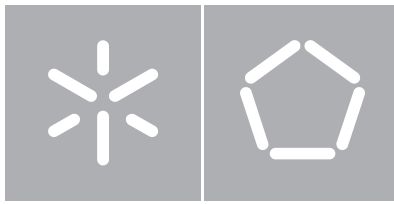


Universidade do Minho

Escola de Engenharia

Alexis David Oliveira Rodrigues

Video Games: Recommendation system to handle fatigue



Universidade do Minho

Escola de Engenharia

Departamento de Informática

Alexis David Oliveira Rodrigues

Video Games: Recommendation system to handle fatigue

Dissertação de Mestrado

Mestrado em Engenharia Informática

Trabalho realizado sob orientação de

Professor Paulo Novais

The reproduction of this thesis integral only for research purposes by written declaration of the person concerned, that such commits.

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



DEDICATION

This thesis is dedicated to my dad Francisco Rodrigues, no longer with us, for his love, endless support and all the sacrifices he made.

"We can only be said to be alive in those moments when our hearts are conscious of our treasures." Thornton Wilder

ACKNOWLEDGEMENTS

I want to thanks all who contributed to make it possible to perform this exciting work. In particular:

To my supervisor, Professor Paulo Novais, for all the guidance, attention, advices and support given throughout this work.

To the members of ISLab, Dino and André for the help and support, and especially to Davide Carneiro who through his experience led me in the most critical moments.

To my closest friends for all the encouragement, conversations and exchanges of ideas that helped to enrich this work.

To my girlfriend Soraia for all the help, support and inspiration that led me to overcome the most difficult phases and move forward in this work.

Finally, my family and specifically my parents Amelia Oliveira and Francisco Rodrigues for encouragment and constant support throughout this work and to whom I owe everything.

ABSTRACT

The quality of life in our modern society is a topic of great interest to the community in general. There are countless negative factors that disturb the well-being of people and one of the most common focuses on how much stress and fatigue affects people in their daily tasks. This work will focus on the importance that video games currently have in the life of a large number of people designated by Gamers whom usually spend several hours in virtual worlds, often violent, with the aim of study the effects of gaming on their behaviour. There are numerous studies related with the effect of video games in the society and the majority of them use intrusive methods to collect the resulting data. Those studies are expensive and difficult to realize but most importantly the use of intrusive methods can influence the behaviour of the player during the study. This new approach proposes to perform an analysis of the players' interaction with a computer using the keyboard and the mouse as sensors, in order to obtain relevant conclusions about the effects of a video game on the individual. The hypothesis presented here is interesting due to the use of non-intrusive techniques to retrieve data as well as the use of common and inexpensive hardware instead of specific and expensive one. The knowledge gained has allowed the creation of a recommendation system for players capable of monitoring the human-computer interaction in real time, informing the user whenever a decrease in performance is detected due to the accumulated fatigue or stress induced by an over exposure to the video game. Video games have dominated the entertainment industry so it is important to create tools that protect players from negative exposure as a result from excess playing time.

RESUMO

Na sociedade moderna em que hoje vivemos, a qualidade de vida é um tópico de bastante interesse para a comunidade em geral. O bem-estar da população pode ser perturbado por inúmeros factores, sendo que um dos mais comuns foca-se no quanto o stress e a fadiga afectam a vida diária das pessoas. Este trabalho focar-se-á na importância que os vídeo jogos actualmente têm na vida de um grupo específico de pessoas, designados Jogadores, que usualmente passam várias horas do seu dia no mundo virtual, por vezes violento. O objectivo é estudar as consequências que o acto de jogar poderá ter no comportamento dos referidos jogadores. O efeito dos vídeo jogos na sociedade é um assunto largamente discutido pela comunidade científica, sendo que a maioria destes estudos utiliza métodos experimentais intrusivos para a recolha de dados. Para além de dispendiosos e de difícil realização, estudos envolvendo métodos experimentais intrusivos podem influenciar o comportamento do jogador durante a execução do mesmo. O presente trabalho propõe uma nova abordagem na análise da interação dos jogadores com o computador usando o teclado e o rato como sensores, de modo a obter conclusões relevantes sobre os efeitos dos vídeo jogos nas pessoas. A hipótese aqui presente é muito interessante devido ao uso de técnicas não invasivas na recolha dos dados, assim como no uso de hardware comum e barato. O conhecimento até então obtido permitiu a criação de um sistema de recomendação para os jogadores, o qual é capaz de monitorizar em tempo real a interação humano-computador, informando o usuário sempre que um decréscimo da performance é detectado devido à acumulação da fadiga e do stress induzidos pela exposição a vídeo jogos. Uma vez que a indústria de entretenimento tem vindo a ser dominada pelos vídeo jogos, é de importância fulcral criar ferramentas que protejam os jogadores dos possíveis efeitos negativos que a exposição prolongada ao jogo poderá causar.

GLOSSARY

AmI	Ambient Intelligence
AAL	Ambient Assisted Living
AI	Artificial Intelligence
CAMCoF	Context-aware Multimodal Communication Framework
CS	Counter-Strike
FPS	First Person Shooter
ISLab	Intelligent Systems Laboratory
IST	Information Society Technology
ISTAG	IST Advisory Group
UM	University of Minho
SSL	Secure Sockets Layers
VE	Virtual Environment

CONTENTS

Contents	iv
1 INTRODUCTION	1
1.1 Motivation	1
1.2 Scope of the dissertation	2
1.3 ISLab project	2
1.4 Objectives	3
1.5 Work methodology / research	4
1.6 Structure of the document	4
2 AMBIENT INTELLIGENCE	6
2.1 What is Ambient Intelligence?	6
2.2 Ambient Intelligence architecture	9
2.3 Ambient Assisted Living	10
2.4 Are we there yet?	12
3 VIDEO GAMES	14
3.1 Evolution of Video Games	16
3.2 Video Games: Negative aspects	18
3.2.1 Fatigue	19
3.2.2 Stress	21
3.3 Video Games: Positive aspects	22
3.4 Related Work	24
3.5 Analysis of the related work	26
4 DATA COLLECTION	27
4.1 Study Objectives	27
4.2 Study Design	28
4.2.1 Interaction Patterns	29
4.3 Selected video game - Counter-Strike	32
4.4 Research Population	33
4.5 Methodology	34
4.6 Data Management and Statistical Analysis	35

Contents

4.7	Study Results	35
5	RECOMMENDATION SYSTEM	41
5.1	System Description	42
5.2	Objectives	43
5.3	Architecture	43
5.3.1	Data collection Interface	45
5.3.2	Main interface	45
5.3.3	Metric Service	46
5.3.4	Communication	46
5.4	System Modes	47
5.4.1	Historical Performance Interface	47
5.4.2	Real-time monitoring interface	48
6	CONCLUSION	50
6.1	Synthesis of the work done	51
6.2	Future Work	52

LIST OF FIGURES

Figure 1	Ambient Intelligence.	7
Figure 2	General Architecture of an Aml system.	9
Figure 3	Life expectancy.	10
Figure 4	Home care system domain.	11
Figure 5	Video games platform.	15
Figure 6	Frequency of gaming (Europe).	16
Figure 7	Ambient Intelligence.	21
Figure 8	Data collecting process.	28
Figure 9	Terrorist planting a bomb.	33
Figure 10	Study result (players percentage).	36
Figure 11	Feature rating system.	36
Figure 12	Feature result chart.	37
Figure 13	Percentage of increasing performance for each feature.	38
Figure 14	Comparison of features.	39
Figure 15	Architecture of the Recommendation System.	44
Figure 16	Data Collection Interface.	45
Figure 17	Historical Performance interface.	48
Figure 18	Real Time monitoring interface.	49

LIST OF EQUATIONS

1	Distance travelled by the mouse.	30
2	Average distance of the mouse to the straight line.	31
3	Signed sum of angles.	32
4	Absolute sum of angles.	32

INTRODUCTION

People are exposed every day to a variety of negative factors affecting them physically and psychologically, in short or medium term. In order to escape and release the daily stress, video games have become an integral part for many people's life in modern society, who use them to get distracted from real world and have fun, being a very actual theme with great interest to the eyes of society since the effect of video games on Gamers behaviour generates a great debate in scientific community.

1.1 MOTIVATION

Video games have brought new experiences to the public, allowing people to find new sensations in the virtual world which would not be possible to get in real life. The success achieved and the steady growth of this market originated a social division due to ethical factors. Currently, there is a negative point of view of the influence of games on players. Video games are seen by the majority as the reason for school failure, increasing aggressive behaviour in young players and causing social isolation [3]. However, there are those who argue that a more balanced perspective is needed, one that considers not only negative effects but also the benefits of playing. In fact, video games also have a very positive contribution. During the last decade they have become increasingly complex, diverse, realistic and social in nature. Different studies in the last five years showed that video games have a good influence in diverse areas as health, education, knowledge, culture, creativity and capacity for social interaction among players [18]. Nowadays in the United States 91% of children between the age of 2 and 17 play video games and 98% of young adult have already played at least once video games [29]. Those numbers are representative of the importance that video games have currently in the modern society. Compared with the cinematic industry, video games in the United State alone (2010) have billed more than twice the revenue of the cinematic industry (24 billion for the video games against 10.8 billion for the

1.2. Scope of the dissertation

cinematic industry) [42]. The money generated by video games increases year after year with the appearance of more complex and more realistic games, attracting more players every year. Still, effects of video games do not meet a consensus within the scientific community. To better understand the effects of playing in the behaviour of the gamers, this work propose a system to analyse player's performance using the data collected representing player's interaction with computer using mouse and keyboard, common and non-invasive devices, in order to achieve the objective. A question emerge: how to convince the gamer that he should stop playing and rest when he is probably not feeling the effects of fatigue or merely ignoring them? Clearly it is not possible to force the gamer to stop playing but the recommendation system will advise him, giving him the statistics during the gameplay time. This way the gamer will be notified when there is a decrease in his performance indicating fatigue in order to avoid an overexposure to the game.

1.2 SCOPE OF THE DISSERTATION

This work proposes to create a recommendation system based in the interaction of the player with a computer using the mouse and the keyboard in order to obtain relevant conclusions about the effects of fatigue and stress during the gameplay time. The hypothesis presented here is interesting due to the use of non-invasive techniques to retrieve data as well as the use of common and inexpensive hardware instead of specific and expensive one. This research took as a starting point the work already developed by the research group (ISLAB) in which this project is inserted. Initially, a collection of data about players' interaction with the computer have been made using the mouse and the keyboard. This collection was possible due to the development of an application to monitor the user's interaction with the computer. From the mouse, data such as velocity or acceleration, number of clicks and click precision was collected. On the other hand, from the keyboard it was collected data such as key pressure time or key usage statistics. After its collection, data have been analyzed using different statistical and data-mining techniques in order to identify different patterns of player's interaction with computer

1.3 ISLAB PROJECT

The work presented in this document is integrated in project CAMCoF - Context-aware Multimodal Communication Framework [9], being developed at the Intelligent Systems Laboratory (ISLab) at the University of Minho (UM). The main objective of this project is to develop a

1.4. Objectives

framework to model the users' context, focusing on stress, and to provide this information to a Virtual Environment (VE) so that richer communication processes can be developed. These communication processes will allow users to communicate in ways that are closer to face-to-face communication. Framework will be non-intrusive in order to facilitate more accurate and frequent monitoring. So, the estimation of stress will be based on transparent analysis of users' behaviour and interaction patterns. The proposal of this project is supported by previous work in which a group of ISLab members successfully measured changes in a non-intrusive way using motion detection and smartphones equipped with basic sensors. From this hardware, they were able to extract features such as touch patterns, touch duration, touch intensity, and touch accuracy, acceleration on the handheld device, amount of movement and a measure of cognitive performance. During preliminary tests, nearly 20 volunteers (students and teachers from the university) were requested to play a game that required them to perform mental calculations in a calm state and in a stressed state. In average, each participant showed significant differences in half of the parameters studied when comparing calm and stressed measurements. Sustained by the preliminary results, the group now aims to acquire more appropriate and precise sensors that will allow them to develop a more accurate framework for modeling stress. This approach will provide meaningful context information to the users of a VE in the form of simple emotional avatars that can complement what is being said using non-verbal information. It will result in more efficient communication processes that will more accurately resemble the context richness of face-to-face communication.

1.4 OBJECTIVES

The main goal of this work is to evaluate how much fatigue induced by video games can affect players' behaviour during gaming time, giving recommendations to the player to stop if his performance decrease due to fatigue. In order to achieve this goal, players' interaction with computer was analysed by recording the movements during playing time, using the input peripherals (mouse and keyboard). The result produce a system capable to inform the player to avoid potentially unhealthy behaviours for a possible personal reflexion in order to improve their quality of life. The objectives for this dissertation are:

- Analysis of state of the art in what concerns the relation between video games, stress and fatigue;
- Definition of a dynamic system to classify player's fatigue level;

1.5. Work methodology / research

- Conduct a study to understand the effects of playing a violent video game during a long time. This task will be conducted in the Intelligent Systems Lab;
- Use the machine learning tools on data collected in the task described above in order to build a personalized model for each user;
- Develop a recommendation system based on this model;

1.5 WORK METHODOLOGY / RESEARCH

To accomplish the objectives enumerated before the Action-Research methodology was followed. This methodology starts by identifying the problem so that a hypothesis can be formulated 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 make its conclusions based on the results obtained during the investigation. For this research model to be followed, six complementary stages have been defined to achieve the planned objectives. The stages defined are described ahead:

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

1.6 STRUCTURE OF THE DOCUMENT

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

1.6. Structure of the document

Chapter 2 starts with a definition of Ambient intelligence, of its architecture and principal characteristics followed by a discussion about the concept of Ambient Assisted Living and the role of ambient intelligence in the future.

Chapter 3 will be dedicated to Video games describing the concept and the history behind this recent phenomenon as well as their evolution since their appearance. The Positive and Negative aspect of video games will also be discussed in this chapter with a special attention to the definition of fatigue and stress which are part of the focus of this work. Later in this chapter are presented and analyzed a few related projects.

Chapter 4 describes the process of data collection. This chapter starts with a description of the study made presenting the study objectives and design as well as the interaction pattern extracted from user's interaction logs. The study methodology and results are discussed at the end of the chapter.

On chapter 5, the Recommendation System is described. This chapter presents the way the system was build describing the different modules that compose the system and how they communicate with each other. Finally, on chapter 6 some conclusions about the project are presented as well as the relevant work developed during the development of this project and some work that could be done in the future to improve the project.

