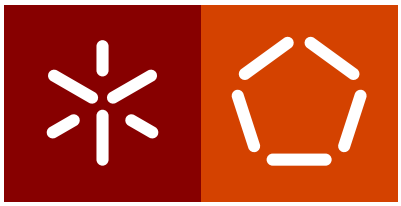

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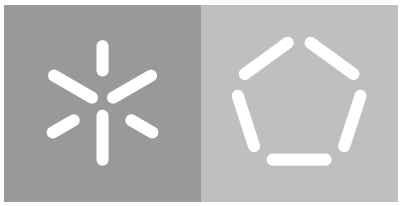

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Monitoring Attention and Performance on Critical Situations

Master dissertation
Master Degree in Computer Science

Dissertation supervised by
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October 2017

ACKNOWLEDGEMENTS

This thesis wouldn't be completed without :

My Mother that supports me every day.

My Father, who gives me advice whenever I need.

Professor Paulo Novais, who showed me my true potential not only during this dissertation but also during the previous years.

Professor Cesar Analide, who gave me useful advice and helped me during the courses while I had him as a professor.

My thesis supervisor André Pimenta for all the help provided during this long process of investigation and writing as well as the opportunity to work alongside him.

To CeSIUM teams, who were with me during three long years allowing me a new opportunity to develop a personal experience while I learned the value of being responsible, working in a team and taking decisions from time to time.

To Doctor Adelino Leite Moreira and his team who faced the challenge of operating my heart during this year giving me a new reason to pursue my dreams and never stop fighting.

To Vanessa Ferreira, who still played a crucial part in my learning process and a big support during my university time even though things didn't work out as intended.

To Carlos Machado and Daniel Carvalho, who allowed me to use their data for analysis during this research and gave me some feedback when reaching conclusions.

Lastly to all the colleagues and friends that worked and supported me during my seven years of university during which I experienced a lot of challenges.

ABSTRACT

In our current lifestyle we often face situations that push us a bit further, over our ordinary limits. These situations can be considered as stress moments that make us react differently from a normal situation, both in a physical or psychological way. While a break can be beneficial to our mind and body when we guarantee proper rest after experiencing this types of moments, when, for instance, we do a physical activity, a chain of stressful moments can have negative impact on human beings leading to serious health problems on the long run if there has not been any preventive action. Whereas the physical aspect is easily understood when looking at, the psychological side is usually forgotten or undervalued because one cannot waste time and focuses on better achievements or simply lacks understanding of this matter. One of the reasons behind this inevitable fatigue is the high competitiveness in the markets, which forces employees to work harder or for longer periods so as to accomplish the same results as in shorter periods of time. In theory working harder can lead to more productivity thanks to challenging factors or it can have the opposite effect when workers suffer from situations like stress or increase of fatigue. In this dissertation we will examine the relation between performance and mental fatigue and will prove how this association works with the help of a simulation environment created for this purpose.

RESUME

À medida que os mercados se tornam mais competitivos, os funcionários são pressionados pelos seus superiores para executar tarefas cada vez mais complexas durante o mesmo período de tempo, de forma a aumentar sua produtividade. Isto pode levar a situações de risco, pois o indivíduo não está habituado a sentir tanta pressão. São situações que não permitem erros, pelo que a atenção e a performance necessitam de estar ao mais alto nível; por exemplo, com um controlador de voos, essas situações precisam de ser seguramente evitadas. O mesmo conceito aplica-se a outras posições em que situações críticas consecutivas podem levar à deterioração das capacidades cognitivas do sujeito e, em casos extremos, onde o espaço de tempo é consecutivamente maior podem provocar de saúde que irão prejudicar severamente a expectativa de vida do trabalhador tanto a longo prazo como no seu dia a dia. Tendo em conta o pressuposto anterior, tentaremos provar a ideia de que situações críticas, distintas umas das outras, precisam de ser abordadas adequadamente, para facilitar a deteção de situações de fadiga mental dos utilizadores, e que existe uma associação entre a fadiga mental e o desempenho ou produtividade de cada pessoa. Para este efeito, criamos um ambiente de simulação que pode ser usado para estudar estes casos de forma a obter os resultados pretendidos. A simulação concentra-se na deteção de desempenho enquanto que para a deteção de fadiga mental será utilizado um software externo, neste caso da empresa Performetric.

