyze the data using machine-learning tools in order to build a personalized model for each user.
- Music Recommendation System: Based on the analysis of the data collected, and the users'objectives in some situations, this recommendation system can recommend songs or styles of music to help the user achieve his objective (e.g. motivation). Users can normally use their computer, while the developed solution runs in the background and collects data. Using this data, through the evaluation of the metrics, it can then provide information on current performance (if it increases/decreases/is maintained) in real time.

The work undertaken in this project represents an advance in the field of monitoring user behavior, providing an easy and inexpensive way to detect stress or any factor that affects the user and his capacity through a recommendation to change the user's mood (behaviour/feelings). This solution is also an interesting approach as it does not require the use of very complex, expensive and intrusive systems.

6.2 RELEVANT WORK

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

Part of the work presented in this dissertation was documented in the following publication, having been presented at the 8th International Symposium on Intelligent Distributed Computing.

da Costa, M., Carneiro, D., Dias, M., & Novais, P. (2015). How Musical Selection Impacts the Performance of the Interaction with the Computer. In Intelligent Distributed Computing VIII, Studies in Computational Intelligence, Volume 570, pp. 19-28. Springer International Publishing. [9].

6.3 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.

In future work, we will address this problem in more detail, namely by including additional variables that can better shape the relationship between music, performance and fatigue and by analysing different music classification mechanisms. This should be interesting, in order to prove in a more conventional way that users can be affected by music, and that more sensors can be used to measure vital signs intrusively . These sensors could interact with this system, such as a mobile phone, which can already measure the heart beat without the user realizing it. Perhaps new metrics and parameters could be studied, thus allowing for a more perfect detection of stress.

Finally, the study of advances in technologies, which occur continuously, as well as the possible advantages that they could provide to this project should also be carried out.

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Parecer sobre Relatório de pré-dissertação

Dino Mickael Ribeiro da Costa

Fevereiro de 2014

Na qualidade de orientadores, do projeto de dissertação de mestrado de Engenharia Informática, com o tema "Effects of music preference and selection on stress management" a realizar pelo Dino Mickael Ribeiro da Costa no ano letivo 2013/14, atestamos a conformidade do relatório com o plano de trabalhos.

5/2/2014