AMBIENT INTELLIGENCE

We believe that in a recent future people will be living easily in digital environments in which the electronics are sensitive to people's needs, personalized to their requirements, anticipatory of their behaviour and responsive to their presence. This concept is called Ambient Intelligence (Aml).

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, being sensitive, adaptive and responsive to our needs. The concept was introduced by the IST Advisory Group (ISTAG), being a new paradigm born thanks to three new key technologies Ubiquitous Computing, Ubiquitous Communication and Intelligent User Interfaces, which is starting to change the way we see computers. Aml is comparable to a computer with multiple other tools (for example another computer), where this tools communicate between them, with ability to automatically adapt for daily tasks and activities users. Computers in intelligent environments are learning what we like, what we do, our habits and our preferences so they can simplify our lives [4].

The ideal intelligent environment should appear a perfectly normal environment, embedding its components in common devices, noticeable only by its actions. An ambient intelligent must have as key feature [1]:

- Embedded - many networked devices are integrated into the environment;
- Context aware - the system can recognize us and our situational context;
- Personalized - the system can tailor itself to meet our needs;
- Adaptive - it can change in response to us;

2.1. What is Ambient Intelligence?

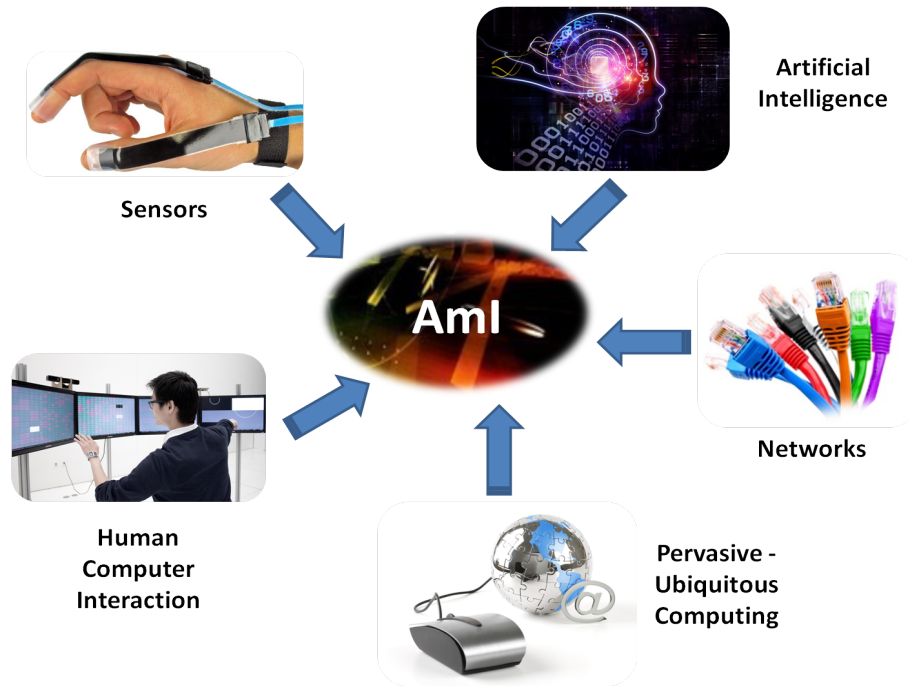


Figure 1: Ambient Intelligence.

- Anticipatory - the system anticipates our desires without conscious mediation;

Inside the environment exists devices, those devices are very common like our mobile phone, air conditioning systems, laptops, media servers, PDA's, etc. All of those 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 each components have functions and together, their job is ensure people's well-being and safety the most discreet way possible.

Kevin Brooks [8] refers the importance for AmI of the "5W's" (Who, Where, What, When and Why) principle of design:

- **Who** : Identify who will use the system and their role within the system in relation with other users. It is important that the system can be able to differentiate elements like pets, robots or other objects with interest;
- **Where**: Location where a user or an object is geographically located at each moment during the system operation;
- **When**: be able to associate activities with time is required to build a realistic picture of a system's dynamic. It consists of identifying the routines of the users to determine when a change occurs, which is fundamental to the understand how an environment is evolving;

2.1. What is Ambient Intelligence?

- What: be able to recognize users activities and tasks in order to provide appropriate help if required. The great variety of possible scenarios that can follow an action makes this very difficult;
- Why: be able to understand intentions and goals behind the users actions is one of the hardest challenges in the area, the system should anticipate needs and serve users in a sensible way.

AmI environments may be so diverse that the possibilities for this type of environments are countless [4], we already referenced the possibility to be omnipresent in our lives, more particularly in our homes, watching our well-being, protecting them from external attacks, accidents and even reducing energy costs avoiding possible wastes. But also in our offices, meetings, schools, hospitals, control centers, transports, touristic attractions, stores, sport installations, music devices, etc.

The introduction of this type of global intelligent systems can help us solve current problems with no feasible solutions in the near future. Two examples are recurrent when intelligent environments are associated with the possibility of saving human lives. Health-related applications are probably one of the social areas' that could benefit more with AmI, healthcare cost are rising [11] and a better resource management is necessary to improve treatments quality. In scenarios of control a patient should recover at home rather than being at the hospital. In the majority of cases, admissions are inserted only for the purpose of monitoring the evolution of the clinical status of the patient even if they are not in danger. This type of monitoring could be done at home by an intelligent system capable to analyse the patient status and notify his physician of its evolution. Philips [1] is one of the pioneers in this field of business research also aimed at establishing more intelligent friendly environment for children who are undergoing treatment in hospitals.

Another problematic area that could benefit from AMI is the progressive aging of the population. Increasingly older people are isolated and have no one to assist them. Some of these people have made the choice to keep their independence, others because they have no one to turn to, but in both cases there is a need to reduce their vulnerability to accidents. Smart environments can be the first line of human assistance and protection in the future filling the gaps in our current system with a better resource management in medical services in order to improve care services and to continuously monitoring people considered at risk and needing to be watched.

For an AmI to be able to do its job efficiently it needs to be sensitive, intelligent and proactive. To show these characteristics, it makes use of several important fields in Computer Science, being

2.2. Ambient Intelligence architecture

the most notorious: Artificial Intelligence, Human Computer Interaction, Sensors, Networks and Ubiquitous Computing (Figure 1).

2.2 AMBIENT INTELLIGENCE ARCHITECTURE

To support the level of services described in the previous topic, an AmI must have a efficient system flow. An AmI can be build from many different ways but there is still some important bases that every system of this kind should have to be successful [4]. Their primary job is to ensure user's well being. To achieve this goal they need to recognize user's needs, preferences and routines. Typically it needs sensors and devices to surround the users with a technological bubble able to observe and collect every piece of information that can be useful. Sensors can provide accurate data to the system on different contexts and transmit it using a network to a middleware layer. As we already know, many different devices and sensors compose the system and each one of them have a different kind of output that needs to be homogenized by the middleware layer, which is responsible for the connection between the environment layer and the decision making layer process.

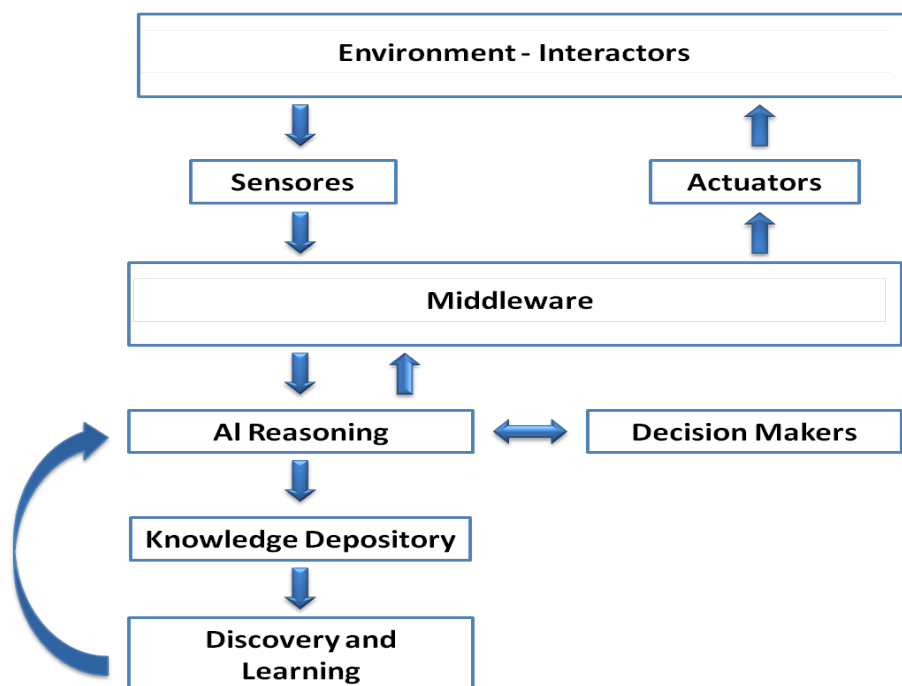


Figure 2: General Architecture of an AmI system.

2.3. Ambient Assisted Living

After the pre-process of the data, the Decision-making process starts. This process is probably the most delicate and challenging. At this point data have been homogenized and can be processed by the artificial intelligence of the system in order to make a decision. During this process the system save all the information into a knowledge deposit, the greater the amount of information in the deposit, the higher the capacity of the system to take proper decisions. Using the information stored in the deposit, scenario is analysed and learned allowing the AI Reasoning to make the decision based on the results. Then, once again, the middleware layer is used as a connection to convert the decision into actions using the actuator to interact with the ambient. This process can be observed in figure 2.

2.3 AMBIENT ASSISTED LIVING

With growing global population, most industrialized countries tend to have more and more elderly people and single households, leading to dramatic effects on a resource limited public and private health care. Better medical care and more effective drugs are two major causes in Humans' longevity growth, being the main purpose to find out an efficient solution to help these elderly people live independently.

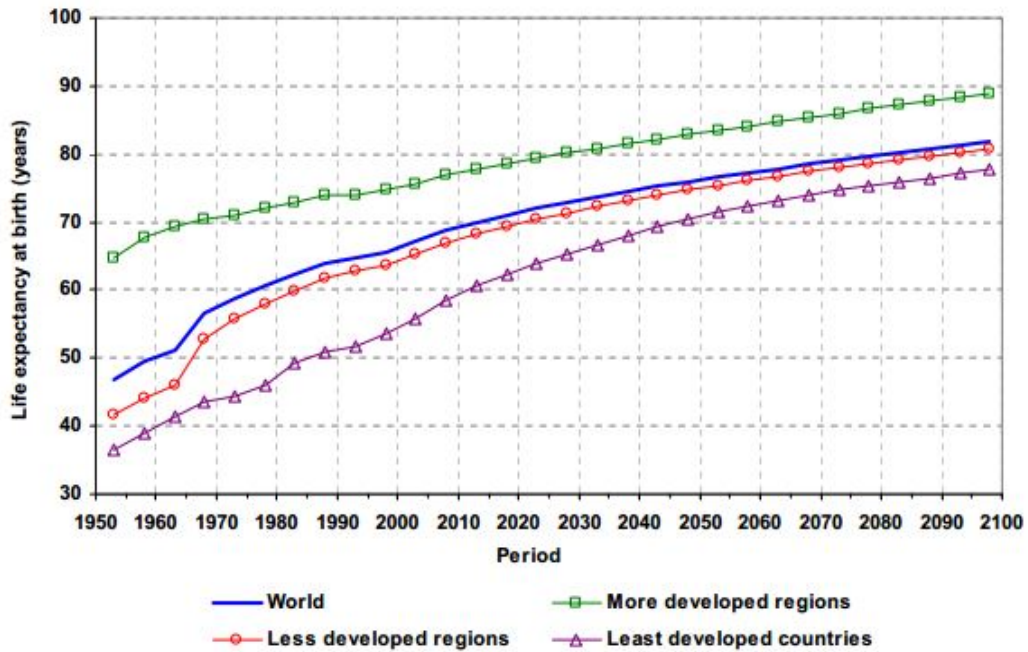


Figure 3: Life expectancy at birth for the world and development groups, 1950-2100. [35]

2.3. Ambient Assisted Living

As we can observe in figure 3 life expectancy is growing. Knowing that most of the health care resources are used for older patients, it is expected an increase of the costs of those treatments or worse, a decrease of the treatment quality. For this particularly reason, it is important to find a way that could help elderly people without compromising the quality of service. The majority of elderly people would prefer to live in their own home rather than in nursing houses. To make this possible, they need some kind of support to help them remain independent at their homes. Since it has been proved that remote clinical therapy will not bring negative effects for the healing process, Ambient Assisted Living (AAL) could be the perfect alternative to the occupation of hospital beds by those who are not at risk. Assisted Living solutions for elderly people using ambient intelligence technology, can help, by providing a context aware proactive assistance to sustain the autonomy of the elderly, in limiting the increasing costs while concurrently providing advantages for the limited people by increasing life quality. The goal is to enable elderly people to live longer in their favorite environment, to enhance the quality of their lives and to reduce costs for society and public health systems [26][44] the greatest advantages of all the stuff we have is that i am here, being recorded for the prosperity hell yeah.

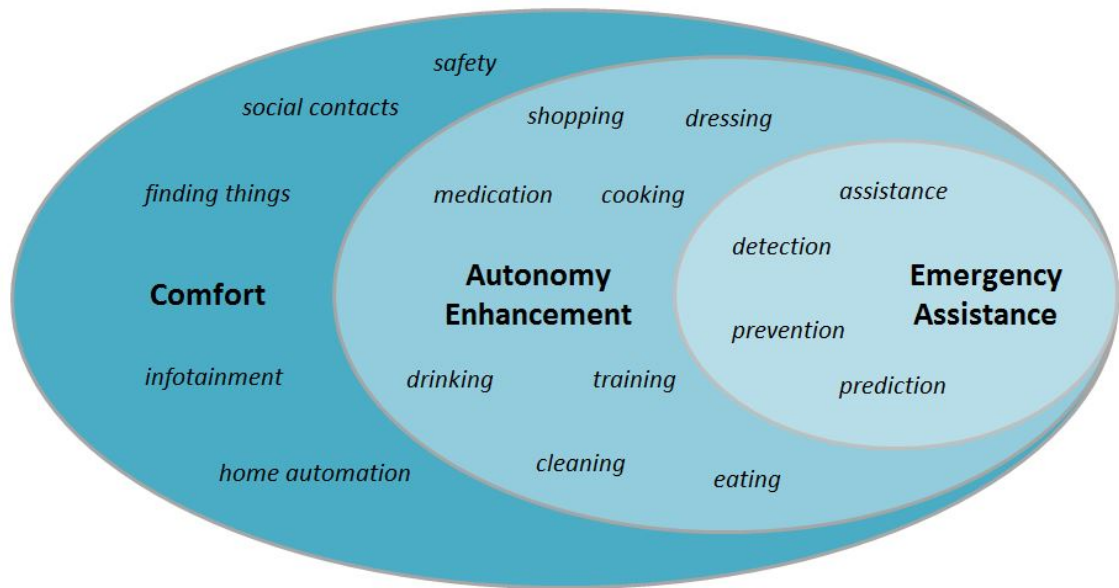


Figure 4: Home care system domain.