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ABREVIATIONS

API	Application Programming Interface.
CPM	Casts per minute.
CRM	Customer Relationship Management.
DI	Departamento de Informática.
DPS	Damage per second.
DTPS	Damage taken per second.
HPS	Heal per second.
MEI	Mestrado em Engenharia Informática.
MMORPG	Massive Multiplayer Online Role Play Game.
NPC	Non Player Character.
PvE	Player versus Environment.
PvP	Player versus Player.
REST	Representational State Transfer.
UM	Universidade do Minho.

1

INTRODUCTION

As society is getting more and more computerised, workers are expected to increase their productivity and work more effectively while using computers or other automate devices that support them. In this way their tasks become complex and require higher mental or physical capability to carry them out. In some jobs this is easily understood. Even though controlling a plane implies lots of automate systems to help it fly, pilots undoubtedly need to react quickly and effectively when an error occurs. The same (difficulty) happens with air flight controllers that control hundreds of planes with a small crew at his disposal, having to communicate with pilots, authorising arrivals and departures for each plane while other tasks are taking place simultaneously. This kind of jobs requires some skills which are not sometimes likely to be acquired. Critical situations don't happen only in jobs that require high levels of performance or satisfy/meet a certain set of characteristics. Currently in most jobs, employees work harder and longer in exchange for excellence performance. This can happen either with regular jobs or in sports careers. As a consequence, situations can cause stress, which leads to health problems, such as depression or chronic stress, mainly when individuals have been exposed to strenuous activity during a considerable period of time. Let's take the example of professional gamers, who can play a video for up to fourteen hours in order to train for the game and compete on professional basis. Therefore, professional gaming teams now have a structure on its core to help players break through hurdles/ obstacles that turn up during their training. This structure ranges from mental and physical coaches who empower their capabilities and prevent exhaustion to game analysts or psychologists that analyse their performance during the game, improve the communication or cohesion within the team and help deal with failure. Finally each situation can be similar considering its critical aspect itself, but it should be looked into from a unique perspective because of the environment itself. It is understandable to realise the complexity of the tasks different from job to job as long as its duration too.

1.1 MOTIVATION

In a critical moment users experience an increase of stress that can sometimes disturb their normal flow of work of the him momentarily physically or mentally. Depending on the job, the probability of critical moments can vary as well as their severity. An increase of customer flow queuing in a store is different from a service failure provided to millions of people queuing in a store. Even though we consider there is obvious difference between these two situations, it is understandable that a critical moment in work status is never good for the companies as they can lose revenue. As for the employees, it can cause temporary effect on their productivity and when recurrent the change will be clear. Therefore, learning to react properly to each situation should be of major importance for the enterprises that run their businesses. Without doubt, companies often favour revenue instead of their workers which can have consequences in the long term. The lack of good work habits and overwork can lead to health problems, changes on their mood and worse performance. These three interrelated factors will severely affect the labour productivity. Bearing this in mind, it is important for workers to take breaks from time to time, recover mental health and do exercise as often as possible to strengthen body and mind. Even though they are connected, there will be only focus on the mental aspect more especially the mental fatigue forum in this dissertation. The main goal of this thesis is to help users by predicting fatigue and helping them prevent diseases that can have irreversible effects in their future

1.2 SCOPE OF DISSERTATION

Even though there are lots of concepts that can be related for the scope of this dissertation, this thesis will develop around two concepts: performance and mental fatigue. Nowadays this two notions are related with each other when we measure characteristics of the working environment.

On the present days companies evaluate its employees by measuring his performance when facing his daily tasks. As the scenario gets more intensive and critical the performance can drop significantly. The characteristics of the environment are a big factor that needs to be addressed when properly identified.