AAL is a sub-field of AmI focused on supporting proximity with the aim of increasing autonomy and independence of limited persons. Figure 4 illustrates the domain of a living assistance, called Home Care System, focused on the support of people with special needs that can be defined by emergency assistance services, autonomy enhancement and comfort [5]. An AAL

2.4. Are we there yet?

allows the creation of a bubble of security that can protect the user without him being confined, for example, in a hospital or in a nursing home. This factor ensures greater normality in patients' lives, improving their confidence and well-being. The advantages of these intelligent systems are huge, since they provide safety and comfort to people that, on contrary, would never have access to a quick assistance.

2.4 ARE WE THERE YET?

As previously demonstrated, the use of smart environments in our day to day would bring huge benefits for users in a general point of view. Imagine a system capable to do whatever we want, when we want in a totally autonomous way. For the first time ever we could have computer working for us instead of us working with the computer. Still, Ambient Intelligence is a relatively new concept as the technologies it is based on, are also recent, which is the reason why there are no commercial implementations in use yet. The proof of concept still needs to be done but the growing number of AmI research projects proves that this is a very interesting field with a promising future.

The interest in this research field has been increasing and due to technological advances of the last decades we never been so close to smart environments become a reality. However, technological limitations are still great and ethical / social issues also affect the progress in this area. The past shows us that progress should be made with caution, computing has already experienced the pain caused by rushed expectations, resulting in disappoint moments and sometimes disasters. For example, between 1985 and 1987 a computer controlled radiation therapy device called the Therac-25 [30][31] had a software bug that allowed a technician to accidentally configure the Therac-25 so the electron beam would fire in high-power mode without the proper patient shielding. The result was at least 6 incidents, patients were accidentally administered lethal or near lethal doses of radiation (approximately 100 times the intended dose). At least five deaths were directly attributed to it, with others seriously injured. Another example of a computer fail occurred in 1991, during the first golf war, where American Patriot Missile system was deployed to protect allied troops and civilians from Iraqi SCUD missile attacks. Due to a software error in the system's clock the patriot battery based in Dhahran failed to intercept an incoming SCUD missile. The missile destroyed an American Army barracks, killing 28 soldiers and injuring around 100 others [45].

These kind of accident can affect the credibility of the system at the eyes of the public opinion and without trust, no acceptance is possible. It is vital that safety in AmI systems is thoroughly

2.4. Are we there yet?

tested to reduce the potential errors. Errors have been made in the past but we do trust in automation today. This trust is based on confidence built over many years in developing highly reliable, complex systems that we use everyday. The previous examples are automated system with intelligence but with a very specific "job" to do. This means that their cognitive function are limited to what they were build to do. An AmI system will have a more general intelligence property, it will learn and adapt himself to any kind of change in the context it is inserted. It is, for this reason, a way more complex system to build so the lessons learnt should be considered carefully and enough preparation should be done before widespread use can occur.

As we already define in the previous topic, AAL are intelligent systems that aim to help elderly and handicapped people to keep an independent life where they feel more comfortable, still elderly people do not have the habit to interact with new technologies. In fact, most of them are afraid and do not trust in intelligent system [44]. They need to learn how to interact and co-exist with an intelligent system. To help this integration, friendly interfaces should be build and trainings to their users should also be provide. Develop an adaptive and natural human computer interface is the main challenge of future interfaces in assisted living as well as get people involved in how to use the devices before they really need them.

If accepted by the society and proving their safety we strongly believe that in a near future AmL systems can help a lot of people all over the world to live more happy, confident and comfortable promoting social interaction and protecting their users in any circumstances.

VIDEO GAMES

"A video game is an electronic game that involves human interaction with a user interface to generate visual feedback on a video device. " (Baer, Ralph H, w.d.)

The appearance of Video Games starts in the late 1950s, with designing simple games, simulations, and artificial intelligence programs as part of computer science research. But it will only reach mainstream popularity between the 1970s and 1980s, when video games were introduced to the general public. Electronic games were born out of a combination of innovation, necessity and curiosity created by the will and the endeavour of artists, designers and entrepreneurs. With initial goal to entertain also came to challenge, captivate and enlighten millions of people around the world [24].

"I love video games, because I have the same experience that I have when I watch a movie that I love or I read a book that captures my imagination, but I'm an active participant instead of a simple observer." (Wil Weaton,2014)

The opinion is divided about who started the era of video games. Some say that it was Nolan Busnell, fonder of Atari, the corporation who first brought the video games to the mass market or Ralph Bear, the creator of the first console with a game called PONG or even Shigeru Miyamoto, founder of Nintendo. But it was Steve Russel, creator of the very first playable game called Spacewar on a PDP-1 (First computer with a visual display) that introduce in 1962 at the MIT the bases for the video game era [24][15].

"The games that were most successful were those that were simple to learn but impossible to master" (Nolan Busnhell,2014).

Nowadays video games are an integral part of our society. They are everywhere, in advertising campaigns or competitive events which are increasingly attracting participants and spectators,

different types of games come with new applications in several areas and the industry as a whole moves increasingly large sums of money (Figure 5) [25]. During the last decade video games have grown up and now they are not just in our living rooms. They're in our pockets, accessible everywhere and anytime.

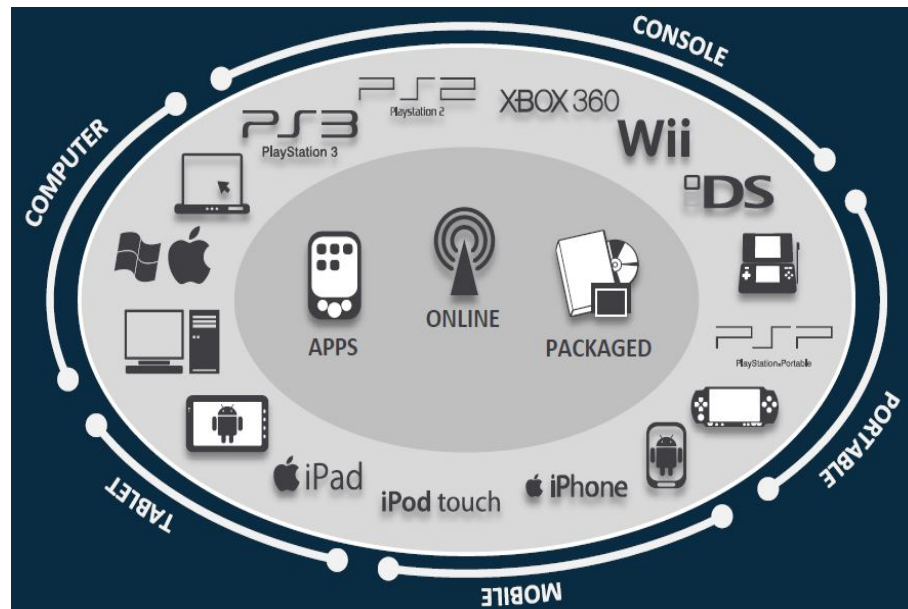


Figure 5: Video games platform¹.

Even those who are not interested find themselves obliged to contact with video games, directly or indirectly. Video gaming has become a popular form of entertainment and a part of modern culture in most parts of the world. However, the effects of "gaming" do not generate a consensus in the scientific community [3][18][2]. According to the Interactive Software Federation of Europe, the average of people who play games at least once a week is 25 % [23]. (Figure 6)

Those numbers are representative of how much importance video games have in our modern society since a quarter of the European population deal with them at least once a week. It is also the reason why it is crucial to understand the effect of the exposition of video games in the human health and behaviour.

1 Interactive Software Federation of Europe - Videogames in Europe: Consumer Study - 2012.

3.1. Evolution of Video Games

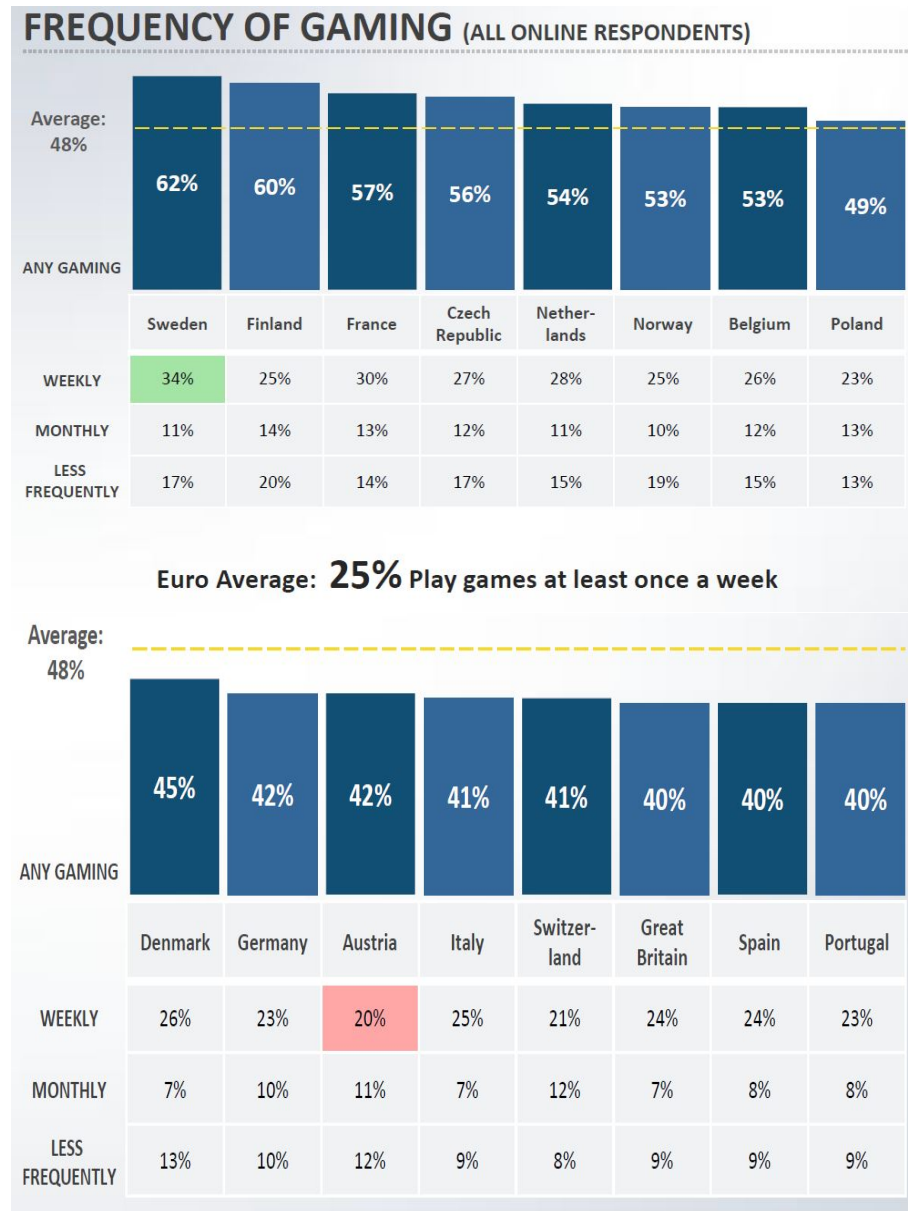


Figure 6: Frequency of gaming (Europe)².

3.1 EVOLUTION OF VIDEO GAMES

"Video games are a combination of every form of art and expression that mankind have ever had." (Phil Fish, 2014)

² Interactive Software Federation of Europe - Videogames in Europe: Consumer Study - 2012.

3.1. Evolution of Video Games

Surprisingly, modern game technology is still based on the same fundamental concepts of the first games but combining new layer of art and science to reach higher levels of innovation and expression. To understand where video games are heading to, we have to take a look into the past, in the late of the 70's early 80's, when the video game industry went to a crisis because of the emergent saturation of the public by the fact of the released video games at the time had a very poor quality and no creativity. The big enterprises were more interested in the creation of a large variety of video games most of the time without any innovation and the public was expecting more. The result was a dramatic fall of the video games sales that affected all of the big companies. In 1985, Nintendo release the Nintendo entertainment system (NES) and revolutionize the video games industry bringing back the confidence of the gamers all over the world. Nintendo understood that players liked to play with characters and not only with spaceships or circular points moving in a screen. Because of that the most favourite character of all time were created, Super Mario was released and quickly dominate the video game sales all over the world. With the rebirth of the video games industry a new kind of gamers was rising. Simple labyrinth games were not enough and the expectation for deeper, more immersing experience was growing. A new generation of consoles with a more powerful technology came to support that need. Then other aspect of video games started gain consideration like graphics beauty and a better way to involve the player into the games[24].

"In the 90's, with the Playstation and the more powerful technology arriving we had the gift of expression. Games became 3D, characters could talk, music could be created and characters could emote trough detail facial expressions." (Hideo kojima, 2014)

Video games have also changed the way people could interact with each other in an cultural point of view. In 1972, a small group of computer science students at the Stanford University artificial intelligence laboratory got the idea to organise the very first video game tournament with the use of computer labs PDP-10. A global society was and born video games became a link between gamers that grew up until today. A society where gamer don't only play and connect on-line but also produces friendships, friendships forged within a game experience that somehow yield a bound that isn't easily broken[24].

Video games have changed the way people could connect with each other, giving to them new worlds where they can exchange experiences and share goals without even meet in the real world and also boosting the imagination of the gamers in a very particular and unique way. Either see a movie or read a book are a passive way to let the story teller giving his vision of the story, but

3.2. Video Games: Negative aspects

with a video game it is possible to change the story and have different ends because the player, has an active participant, made that choice.

3.2 VIDEO GAMES: NEGATIVE ASPECTS

Part of the scientific community sees the video game as a negative phenomenon in our society, blaming them for a series of events linked to violence and caused by young people who played violent video games online such as a school shooting spree in Santee, California (March, 2001); a violent crime spree in Oakland, California (January, 2003); five homicides in Long Prairie and Minneapolis, Minnesota (May, 2003); beating deaths in Medina, Ohio (November, 2002) and Wyoming, Michigan (November, 2002); school shootings in Wellsboro, Pennsylvania (June, 2003) and Red Lion, Pennsylvania (April, 2003); and the Washington, DC. "Beltway" sniper shootings (Fall, 2002). Video game related violent crimes have also been reported in several other industrialized countries, including Germany (April, 2002), and Japan (Sakamoto, 2000) [2].

A study made by Anderson and Bushman (2001) [3] used modern meta-analytic techniques to combine the results of empirical studies of violent video game effects on five types of outcome variables: aggressive behaviour, aggressive cognition, aggressive effect, helping behaviour, and physiological arousal. They found significant effects of violent video games on each of these five variables. Exposure to violent video games increases aggressive thoughts, feelings, and behaviours, increases arousal, and decreases helping behaviour. There was no evidence of moderator effects. That is, these effects appeared to be about the same for males and females, for youths less than 18 years as well as older participants, and for experimental and correlational studies.

Play video games has some benefits in certain clinical settings, but a growing set of evidence highlights the more negative aspects of play particularly on children and adolescents. These include the risk of video game addiction [13], (although the prevalence of true addiction, rather than excessive use, is very low) and increased aggressiveness [3]. There have been numerous case reports of other adverse medical and psychosocial effects. For instance, the risk of epileptic seizures while playing video games in photosensitive individuals with epilepsy is well established. Graf et al report that seizures are most likely to occur during rapid scene changes and when games include patterns of highly intense repetition and flickering [16]. Seizures and excessive or addictive play do not seem to be linked directly, however, as occasional players seem to be just as susceptible. On balance, given that video game playing is highly prevalent among chil-

3.2. Video Games: Negative aspects

dren and adolescents in industrialized countries, there is little evidence that moderate frequency of play has serious acute adverse effects from moderate play. Adverse effects, when they occur, tend to be relatively minor and temporary, resolving spontaneously with decreased frequency of play.

Everyday millions of players spend many hours in front of a screen playing without even think about the possible effects of their behaviour in their health. A player during the playtime is boosted by adrenaline and his desire to go further in the game. Given its direct participation in history, a player quickly feels involved and captivated by the game increase. Still, a long exposition to video games can lead to episodes of fatigue, either physical or mental, and stress. The video effects and quick color transition associated with the necessity to achieve the game objectives cause stress pikes during the game play. In order to really understand the short time effects of video games in players, we need to take a look and understand the concepts of Fatigue and Stress .

3.2.1 *Fatigue*

"...a combination of symptoms include: poor performance (less attention, slow reaction, poor performance on tasks where they have capacity and sleep problems) and subjective feelings of sleepiness and tiredness..."

The concept of Fatigue, also called exhaustion or tiredness, describes the physical weakness and/or psychological of someone which prevents the natural or spontaneous development of a daily task. Fatigue is considered to be a set of factors that limit the normal behaviour of a person in a recurring activity. Fatigue is a recurring problem in our daily life, especially at work. It has been addressed and attempted to solve this problem for years looking for a way to measure fatigue and thus be able to manage it. However subjectivity that involves the concept of fatigue has been a problem, giving rise to different investigation and countless solutions. Despite the subjectivity of fatigue it has been proved that it is possible to define it as a loss of performance and with subsequent increase of errors / failures, regardless of the context and the person [38]. There are two types of fatigue: physical fatigue, often and wrongly confused with the main term fatigue, and mental fatigue, on which falls greater attention in this study. Mental fatigue is a state that can be caused by mental and/or physical efforts, as well as by the strong influence of attention on certain activities, which can easily lead to high levels of stress or a particular emotional state. Both of those types of fatigue are directly related and cannot be treated independently [6][38].

3.2. Video Games: Negative aspects

- Physical fatigue - Physical fatigue is usually associated with loss of muscle strength or speed, limiting the performance during the execution of physical tasks. It can also be seen as a temporary fatigue, which usually results from an excessive effort, or a poor physical preparation for the performance of certain tasks [6] [38].
- Mental fatigue - Mental fatigue may be seen as a state which involves a number of cognitive, emotional and motivational effects [46] emerging of a set of limitations. Some of these effects imply that a person is not willing to engage in tasks of effort, or if they do, they do it way below their normal capacity [48]. Mental Fatigue is responsible for loss of initiative, which can be associated with the lack of energy and is also typically associated with difficulties in concentration, attention, visual perception, sleepiness, among others [38].
- Fatigue Levels - As we know, fatigue affects us in different ways (mental and physical) but it also has different levels of durability. The time factor determines the duration of fatigue but can also determine its severity, because the longer the time the fatigue has last, higher is the probability of being progress to a more serious problem, as well as its treatment become more difficult. Fatigue can then be divided into two levels: acute fatigue, or fatigue of short duration, and chronic fatigue, or Long-term fatigue [38].
- Acute Levels - The acute fatigue is the most common affecting people on a daily basis. It usually comes after doing some efforts and it is the result of a momentary lapse of energy. Normally it has relatively short duration and only arises as a result of stress and despite being restrictive it is not considered a factor that negatively influences health [38].
- Chronic Levels - Chronic fatigue is a kind of persistent fatigue that usually is not associated with effort or exercise. It is associated with cognitive difficulties, mental and physical chronic exhaustion often severe. This is the kind of fatigue with long duration, requiring specialized treatment, and may even be considered a rare disease, chronic fatigue syndrome [6]. When a person is in a state of chronic fatigue they see their life being strongly limited as well as their health, happiness and productivity. The recovery is also quite difficult, a complete recovery of the condition occurs in only 5-10% of cases [32].

3.2. Video Games: Negative aspects

3.2.2 Stress

One of the first definitions of stress was proposed in 1956 by Selye [41]. Stress was then defined as a non-specific response of the body to external demands. These demands (the load or stimulus that triggered a response) are called stressors while internal body changes produced by them are called reactions to stress. Nowadays, the definition of stress is still under discussion and is not consensual in the scientific community. The various factors involved in stress factors, combined with the fact that many of them are subjective, lead to numerous interpretations that make it difficult to define. How can we define something that affects everyone in a different way[10]?

Attempting to resolve this question, researchers started to deal with stress from an empirical point of view. Therefore, they focused on the analysis of the cognitive and behaviour effects and they started to view stress as a mind-body, psychosomatic or psycho-physiologic phenomenon. In this line of analysis, a more recent view of stress looks at it as a psycho-physiologic arousal response that occurs in the body as a result of stimuli. This view also considers that the stress effects of stimuli depend on cognitive interpretation of the individual [10]. Concluding, stress is a physical reaction of the body to a situation that requires a new response from us. Thus our body prepares itself against a possible danger / need. This reaction leads to a rush of adrenaline that can be very useful when the need to escape from a situation of imminent danger or time of great importance such as the final of a world cup comes. However, when in excess, stress can lead to negative consequences to the physical and mental well-being level.

- **Stressors** - Stress factors are all things that surround us in our day-to-day for which we are responding. It can be anything from a simple background noise to a complex situation of social relationship. Stress is the feeling we feel and the stress factors are the source of this feeling.



Figure 7: Ambient Intelligence.

3.3. Video Games: Positive aspects

Normally, the greater amount of stress factors (figure 7) which we are subject, the greater the amount of stress we feel, but it is important to note that this relationship is not always present. What are factors of stress for one person may not be for another. This essentially depends on our experience of life and what we consider to be a threat or not and this is why it is a highly subjective phenomenon.

Despite its ordinary nature, we can consider mental fatigue as a highly complex phenomenon that involves changes in mood, information processing and behaviour [12], making it a difficult subject to study. Mental fatigue is as psychophysiological state resulting from sustained performance on cognitively demanding tasks and coinciding with changes in motivation, information processing, and mood [34]. When played many hours in a row, video games can be the cause of mental fatigue by making the player have repetitive pikes of tension and adrenaline, forcing himself to stay focused on the game deprived of sleep and the necessity to rest. As far as we know, there is no other study relating fatigue with video gaming, making this work such an important one since fatigue may conditioning our behaviour during our daily tasks. For example, mental fatigue can increase resistance against further effort and tend to reduce task engagement [22] [34] [40]. It's proved that, even in situations where they cannot stop working, fatigued people still tend to reduce task engagement, often unintentionally [34] [40]. Such reduced task engagement will not manifest itself as a complete withdrawal from the task or as a complete break-down of performance. More likely, periods of adequate performance will more frequently be alternated with lapses of task-engagement under fatigue [40]. Several studies have already demonstrated a clear decrease of performance under high levels of fatigue [28] [21] [36] [39] [17]. In the same way, we expect that the fatigue and stress accumulated by an over exposure to video games will have a negative impact on the performance of the player.

3.3 VIDEO GAMES: POSITIVE ASPECTS

"Video games provide a space for learning how to fail safely and successfully. To how to problem solve and think through an issue." John Sharp

Most of the studies related with video games only refer negative aspects of playing (Social isolation, increase of aggressiveness, addiction and depression) but there are others, more recent, arguing that video games have very positive effects in players in various points, like concentration capacity, creativity, social interaction and even in education [13]. Surprisingly for some, video games have proven to be a powerful weapon in the fight against some types of diseases.

3.3. Video Games: Positive aspects

One of the most obvious improvements in the human body is the significant increase of the capacity to concentrate and perform actions faster and more efficiently, because the vast majority of games available on the market require, somehow, a high degree of concentration on the part of the players aiming to perform better during the game. According to the results of a study conducted in 2009 by the Annual Review of Telemedicine and Cybertherapy, it is proven that the majority of players consider that stress relief is one of the benefits that lead them to play video games[47].

Another study conducted by the Department of Psychology, Wheeling Jesuit University, say that sports games can be a help in oblivion of pain and physical discomfort. This factor may have a very great importance when associated with patients in painful treatment procedures, or perhaps as a treatment of Chronic Pain. [27] Video games have been used as a form of physiotherapy for arm injuries, in training the movements and as a form of occupational therapy to increase hand strength.

Therapeutic benefits have also been reported for a variety of adult populations including wheelchair users with spinal cord injuries, people with severe burns, and people with muscular dystrophy. Video games have also been used in comprehensive programs to help develop social and spatial ability skills in children and adolescents with severe learning disability or other developmental problems, including autism; children with multiple handicaps (for example severely limited acquisition of speech); and children with impulsive and attention deficit disorders[33][20]. The benefits of video games also involve other areas than health such as education, creativity and social interaction. Video game technology brings new challenges to the education area because they represent a new technique that may be available to the classroom teacher. Video and computer-based games may possess advantages not present in other learning strategies. For example, the ability to choose different solutions to a complex problem and then see the effect of those decisions have on a fictional game allows students to experiment with problem-solving in a relative safe environment. Video games have great positive potential in addition to their entertainment value. There has been considerable success when games are specifically designed to address a specific problem or to teach a certain skill [19].

Many would think that what is required of the creative ability of a player is limited to the combination of different weapons, abilities or spells, the construction of alternative tactics in strategy games, or perhaps a new approach in any puzzle that is be particularly difficult to overcome. However, this is not true, video games increasingly move to a level where the game itself lives to the capabilities of the player rotates around its imagination and reveals good or bad depending on what each person can do with it. Nowadays it is possible to enjoy an emotionally intense

3.4. Related Work

and immersive experience as rich as those we see in any movie theater. We have witnessed an exponential development of scripts, which now also focus on creating culturally rich experiences, with much to teach. For example through the streets of Florence, San Gimignano and Rome in Assassin's Creed series conveys unimaginable information about Italian culture throughout the season number, possibly arousing a desire to visit the place in real life.

Another typical stereotype is that video games are seen as a factor of social isolation. This might be true 20 years ago but nowadays video games are also platforms for social interactions between players all around the world. The co-operative multiplayer options of video games, both on-line and offline, allow two or more people come together with a common goal. This momentary union could foster the relationship with other players, aiming to accomplish a set goal that interests them both. Practical applications development and enhancement of this capacity on a day-to-day are more than obvious.

It is also important to note that video games can only bring benefits to society if used the right way and with due moderation. Using common sense it is easy to see that changing a walk with friends for a marathon game in a first shooting simulator will not have a positive impact on your relationship skills or social life. The video game effectively have much potential and show great importance in many fields of society but it is up to the players use them with due sense[13].

3.4 RELATED WORK

During our research we couldn't find studies relating video games with fatigue and performance. Even if video games are a theme of great interest, the research community have been focused in long term effect of video gaming than to discover the impact of video games exposure in a short term. Still, some previous work have been done and some of them, due to their relative proximity with this work have been analysed and helped in our research and study design. One of them is called "Stress Monitoring in Conflict Resolution Situations", it is part of a project being developed by researchers of Department of Informatics of University of Minho. The purpose of the project is to develop an Online Dispute Resolution (ODR) framework which takes into account information about the users' context [14]. Online Dispute Resolution is growing to become the major alternative to litigation in court. Given the characteristics of current disputes, technology-based conflict resolution may be a quite effective approach, although in this shift of paradigm there are some threats that should be considered.

A particular part of this project deals with the problem of the lack of important context information when parties communicate in a virtual environment. In this project, researchers propose

3.4. Related Work

the addition of a monitoring framework capable of measuring the level of stress of the parties in a non-invasive way. The gathering of the information was done by the platform and the mediator along the complete conflict process to adapt strategies in real-time, resulting in a context-aware and more efficient approach. The use of non-invasive tools for the different measurements is particularly challenging because almost every study made in this field have used invasive methods which might had an influence in the results. Because of that Tomass Ratecki build a Fatigue Monitoring System at the University of New Orleans that consisted in the development of detection system and monitoring of fatigue through the use of Webcams. The software developed monitors and tracks eyes for signs of fatigue by measuring PERCLOS as a metric to detect fatigue. It was developed to runs on the workstation and is designed to draw limited computational power, so as to not interfere with the user task and using only non-invasive track records[37].