Productivity refers to the amount of work a employee or a machine can produce as goods or services in a period of time. On a economic perspective it is a good value to be measure over the course of years in order to approach the maximum revenue possible. But this is considered in a general way. Taking for example how much is produced over a week or month, we know that production rates are likely to be different on each working day.

On other hand performance is associated to the ability to perform over a situation with a set of characteristics that are related on a much shorter period of time for that activity .

When a critical situation occurs it is key for the employees to react and perform by adapting to the new conditions that were set. If the adaptation is not successful it can cause problems for all the involved parts associated. In the case of a critical situation it is interesting to understand the behaviour of the subjects and quantify their performance from a individual and team perspective. [13] [7] That way we can compare during the interval where the demanding case occur on all the aspects we tracked and improve the detection for further cases that can happen. Furthermore we can easily recover and boost the performance of the workers by the analysis provided each crucial moment.

We can't exclude the fact of productivity and performance are being related to each other and those two are also related to mental state of the user. This final part can help analyse the correlation from a wider perspective. In fact there are studies that indicate that the mental health of the patient has a strong influence on their work in a short period of time and if not taken into consideration it can lead to bigger health problems for the individual from social mentally and physical perspectives. With this looking for metrics that can help the actual tools of mental fatigue detection can be a improvement into preventing this kinds of situations.

1.2.1 *Context*

In an increasingly competitive job market, where each day new applications, business and ideas appear with new and better features, companies try to keep up with the evolving world and push all of their resources to the limit in order to be successful in this increasingly fierce environment. This can happen to any service, company or job. As the complexity increases workers are challenged to make better in less time to keep up with this revolution.

Of the resources that can be associated with companies, their employees are a vital part of the companies' success, to which they are exposed to physical weariness and increasingly to psychological or mental wear and tear. With the accumulation of consecutive hours of work per day, with a limited number of breaks or even without any type of rest, this same group when exposed for several months to this type of wear can in most cases reduce its potential for Undesirable levels by the company and by the individual himself, being noticed by income or performance. [34]

These performance failures can be associated with conditions such as fatigue, burnout, or even lack of attention at work.It is sought to monitor these various aspects that can be good indicators of evaluation for employees so that there is a better management of resources and time, seeking to improve and increase their productivity. With many possible market areas and *tracking* of these metrics, it was necessary to search for the most needed area of this same monitoring. With such a big diversity its important to look for situations where is more obvious the importance for this matter. So looking for situations where a drastic

change happens is crucial for the success of this matter. Since every situation is unique it is also relevant to mention that since every situation is different it should be taken as an isolated case in the first instance and then compare with other similar situation. A critical environment will always trigger more metrics that can be used later for analysis.

Bearing this we use a game environment with several difficulties to simulate normal situations to chaotic ones from two different perspectives. The results from this investigation if successful will result in more open possibilities that can be used for each specific situation after the proper study was made considering that performance necessary for the success of those cases.

1.3 work theme and objectives

The work is based on using distinct systems that can provide us with metrics for analysis that can provides useful information such as the importance of that value for the system and the relationship between them. The systems should be based in two different perspective. The first related with the performance of the user on the environment or as biometric values and the mental fatigue of the instant of the user. On the analysis the idea is to get the same time stamp for each systems and compare results in order to prove the value of performance into fatigue and vice verse. This will be done using statistical formulas to have concrete outcomes. As a conclusion some of the metrics are available in some APIs that can help us define better the environment and compare with other users later on. If the outcomes are position it can be concluded that each situation can have a different perspective to be analysed.

To follow this investigation methodology it will be followed the following steps:

- Specify the problem and its characteristics.
- Constant Update of the State of the Art.
- Modelling and Implementation of the system.
- Analysis of the results and formulation of the conclusion.
- System validation.
- Specification and disclosure of the final results.