The same way that ambient intelligence is hidden from the users and only noticeable by its action, we believe that the use of non-invasive ways should be the preferential choice making the user being more comfortable during the monitoring avoiding the stress induced by the use of sensors applied directly to the body. This could be an advantage when one of our objectives is to study the effect of stress using video games, like a study made by S. Bouchard named "Using Biofeedback while Immersed in a Stressful Video game Increases the Effectiveness of Stress Management Skills in Soldiers" which objective was to evaluate the efficacy of using visual and auditory biofeedback while immersed in a tridimensional video game to practice a stress management skill. All 41 participants were soldiers who had previously received basic stress management training and first aid training in combat. On the first day of the study the soldiers were assigned to either: (a) no additional stress management training for three days, or (b) 30-minute sessions (one per day for three days) of biofeedback assisted stress management training while immersed in a horror/first-person shooter game.

On the last day, all participants underwent a live simulated ambush with an improvised explosive device, where they had to provide first aid to a wounded soldier. Stress levels were measured with salivary cortisol collected when waking-up, before and after the live simulation. Stress was also measured with heart rate at baseline, during the apprehension phase, and during the live simulation. The results confirmed that practicing stress management training was effective in reducing stress, proving the advantages of the proposed program for military personnel and the need to practice stress management training [7].

3.5. Analysis of the related work

3.5 ANALYSIS OF THE RELATED WORK

A very few projects concerning video games are related to the monitoring of fatigue. Previously, some of them were presented, showing their objectives, challenges, and some results obtained at the end. Despite their relation with the theme of this work, none of them are close to the objective of this project.

As reported before, video games are an important factor within our society, raising many questions in this matter. During the last few years many studies have attempted to demonstrate the positive and negative effects of video games in players' life and welfare. Most of these studies agree that in excess, video games are a negative factor for players the same way that it has been proved that playing video games also had benefits. Using that knowledge as a base, this project will analyze the player behaviour during the gameplay in order to recommend him to stop playing when the negative aspects start to show up.

To achieve this goal, the recommendation system will focus in fatigue and stress using only non-intrusive methods and a video game as scenario for the study. This approach is totally new and will allow us to extend the knowledge acquired so far and build a system capable of analyse the player behaviour in real time.

DATA COLLECTION

In a society always anxious for new technologies and new forms of entertainment, video games have been gaining more and more space on the people lives. This tendency has been growing and although there is no consensus about the possible effects on the players, no research has been done to determine how much a person can play without affecting negatively their behaviour and welfare decreasing their efficiency and performance. Video games lead to stressful periods during the gameplay and a long duration exposure can lead to the player having peaks of fatigue that can change the way he is interacting with the device used to play. While short periods of gaming might even improve the gamer performance, prolonged periods of exposure may significantly decrease it. In this context, the aim of this study is to find if video gaming may contribute to further improve or worsen the performance of the player and define if it is possible to find the break point that symbolize the moment when negative aspects start to show up. With this research we aim to develop recommendation strategies that can improve the experience of the player while interacting with video games, in order to adjust the time spend playing .

4.1 STUDY OBJECTIVES

The main goal of this study is to determine the influence of violent video games on the performance of players, on their behaviour within the environment and on their emotional state. Determining the existence of these changes and measuring their magnitude will enable the development of a recommendation system aimed at improving individual performance indicators advising the player of the negative aspects of his long time exposure to the game. The main objectives of the study are:

- Determine if video games have positive or negative effects on any/some/all the following variables:

4.2. Study Design

- the interaction patterns of the player with the computer;
 - the behaviours the player evidence in the environment;
 - the performance of the players during the game play time;
- Study and quantify the effects of violent video games on the variables;
 - Determine if, at the end of the study, users are conscious of any fatigue/stress or, at least, of some effect at some level;
 - Determine if the effects observed can be associated to the population in general. (e.g. violent video games affects a large percentage of the population in a similar way).

4.2 STUDY DESIGN

An experimental study was conducted to address the goals and objectives described in the previous section. A group of voluntary players were selected to play a violent video game with the aim to prove that long exposure video games have immediate negative effects on the performance of the user due to the fatigue and stress caused by the video game action. The expected result of the study can be defined in two distinct parts: the first is about the initial time of the study, at this time the player is still fine physically and mentally, without any sign of fatigue.

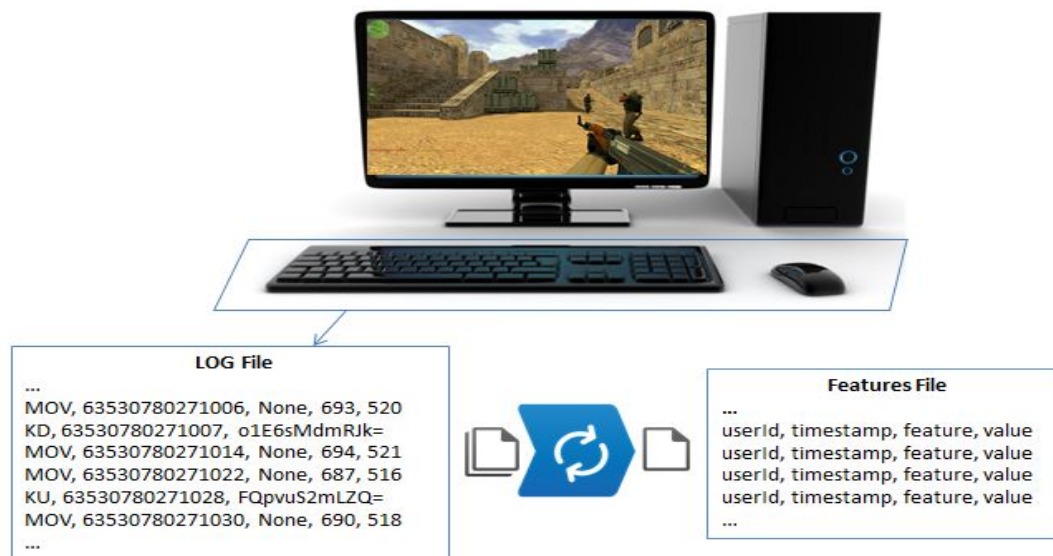


Figure 8: Data collecting process.

4.2. Study Design

It was expected at this first part that the performance of the player increase since he was going to be more accustomed to the game. Then, due to the long time playing a video game that requires fast reaction and concentration it is expected that fatigue start to influence the performance negatively, beginning the second part where the performance is decreasing. Players will use a custom computer with a keyboard and a mouse to interact with the video games. Since we are not using intrusive sensors, the keyboard and the mouse have provided us the necessary data for the performance analyses (figure 8). At the end of the study each player had a log file with every interaction with the keyboard and the mouse made during the study. Each log file was then processed to get a set of interaction patterns. The next section will tell more about those interaction patterns.

4.2.1 *Interaction Patterns*

Interaction patterns are described by a number of features, 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:

- MOV, timestamp, posX, posY - an event describing the movement of the mouse, in 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, in a given time;
- KEY_DOWN, timestamp, key - identifies a given key from the keyboard being pressed down, at a given time;
- KEY_UP, timestamp, key - describes the release of a given key from the keyboard, in a given time;

4.2. Study Design

These events are considered 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 (x₁,y₁) and (x₂,y₂), that took place respectively in the instants time₁ and time₂. 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 1:

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

- **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,

4.2. Study Design

respectively in the coordinates (x_1, y_1) and (x_2, y_2) . To compute this feature, first it is measured the distance in straight line between the coordinates of 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 , holding the coordinates of the consecutive MOV events between mup and mdo. The distance actually travelled by the mouse, $rdist$ 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 $\frac{sdist}{n}$.

$$s_dist = \sum_{i=0}^{n-1} ptLinedist(posx_i, posy_i) \quad (2)$$

- 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 $\text{degree}(x_1, y_1, x_2, y_2, x_3, y_3) = \tan(y_3 - y_2, x_3 - x_2) - \tan(y_2 - y_1, x_2 - x_1)$. Let us now assume two consecutive MOUSE_UP

4.3. Selected video game - Counter-Strike

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.

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

- Absolute Sum of Angles - this feature is very similar to the previous one. However, it seeks to find only how much the mouse "turned", independently of the direction to 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.

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

- 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 1 .

4.3 SELECTED VIDEO GAME - COUNTER-STRIKE

The Video game chosen for this study was Counter-Strike, a first person shooter released in 2000 and considered one of the most successful game in the world. Every day, thousands of players are simultaneously playing this electronic video game being part of an important community with the players themselves but also with professional teams, fans and enthusiastic spectators[43].

4.4. Research Population

Tournaments are organized every year where the best teams in the world clash between them to win the world champion title. The popularity and success of this violent video game make it a good choice for this study. Counter-Strike is a strategic team game where two teams (Counter-Terrorists and Terrorists) confront themselves in order to achieve an objective. Both teams have two minutes to accomplish their objective, if the objective is not complete within the time the other team wins. The objectives may vary: there is a bomb planting mode in which the terrorists have to plant a bomb in one of two available bomb-sites (figure 9), the counter-terrorists must defend these areas and defuse the bomb if it was planted before it burst.



Figure 9: Terrorist planting a bomb.

The other mode consists in the counter-terrorists having to save hostages that are prisoners by terrorists. to win, one of the teams has to achieve their goal or eliminate all the enemies. The cooperative nature of CS and the complexity of the different scenarios make this video game almost unique. A very few other Video games can get the same interests from the players, e-sport organizations and sponsors. Counter-Strike is a very good choice to analyse how players behave during game time in an environment that requires high concentration, speed of analysis, execution and strategic thinking to achieve victory.

4.4 RESEARCH POPULATION

Two type of participant could be chosen for this study: participant with video game experience and already familiarized with the chosen game or participants with no experience with the game. Given the scope of the project, we focused at this point on participants that are within working

4.5. Methodology

age and already are familiarised with counter strike or first shooting video games. Still, it could be interesting to compare the results of the two types for the same study.

4.5 METHODOLOGY

To assure the control of the surrounding environment the study took place in the Intelligent System Lab of the University of Minho. The study has consisted in the observation of nine players during a period of time of three hours. This amount of time have been chosen to simulate a competitive Counter-Strike game where each team confront themselves in three different maps, each one with a maximum game play time of one hour. To interact with the game the player will use a normal PC. Performance and behaviour are measured as described in the Study Design.

In a first shooter game there is a wide variety of options that can influence how the players interacts with the keyboard and the mouse. In counter-strike there are five different categories of weapons: pistols, shotguns, sub-machine guns, rifle, machine guns. The way the players handle the weapons varies even within a category. For example, in the rifle category a player can choose between a fully automatic weapon with a high rate of fire resulting in a longer click into the fire button representing many shots in a row, or a sniper rifle with high power but a very low rate of fire. Using a sniper rifle the player would make quick clicks, firing a single bullet instead of long duration clicks representing bursts of shots fired with an automatic weapons. For this reason, it was very important to ensure that throughout the study evaluation all the players always used the same gun and played on the same map. The study followed the next steps:

1. The participant arrived at the ISLab;
2. The participant was briefed with all the information concerning the study;
3. The participant sits at their computer and started playing Counter-Strike using headphones;
 - The ISLab logger application was running in the background, building the log mentioned in the Study Design, that allowed to compute the mentioned features ;
4. While playing the participant in the study was not interrupted;
5. At the end of the three hours game play the study ended.

4.6. Data Management and Statistical Analysis

4.6 DATA MANAGEMENT AND STATISTICAL ANALYSIS

The data collected in this study was stored in different folders, one for each user. Each folder, identified with the number of the participant, will contain the following files:

- Activity log – raw data describing the interaction of the user with the mouse and the keyboard;
- Features – values of the several features, computed from the activity log.

This data will be analyzed with statistics software in order to determine and quantify behavioural differences between each player. This analysis will be done at a feature level. It will start with a visual analysis of the data and the computation of standard measures of variability and central tendency. This will be useful for determining the potential existence of differences and how these differences affect the variables.

4.7 STUDY RESULTS

After the realization of the study, a more profound analysis of the data was done in order to confirm the expected results. As a comparison base, the study done by André Pimenta called “Análise e monitorização de fadiga mental” (Analysis and motorization of mental fatigue) [38] used the same approach as this work, using a keyboard and a mouse as sensors as well as a set of metrics inspired in behavioural biometric, proved that it is possible to detect mental fatigue in user behaviour when handling these two devices. It was further proved that the presence of mental fatigue announces itself with the loss of performance and an increased number of errors. Keeping that in mind, it was expected two distinct phases. The initial phase should represent an increase of the performance as the player goes through a process of adaption to the game and its context within which will improve their performance until it reaches its normal level. Closer to the end of the study, it was expected the decline of player performance due to fatigue accumulated by playing for some time. First person shooter (FPS) video games require high concentration and speed of reaction from the player who is under pressure and stress given the context of the game itself. From the nine volunteers that participated in the study, only two complied with what was expected, which means that only two players (22.2%) saw their overall average performance decrease in the three-hour duration of the study. For the remaining, five players (55,5%) counteracted the expectations and improved its overall average performance

4.7. Study Results

throughout the study while the two remaining players maintained their performance without significant increases or decreases in the observed values.

General performance at the end of the study	Average of players
Performance has improved	55,6%
Performance has worsened	22,2%
No significant change	22,2%

Figure 10: Study result (players percentage).

Clearly, the results were quite unexpected since the majority of the research population have improved their performance instead of the inverse (figure 10). To better understand what happened we have first to look at the classification system we used for the data analysis. The figure 11 represent the classification system for each feature.

	More performance	Less performance
Key Down Time	↓	↑
Time Between Keys	↓	↑
Mouse Acceleration	↑	↓
Mouse Velocity	↑	↓
Time Between Clicks	↓	↑
Average Excess of Distance	↓	↑
Time Double Clicks	↓	↑
Average Distance Point Line 2 Clicks	↓	↑
Total Excess Distance 2 Clicks	↓	↑
Distance During 2 Clicks	↓	↑
Distance Between Clicks	↓	↑
Signed Sum of Angles	↓	↑
Absolute Sum of Angles	↓	↑

Figure 11: Feature rating system.

4.7. Study Results

For each player the set of features defined previously was calculated and used a simple rating classification to define if the performance was increasing or not. Two features differ from the others by having different interpretations which are the Mouse velocity and Mouse acceleration. For both of this features if their value grow during the game time it means that the player is reacting more quickly to the game, with faster movements. Which is the opposite of the other features when the value calculated for this two features grow, it means that the performance is also increasing. For every other feature if the value calculated grow it means that the performance is decreasing. For example the average distance point line between two clicks measures the average distance of the mouse to the straight line defined between two consecutive clicks. It is representative of how efficient can be the displacement of the mouse between two points. If the value increased during the study it means that the efficiency of the gesture is decreasing and, consequently, so is the performance. The combination of those three features with the context allows us to understand more about the evolution of the player in the game itself. Indeed, if the player improves the mouse velocity, acceleration and become more efficient by decreasing the excess of distance between two clicks, it can be a sign that the player is improving his aim.

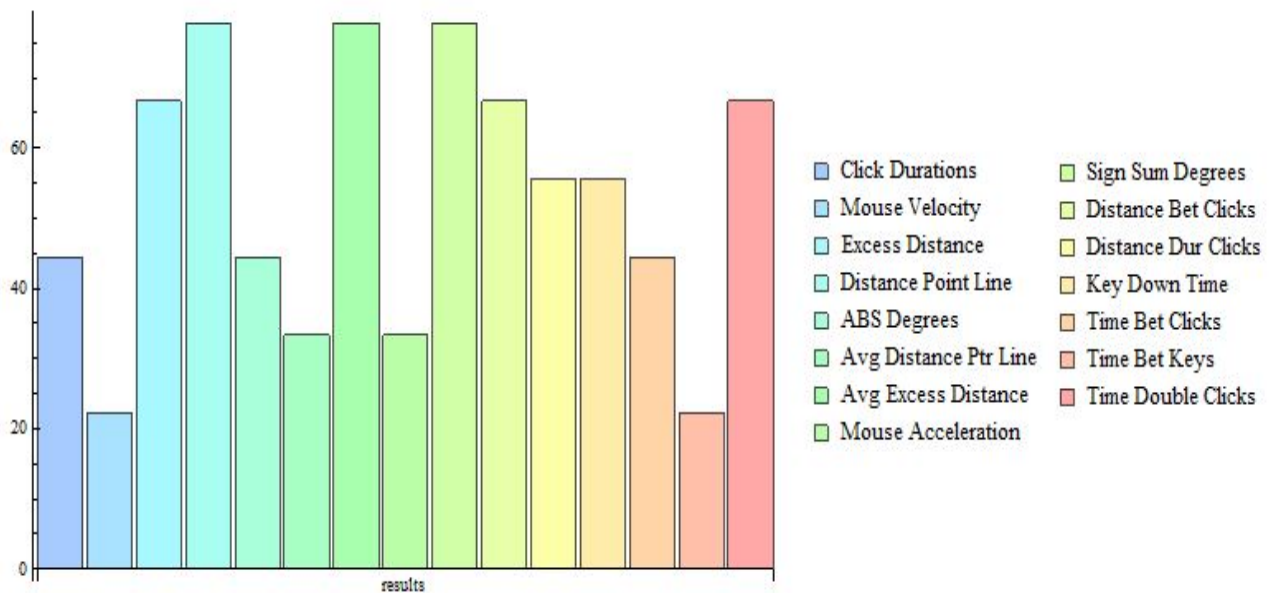


Figure 12: Feature result chart.

To determine each feature evolution during the study time we have divided them into five intervals of time and for each one of those intervals have been calculated a set of metrics such as the mean, median, maximum value, minimum value, standard deviation and created charts to facilitate the analysis.

4.7. Study Results

Features	Percentage
Key Down Time	55,56%
Time Between Keys	22,2%
Mouse Acceleration	33,3%
Mouse Velocity	22,2%
Time Between Clicks	44,4%
Average Excess of Distance	33,3%
Time Double Clicks	66,67%
Average Distance Point Line 2 Clicks	77,78%
Total Excess Distance 2 Clicks	66,67%
Distance During 2 Clicks	55,56%
Distance Between Clicks	66,67%
Signed Sum of Angles	77,78%
Absolute Sum of Angles	44,4%

Figure 13: Percentage of increasing performance for each feature.

The figure 12 and 13 are representative of the percentage of players that improved their performance for each feature. These two figures allow us to better understand which features are most likely improved when playing FPS video games. Observing the figure 13 that the features referencing the average distance crossed between two clicks and the signed sum of angles are the ones where approximately 78% of the players have improved, probably it is the necessity to improve the aim to shoot an enemy that can explain those results. Using this data it is possible to build a profile of the game, for example, only 22% of the players have improved the mouse velocity, which means that the tendency playing counter strike is to become slower when moving the mouse.

A more individual approach was also analysed, as we say earlier the majority of the voluntaries have improved their performance during the three hours study. The evaluation is considered good if more than half of the features had a positive evolution. The figure 14 represent a comparison between two players: Player A had the expected behaviour because his performance decreased during the study showing fatigue; Player B belongs to the set of player that have improved their performance during the study, showing a greater resistance to fatigue.

4.7. Study Results

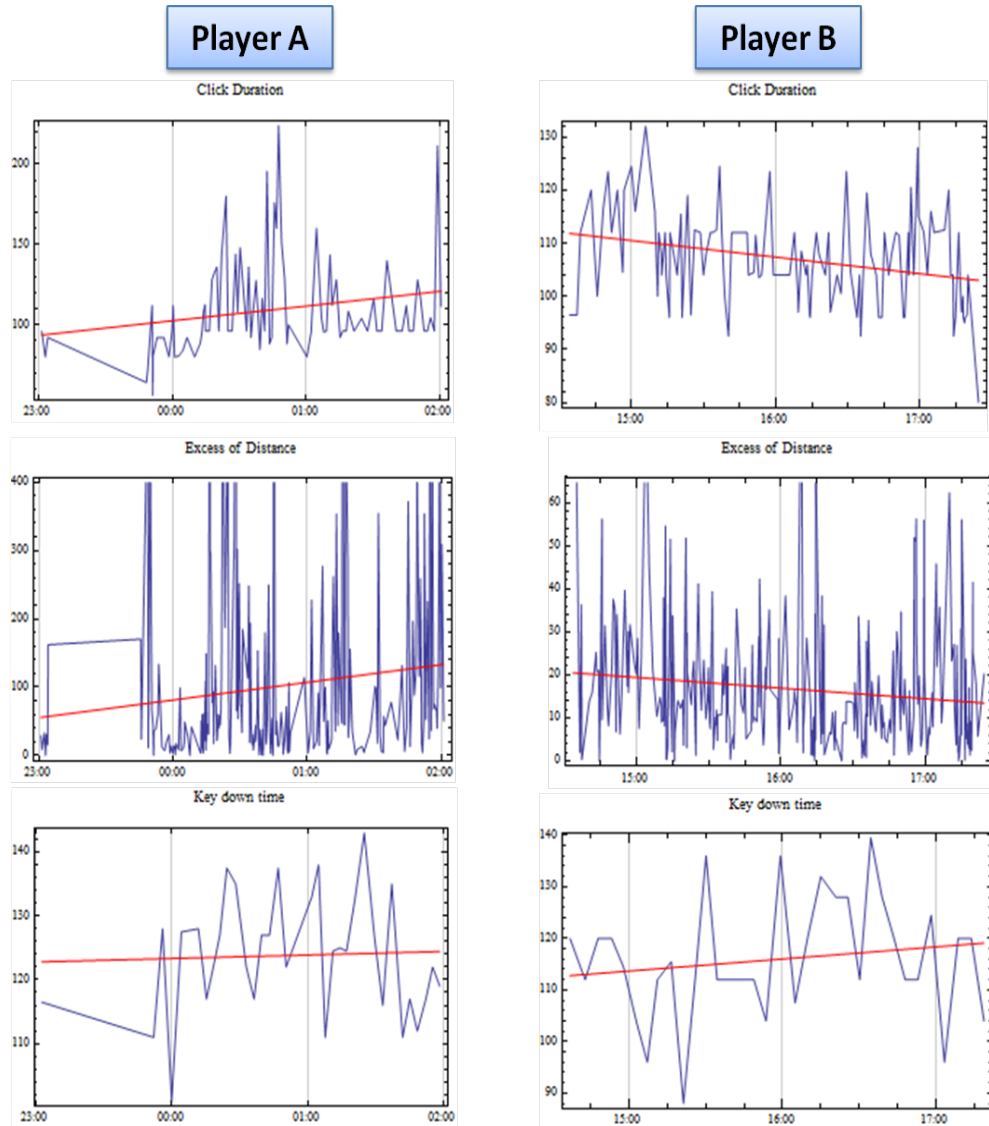


Figure 14: Comparison of features between two players: Player A (performance decreased during the study) and Player B (performance increased during the study).

Observing the first two features we can clearly see the differences of the red line in the charts between the two players. For the player A the red line is representative of the increase of the value which mean a decrease of the performance. For the player B it is the opposite, the red line representing the feature value is decreasing on the first two feature proving that the performance increased during time.

The last feature (Key down time) have interesting results. Both player have increased the time when they are pressing a key, nut player B have an accentuated slope. Normally it would mean

4.7. Study Results

that in this case the player B had worst results than the player A. Still this case is subjective because in a FPS video game when a player press a key it mean that he is moving in the game. So, the increase of the key down time during the study can simply mean that the player have moved more through time.

RECOMMENDATION SYSTEM

In the previous chapters, we have learned that video games are spread globally and millions of players around the world spend time playing every day to escape from the daily stress and have fun. We also learned that video games have a positive effect if they are used properly and without any over exposure. Too much time playing video games can have serious negative effects for the players but nowadays the majority of them spend too much time in front of the screen ignoring signs of fatigue and reducing the time of sleep in order to spend more time playing. Most of those players haven't the conscience that their behaviour is affecting their well-being.

With this work we build a system that could be able to "observe" the users behaviour, analysing their metrics and evaluate the performance level in order to advise the user when negative aspect start to show up repeatedly. Using this system the user will be aware of his performance evolution and immediately notified when fatigue is detected through a decrease of the performance. The prototype build is physically invisible for the user since it is used the keyboard and the mouse to collect the necessary data for the performance evaluation. Using a non-intrusive method we guarantee that the system will not influence the result by perturbing the user.

Today, despite the concern of the society towards video games, there is no system capable to monitor video game players using non-intrusive methods, hidden from the users, working autonomously to assist and protect them from the negative aspects of playing video games in excess. Still, as we discover during the study made, each player have his own behaviour and own level of resistance. This means that even playing the same game with the same context, two players can have two totally different performance results. So, it is not enough to have a simple monitoring system hidden from the view of the player, it has to adapt himself to each player in order to give the better recommendation possible at each moment based in previous experiences.

This chapter will describe the recommendation and monitoring prototype build with the aim of provide a new mechanism for video games users to control their behaviour and the amount of time spend playing with a real time valuation of their performance.

5.1. System Description

5.1 SYSTEM DESCRIPTION

During system's planning some essential requirements were identified to have an efficient recommendation system:

- Capacity to register every user interaction with the mouse and the keyboard during the gameplay time, without any interference with the user and with the game itself;
- Autonomy to work and adjust itself to each user;
- Ability to interact with the user in the most natural way possible giving to him recommendations about his performance;
- All the evaluation process must be done in real time.

To comply with the requirements, the recommendation system has been divided in different components, each one of them with their own purpose.

The system build use three distinct components to work. As we described before, the keyboard and mouse are used as an input of the user interaction with the computer. The data is collected by a first component that register every movement of the mouse, mouse clicks and when a key is pressed or released. The data collected is send to the main component of the recommendation system that filter the data, preparing it to be send to the third and last component of the system. The third component is a service and have the job to calculate all the metrics using for that the received data. After the metric are calculated they are sent back to the main component of the system where they are used for the final evaluation.

The interaction between the system and the user is done through two different channels. The first is an interface with the historical data from previous evaluations that are available to be consulted by the user. With the historical module the user can check the different features calculated and compare their evolution through the time. The second channel of communication is the most important of the system, because it is this component that evaluate the performance and give the recommendation to the user. The module responsible to transmit the recommendations to the user doesn't have a physical module like the historical module. It consists in a speech synthesizer Api from Google that will allow the system to give the recommendation using the audio of a human voice. This approach have been chosen for two main reasons. Firstly because any visual feedback would interfere with the video game and could cause nuisance to the user. Secondly because recommendations given using a human voice have a more natural effect to the user which is more used to this kind of approach in, for example, Global Positioning System

5.2. Objectives

(GPS). A more profound description of the different components and modules composing the system is present in the next topics.

5.2 OBJECTIVES

The recommendation system has for main purpose to give the best advices to the user based on their performance in order to avoid problems like mental fatigue or stress that could influence negatively the user well-being. To be successful the system must achieve a set of objectives to be considered fit and be accepted by the users. The acceptance of intelligent systems is normally challenging because most of the user do not trust or do not accept a computer program orders to them what they have to do. So, the following objectives were set:

- The system must adapt to each user, using the collected data to build an individual and personalised model;
- Using the calculated results, the system must understand the effects of video games on player;
- Using the model created and the historical data stored from previous analysis, the system must give valid recommendations to the users;
- Allow the access to the users of their performance evolution during their game play time.

To be successful, a system like the prototype build in this work must prove its reliability to the public in order to be accepted and used. Resuming into only one main objective, the recommendation system must support, recommend and inform the users of their behaviour, making them have conscience when excesses are being made.

5.3 ARCHITECTURE

As described previously in the ambient intelligent chapter, it is very important for a system like this one to have an efficient system flow since it is that flow that will assure the transmission of the data through the different steps until the performance evaluation reaches the user. So we opted to build a set of different components, each one of them with its own purpose, interacting with each other in order to achieve the main objective of this work. Those components, or modules, must meet the following requirements:

5.3. Architecture

- Collect data regarding user's interaction with computer;
- Calculate metrics based on data collected;
- Evaluate, using the calculated metric, and compare the result with historical data stored previously;
- Interact with the user in order to transmit the evaluation.

The system architecture here presented can be described as a composition of three distinct modules that relate themselves with the objective to provide to the user a constant and reliable update of his performance in order to help him change his behaviour, if considered a risk, reducing the probability of being affected by negative effects like the accumulation of fatigue and stress. As we can see in the figure 15, the system is composed by the Data Collection Interface, responsible to collect every human-computer interaction using computer keyboard and mouse. It is also composed by the Metrics Service, with the purpose of calculate user's metrics used later for the evaluation. Finally the recommendation system main interface, which function is to assure the information flow, evaluate the performance and interact with the user.

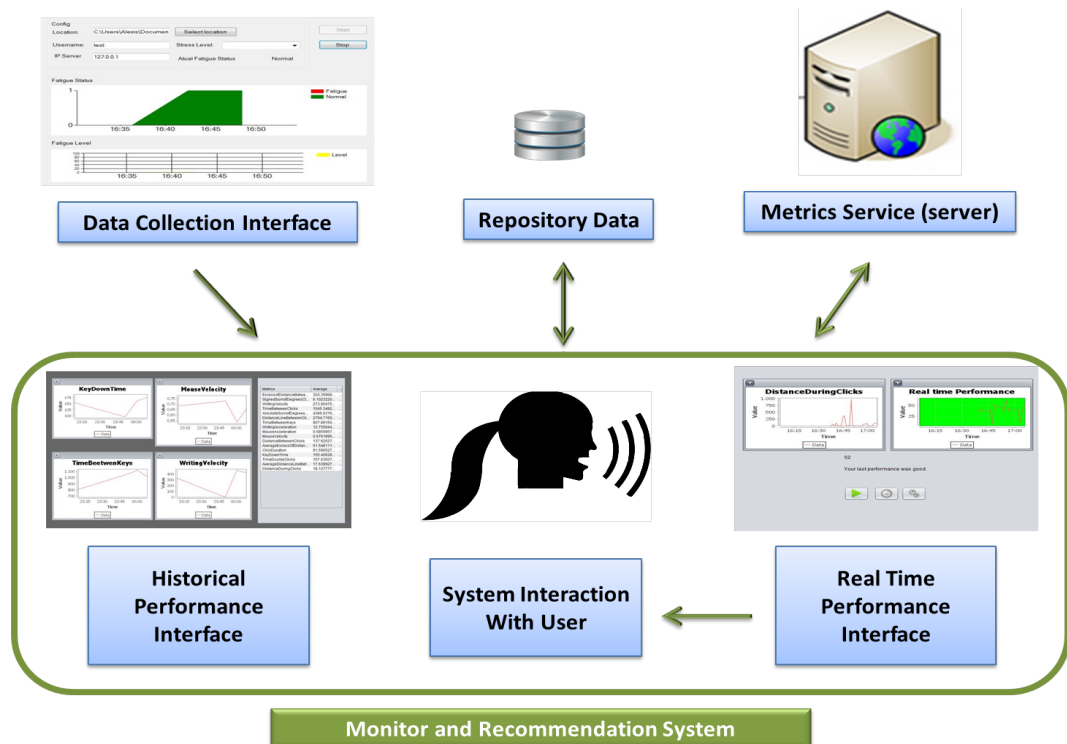


Figure 15: Architecture of the Recommendation System.

5.3. Architecture

5.3.1 Data collection Interface

Collection of information related to user's interaction with computer during the game play time is one of the vital processes, enabling later evaluation of performance and subsequent analysis by the main module of the recommendation system. It is necessary a tool capable of, firstly, make a constant and efficient collection of the information needed, and secondly, make it discreetly without interfering with the context in which the user is inserted. Built in C# at the ISLab and using the KeyboardHook and MouseHook libraries, this component collect the data from the input peripherals and send the data to the main interface of the recommendation system (figure 16).

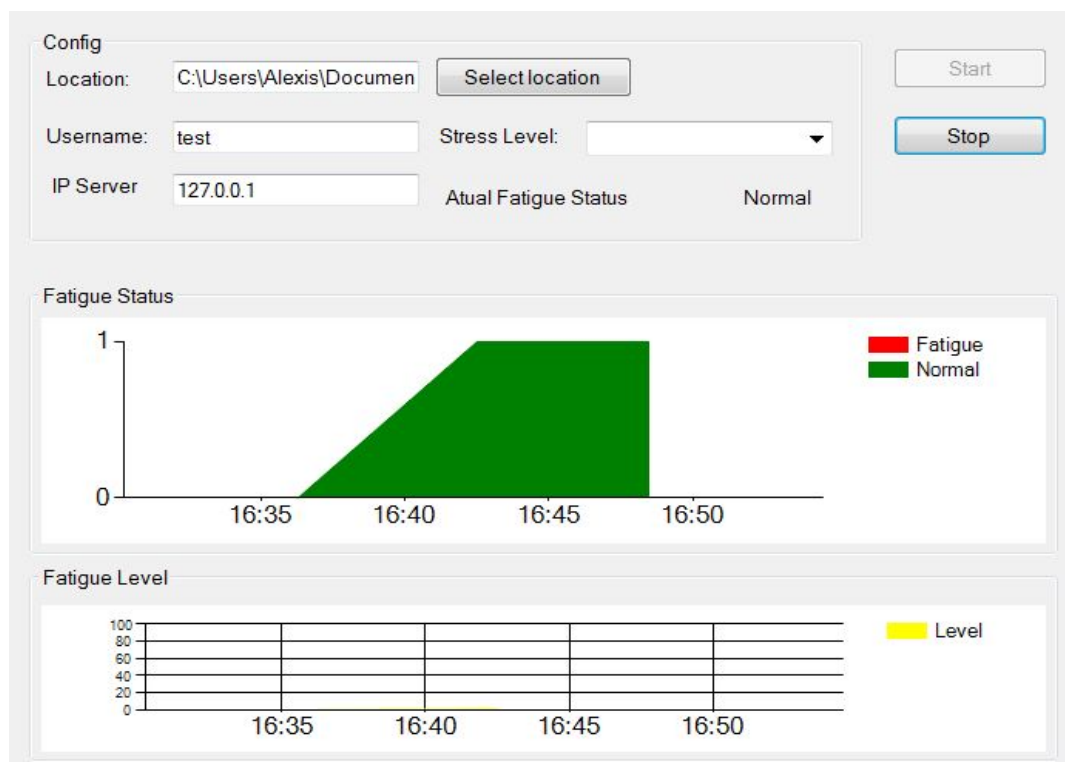


Figure 16: Data Collection Interface.

5.3.2 Main interface

Main interface it's the central module and the most important of the system, because its the link between the two other components and it's also the responsible for the communication with the user. Indeed, the main interface is the module that receives data of user's interaction with com-

5.3. Architecture

puter collected by the data collection module and, later, send it to the Metrics Service available on the network to calculate the different metrics. The calculated result by the service is send back to the main module. A more profound analysis of the recommendation system interface is done ahead in this document.

5.3.3 *Metric Service*

Built in Java by ISLab researchers in the context of the CAMCoF project, the Metrics module differentiate itself from the other two modules of the system because it works autonomously, as a service. The purpose of this module is to receive the data send from the main module of the recommendation system and, after calculate all the metrics necessary for the next step of the process, it sends the result back to the main module. This service module is the only module of the system not hosted in user's computer. This way, the service can be accessible through network to a variety of users.

5.3.4 *Communication*

As described previously, the recommendation system is composed by different modules that need to communicate with each other in order to transmit information. To enable the communication a network structure has to be defined, the chosen model was a based in the client-server model where the client and the server are separated physically and connected using an available network. Following the client-server logic, the main interface of the recommendation system and the Data collection interface are on the client side, on the server side is present the metrics service. Since the Metrics service work autonomously, it is independent from the recommendation system but still an essential part of it. The main advantage of having the Metrics service, build as a RESTFull web service, separated from the rest of the system, is that this way many other user can use the same service instead of having to replicate it in every computer using the recommendation system. Of course, there is also a disadvantage, to work, the system must be on-line which means that it is depending on the Internet connection to be available. Once again, if we take a look at the beginning of the process we have the Data collection interface collecting data from the user. This data is encrypted on the client side and send to the metric service (server side) using SSL (Secure Socket Layer). The encryption of data is essential to assure the privacy and the security of the user personal information. To assure the communication between the Main interface and the

5.4. System Modes

Data collection interface, communicate with each other we are using Sockets, a simple, secure and effective way of communication.

After the end of the evaluation process the system must interact with the user, transmitting to him the result. To do that we have chosen to use sound communication in order to make the human-computer interaction feel more natural and also to avoid any type of visual interference of the system in the game during the game play time. So, every recommendation will be communicate to the user by a synthesized voice through the computer speaker or the user's headphones.

5.4 SYSTEM MODES

A major concern during the planning of the recommendation system was that the system should be simple, efficient, fast and above all, as discreet as possible, minimizing then any interference with the environment in which the user is inserted. Real time monitoring of user's interaction with a video game can be considered as a stealth mode of the system because it runs hidden from the user visibility. Still, the recommendation system offers another option to the users interested in study their performance. Using the Historical data interface of the recommendation system, the user can observe his past performances, compare them and even do a more profound analysis selecting the different features individually.

5.4.1 *Historical Performance Interface*

One of the most important aspects of intelligent system resides in the necessity to have the maximum amount of data as possible to be able to find the most suitable solution for a problem. The greater is the system knowledge, greater will be its capacity to solve problems. To gain knowledge the system must learn with the context where it is inserted. For the recommendation system described in this work, the principle is the same: system will first start a learning process to be able to evaluate the user performance. Knowledge can be acquired in two distinct ways: the first one use real-time monitoring to save data collected, which means that system will become more efficient after a few uses, when the knowledge acquired will allow the system to be more precise when compared with data; the other way is the possibility, offered by the system, to upload external files with calculated metrics that can be used for comparison, or simply to allow user to observe data in a more organized and readable way at the historical performance interface. Data stored can be analysed in a general perspective where all the calculated values are presented in a table with all the features and a dashboard with four graphics representing the four most

5.4. System Modes

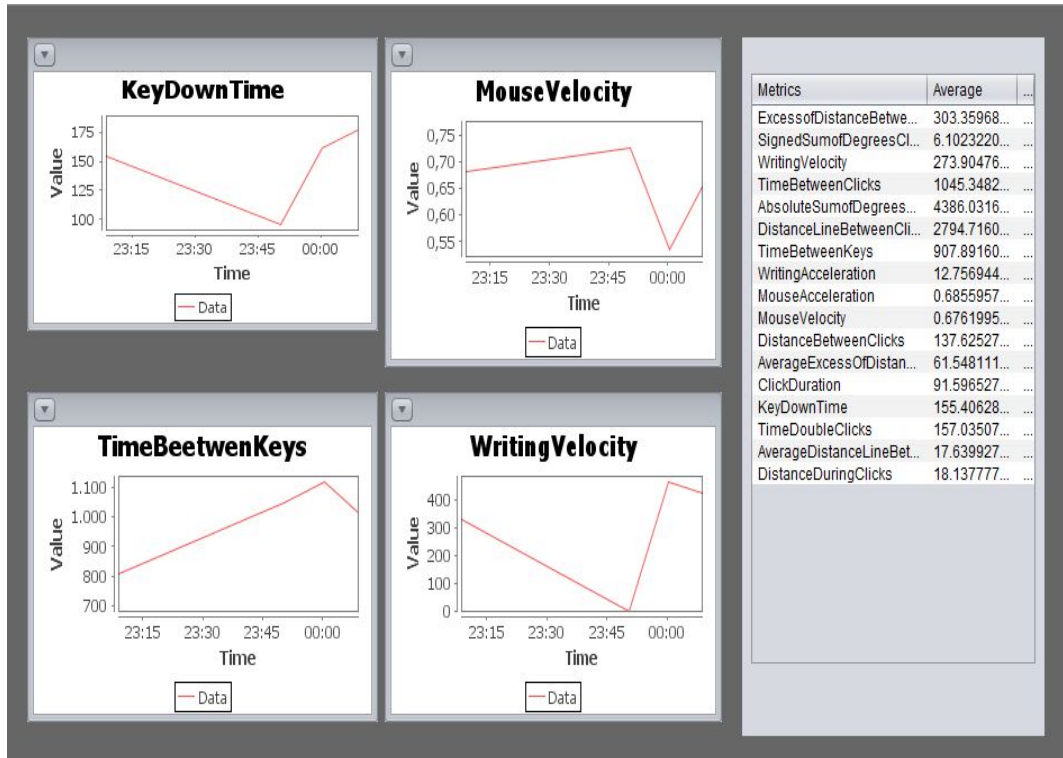


Figure 17: Historical Performance interface.

representative features. An individual analysis can be done selecting the desired feature in the table. The graphics generated by system show the variation of features value over monitored time (figure 17).

5.4.2 Real-time monitoring interface

The ability to monitor one user playing a video game in real-time and give recommendation to him based on his performance is probably the most important feature of the system. To activate this option, user only have to select real-time monitoring button and click into start button.

If all the modules of the recommendation system are on-line, evaluation begin using stored knowledge as a comparison. With data stored in the repository, system calculates range between two values which are the maximum and the minimum values of the general performance that are used to define the maximum and minimum limit. Calculated metrics are then used to calculate the general performance and compared with the predefined interval of values. Then, using proximity of this values to the limits, is defined if the performance is good or bad. This too have a dashboard

5.4. System Modes

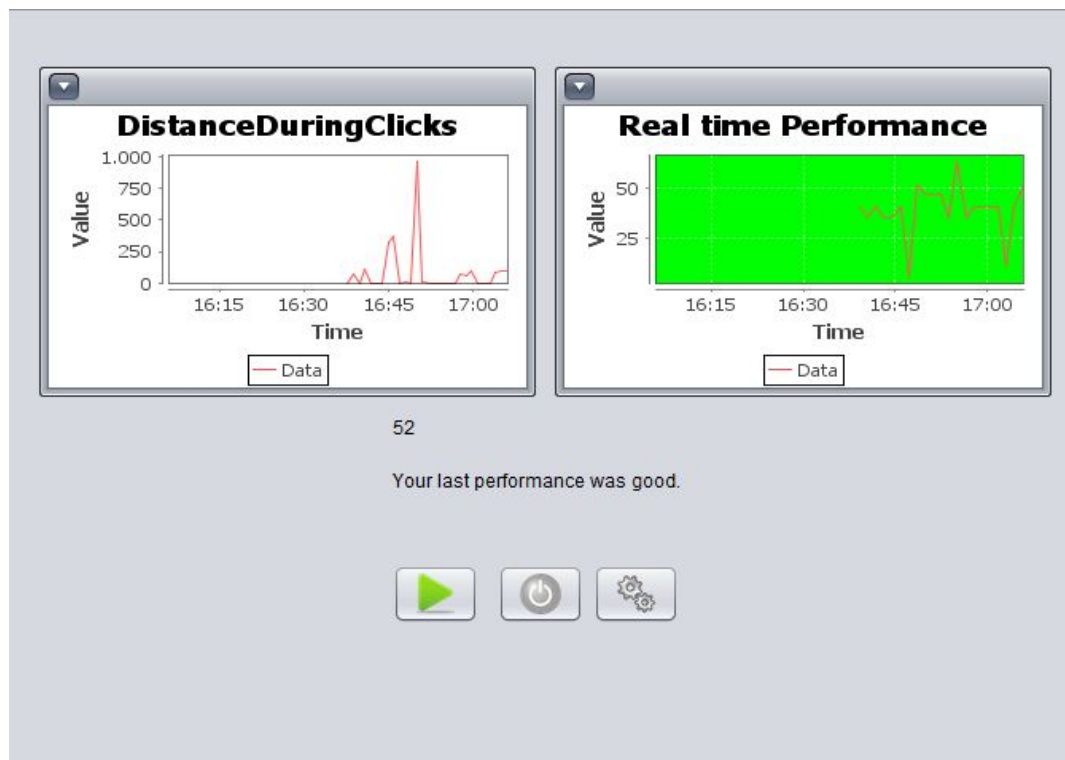


Figure 18: Real Time monitoring interface.

with graphics allowing the observation of the values in real time, once again, the user may chose the feature he wants to see (figure 18).

CONCLUSION

Everyday, people are exposed to emotional stress and high loads of pressure, affecting their well being for personal or professional reasons. Situations of cumulative fatigue and the reduction of hours of sleep are an increasingly common factor that is, most of the time, ignored by those affected.

Video games have become a way to release the daily tensions and give the possibility to people to have fun in virtual and simulated worlds. As we described previously, video games have many positive effects on players but an over exposure due to the excess of time playing and the lack of rest can be very bad for the players. Still, with video games everywhere, even in our pocket, it is difficult to control how much time we spend looking at a screen playing. Too many people spend way too much time playing video games without having the conscience that their behaviour is hurting their physical and psychological well-being. One of the negative effects associated to the over exposure to video games is fatigue, it is seen as a decrease of performance being difficult to detect and subjective.

In this work we decided to prove that calculating players' performance using a set of metrics inspired in behavioural biometric, fatigue can be detected using non-intrusive methods. This work used the same approach of the research done by André Pimenta in "Análise e Monitorização the Fadiga Mental" [38] (Analysis and monitoring of Mental Fatigue) where the use of non-intrusive methods and biometrical metrics proved that Keystroke Dynamics and Mouse Dynamics are capable of measuring fatigue revealing a difference statistically significant between a normal state and a state of fatigue. Using this previous research as a base of knowledge we were able to build a recommendation system using non-intrusive methods to monitor the user interaction with the computer.

During our learning process a study was made in order to better understand how a player interaction with a video game using a computer can vary during time. Using Counter-Strike, a First Person Shooter (FPS), as the chosen video game for the study, the results were unexpected.

6.1. Synthesis of the work done

A set of voluntary players, all familiarized with counter-strike, played three hours in a row in the same context (same weapon and same map). The expected was their performance begin to decrease after a certain point. Still, the results showed that the majority of players' participating in the study increased the general performance until the end of the study, which means that at the end their performance was higher than at the beginning of the study. Two main conclusion have been made as a result of the study: three hours of playing time aren't enough to determine the break point that will define when the performance start decreasing. A more prolonged study is necessary to prove what we were expecting. The second important conclusion is that we were able to observe that usual FPS gamers have a great resistance to fatigue because they are used to play for extended periods of time.

The results of the study have shown the even greater importance to have a recommendation system with an individual model that can adapt himself to each player, because every player have different levels of resistance and different types of interaction with the computer when playing video games.

Considering the paradigm of ambient intelligence the prototype build as part of this work has the particularity to be invisible to the user during monitoring process without any interference that could influence the results, but also to become more acceptable for a player instead of having constantly the system remembering him that he is being monitored. With this work we were able to build a functional recommendation system that not only work as a monitoring and recommendation system but also as a tool that allow the user to follow their evolution and have a better control with the time they spend playing by seeing in a simple way the immediate effects of their behaviour. The best way to make users protect themselves from actions that are harmful to them is to make them have conscience of their bad behaviour which is easier if the information stored is their own.

6.1 SYNTHESIS OF THE WORK DONE

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

- Recommendation system application: A fully functional prototype of the recommendation system have been build. It is capable to monitor player during game play time, evaluate their performance in real-time and give recommendations when fatigue start to show up due to a decrease of the player performance;

6.2. Future Work

- Real-Time performance classification: Based on the data collected and the behavioural metrics calculated, a model was created to determine the value of user's performance. That model allow the system to evaluate the performance and define if it is bad or good;
- Historical performance analysis: The system gives the possibility to the user to store data collected for subsequent analyzes and comparisons;
- Recommendation System Architecture: The Architecture of system was build to evaluate the user performance autonomously.

It is important to note that currently there is no application or tool capable of monitor and recommend video games players. The work done on this project, represents an advance on the field of fatigue detection based on the user performance without the use of very complex, expensive and intrusive systems.

6.2 FUTURE WORK

Although the objectives of this thesis have been achieved, a lot of work still needs to be done to improve the efficiency of the recommendation system. Firstly, a more extended study must be done, since we observed that three hours aren't enough to verify break point which define the point when a player performance start to break and start decreasing due to the fatigue. Another important aspect will be to compare the result between non usual players and usual players to discover if usual video games players are more resistant to fatigue. Other considerations must also be implemented, such as:

- Research new metrics that could increase the efficiency of the detection of fatigue by the system;
- Add a speech recognizer to the system that could receive orders by voice and detect offensive language by the player;
- Improve performance mechanism evaluation by taking in account others users particularities such as the genre, age and if the user is used to play video games;
- Expand the recommendation system to other video games platforms.

Finally, in order to confirm the results obtained, it would be beneficial to use the intrusive sensors to measure users' vital parameters. Indeed, using a sensor we can prove in a more

6.2. Future Work

conventional way when a player is under fatigue or not. And, of course, it is vital to continue upgrading the system with new technological advances that can bring improvements to the system and provide more value to this work.

BIBLIOGRAPHY

- [1] E. Aarts. Ambient intelligence: a multimedia perspective. *MultiMedia, IEEE*, 11(1):12–19, Jan 2004. ISSN 1070-986X. doi: 10.1109/MMUL.2004.1261101.
- [2] Craig A Anderson. An update on the effects of playing violent video games. *Journal of adolescence*, 27(1):113–122, 2004.
- [3] Craig A Anderson and Brad J Bushman. Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: A meta-analytic review of the scientific literature. *Psychological science*, 12(5): 353–359, 2001.
- [4] Juan Carlos Augusto and Paul Mccullagh. Udc 004.81 ambient intelligence: Concepts and applications.
- [5] Martin Becker, Ewoud Werkman, Michalis Anastasopoulos, and Thomas Kleinberger. Approaching ambient intelligent home care systems. In *Pervasive Health Conference and Workshops*, pages 1–10, 2006.
- [6] Germán E Berrios. Feelings of fatigue and psychopathology: a conceptual history. *Comprehensive psychiatry*, 31(2):140–151, 1990.
- [7] Stéphane Bouchard, François Bernier, Éric Boivin, Brian Morin, and Geneviève Robillard. Using biofeedback while immersed in a stressful videogame increases the effectiveness of stress management skills in soldiers. *PloS one*, 7(4):e36169, 2012.
- [8] Kevin Brooks. The context quintet: narrative elements applied to context awareness. In *Human Computer Interaction International Proceedings*, volume 2003, 2003.
- [9] Davide Carneiro. Simulating and monitoring ambient assistant living, 2009.
- [10] Davide Carneiro, José Carlos Castillo, Paulo Novais, Antonio Fernández-Caballero, and José Neves. Multimodal behavioral analysis for non-invasive stress detection. *Expert Systems with Applications*, 39(18):13376–13389, 2012.

Bibliography

- [11] Ricardo Costa, Davide Carneiro, Paulo Novais, Luís Lima, José Machado, Alberto Marques, and José Neves. Ambient assisted living. In *3rd Symposium of Ubiquitous Computing and Ambient Intelligence 2008*, pages 86–94. Springer, 2009.
- [12] Paula A Desmond and Peter A Hancock. Active and passive fatigue states. *Stress, workload and fatigue*, 2001.
- [13] António Farracho, 2013. URL http://pt.videogamer.com/features/article/a_importancia_dos_videojogos_na_sociedade_parte_1_sa_de_2.html.
- [14] Marco Gomes, Davide Carneiro, Paulo Novais, and José Neves. Modelling stress recognition in conflict resolution scenarios. In *Hybrid Artificial Intelligent Systems*, pages 533–544. Springer, 2012.
- [15] J Martin Graetz. The origin of spacewar. *Creative Computing*, 18, 1981.
- [16] Diana L Graf, Lauren V Pratt, Casey N Hester, and Kevin R Short. Playing active video games increases energy expenditure in children. *Pediatrics*, 124(2):534–540, 2009.
- [17] Giampietro Granatelli, Tim J Gabbett, Gianluca Briotti, Johnny Padulo, Antonio Buglione, Stefano D’Ottavio, and Bruno M Ruscello. Match analysis and temporal patterns of fatigue in rugby sevens. *The Journal of Strength and Conditioning Research*, 28(3):728–734, 2014.
- [18] Isabela Granic, Adam Lobel, and Rutger CME Engels. The benefits of playing video games. 2013.
- [19] Mark Griffiths. The educational benefits of videogames. *Education and Health*, 20(3): 47–51, 2002.
- [20] Mark Griffiths. Video games and health. *BMJ*, 331(7509):122–123, 2005. ISSN 0959-8138. doi: 10.1136/bmj.331.7509.122.
- [21] Shona L Halson, Matthew W Bridge, Romain Meeusen, Bart Busschaert, Michael Gleeson, David A Jones, and Asker E Jeukendrup. Time course of performance changes and fatigue markers during intensified training in trained cyclists. *Journal of applied physiology*, 93(3): 947–956, 2002.
- [22] Robert Hockey. *Stress and fatigue in human performance*, volume 3. John Wiley & Sons Inc, 1983.

Bibliography

- [23] IpSos MediaCT. Video games in europe: Consumer study - european summary report, 2012.
- [24] Jeremy Snead (Producer). Video games: The movie, 2014.
- [25] Jennifer Johns. Video games production networks: value capture, power relations and embeddedness. *Journal of Economic Geography*, 6(2):151–180, 2006.
- [26] Thomas Kleinberger, Martin Becker, Eric Ras, Andreas Holzinger, and Paul Müller. Ambient intelligence in assisted living: enable elderly people to handle future interfaces. In *Universal access in human-computer interaction. Ambient interaction*, pages 103–112. Springer, 2007.
- [27] Kolks. Effects of video game play on pain distraction. 2010.
- [28] Nicole Lamond and Drew Dawson. Quantifying the performance impairment associated with fatigue. *Journal of sleep research*, 8(4):255–262, 1999.
- [29] Amanda Lenhart, Joseph Kahne, Ellen Middaugh, Alexandra Rankin Macgill, Chris Evans, and Jessica Vitak. Teens, video games, and civics: Teens’ gaming experiences are diverse and include significant social interaction and civic engagement. *Pew Internet & American Life Project*, 2008.
- [30] Nancy Leveson et al. Medical devices: The therac-25. *Appendix of: Safeware: System Safety and Computers*, 1995.
- [31] Nancy G Leveson and Clark S Turner. An investigation of the therac-25 accidents. *Computer*, 26(7):18–41, 1993.
- [32] Monicque M Lorist, Merel Klein, Sander Nieuwenhuis, Ritske Jong, Gijsbertus Mulder, and Theo F Meijman. Mental fatigue and task control: planning and preparation. *Psychophysiology*, 37(5):614–625, 2000.
- [33] Sakamoto K Kitamoto I Kohji U Tashima S Maeda Y, Kurokawa T. Electroclinical study of video-game epilepsy. *Develop Med Child Neurol*, pages 493–500, 1990.
- [34] TF Meijman. The theory of the stop-emotion: On the functionality of fatigue. *Ergonomics and safety for global business quality and production*, pages 45–50, 2000.

Bibliography

- [35] Department of Economic and Social Affairs (United Nations). World population prospects: The 2012 revision, 2012.
- [36] Ermanno Rampinini, Franco M Impellizzeri, Carlo Castagna, Aaron J Coutts, and Ulrik Wisløff. Technical performance during soccer matches of the italian serie a league: Effect of fatigue and competitive level. *Journal of Science and Medicine in Sport*, 12(1):227–233, 2009.
- [37] Tomasz Ratecki. Fatigue monitoring system.
- [38] André Pimenta Ribeiro. Análise e monitorização de fadiga mental. 2013.
- [39] Samuel Rota, Baptiste Morel, Damien Saboul, Isabelle Rogowski, and Christophe Hautier. Influence of fatigue on upper limb muscle activity and performance in tennis. *Journal of Electromyography and Kinesiology*, 24(1):90–97, 2014.
- [40] Andries F Sanders and Andries Sanders. *Elements of human performance: Reaction processes and attention in human skill*. Psychology Press, 2013.
- [41] Hans Selye. The stress of life. 1956.
- [42] Theatrical Market Statistics. Motion picture association of america, 2011, report, 2010.
- [43] Steam, 2014. URL <http://store.steampowered.com/app/10/>.
- [44] Hong Sun, Vincenzo De Florio, Ning Gui, and Chris Blondia. Promises and challenges of ambient assisted living systems. In *Information Technology: New Generations, 2009. ITNG'09. Sixth International Conference on*, pages 1201–1207. Ieee, 2009.
- [45] US General. Accounting office. patriot missile defense: Software problem led to system failure at dhahran, saudi arabia, 1992.
- [46] Dimitri Van der Linden and Paul Eling. Mental fatigue disturbs local processing more than global processing. *Psychological research*, 70(5):395–402, 2006.
- [47] Shankar Vedantam. Researchers explore mental health benefits of video games, 2009. URL <http://www.washingtonpost.com/wp-dyn/content/article/2009/08/17/AR2009081702114.html>.

Bibliography

- [48] Richard J Williamson, Shaun Purcell, Abram Sterne, Simon Wessely, Matthew Hotopf, Anne Farmer, and Pak C Sham. The relationship of fatigue to mental and physical health in a community sample. *Social psychiatry and psychiatric epidemiology*, 40(2):126–132, 2005.