1.4 dissertation structure

The structure of this dissertation is gonna be presented as the following: On Chapter 2 will be presented the state of the art off relative to the subject of this report. It will be also

presented a small case study that will be subject to examination during this project. During this case study will be presented all the possible routes and which choice will be taken in order for the success of the project considering the closed environment on what be created the system. Considering this it will be also introduced the main aspects to be monitored during this assignment in terms of better precision to guarantee good results in the end of the dissertation. Some of the aspects need to be develop in order for them to be used as results. On Chapter 3 the main concept is around the simulation environment that its gonna be created for this work. On this chapter we discuss the challenges for this simulation as well as the expected results for the outcome of the project. On Chapter 4 represents the development of the structure as well as some programming decisions that were taken into consideration during the work flow of the dissertation considering between the initial programming to the final results. In this chapter will be specified with a high level of detail the architecture of the system that was programmed during the months of investigation and main concepts that were developed during this period as long as the difficulties that were encountered. There will be also discussed the metrics that were considered the most relevant. Chapter 5 concludes this report where will be presented the results of this investigation as long as possible future work or next steps for future investigations on the subject. Other considerations will be present if they are considered important. On Chapter 6 it is mentioned the future research that can be done from this starting point.

1.5 Work and Investigation Methodology

For this project it will be necessary some preview investigation to get previous analysis around detection of mental fatigue and the implementation of that detection on critical situation as well as other encounters that are the main target of this investigation. Considering all the information gathered we look forward to implement similar data collection centres to focus on performance, mental fatigue and reaction or that in some way can help existent programs detection this kind of problems. With that data collected we look into create a system that can work with the collected results and create a output as a conclusion. To get a better group of results it will be proposed a investigation method between the research part until the end with proper conclusions where we follow a action-research methodology. [24]

That way the project will be divided in the following steps:

- Bibliography Investigation of Non Intrusive Methods
- Writing of the Preview Dissertation Report
- Development of data gathering methods in simulated environments

- Development of networks to interpret the data obtained previously
- Experimentation on premises
- Conclusion of the results
- Writing of the final dissertation

2

STATE OF THE ART

On this chapter we are gonna present all the relevant research that supports the dissertation plan and was done during work flow of this plan. This chapter will be divide in two distinct sections. The first subsection gather information and dissects the perspective of critical situations on the human life especially the viewpoint on the current jobs for workers. Their will be discussed the potential problems in some different environments that can be related to this moments and how can they be solved. The second part of this thesis is all about the concepts that will be involved during the investigation and that are related with the first segment. Finally on this section it will be presented some existent applications that are working into solving this issue and apply better health habits on the business and their workers.

2.1 CRITICAL SITUATIONS

A critical situation occurs when conditions are created that will affect the normal behaviour or functioning of a exercise. This can be also named stress situation because it creates tension on the individuals or machines. This relationship is felt more closely when the environment interferes with the optimal state of the system. [14] Despite the fact that stress is related to a person it has a lot of influence on the environment itself by creating the possibility of spreading to itself such as more individuals. This can cause reactions that are a consequence of this effect. Nonetheless a situation that requires way more power to be executed instead of the normal to be performed is usually considered a bad situation but sometimes that not the case. An example is when someone makes exercise. In a moderate amount of time it helps the human physical condition for improving blood circulation or reduce the overall stress condition but if it is done for too much time it can cause for instance muscular pain or burnout. [14] When talking about machinery a stress point is when the capacity of that machine is being used over it. The same can happen for the human being as it is more complex affecting the physical and physiological systems and forcing sometimes uncontrolled reactions.

This conditions can be caused by unpredictable situations such as noise or by characteristics of the environment by the demanding of tasks can lead to reduce of performance to the system. [9] Even though the human is able to adapt to this extreme situations there will be always repercussions that in some cases become permanent. This symptoms at start can be harmful but continuously can lead to critical problems on the human health including mental and socially. This kind of situations should be avoided at all cost and reported as soon as possible to avoid harming the health of the systems involved or decrease the normal performance of the work flow. [9]

2.2 INDUSTRY COMPETITIVENESS

Each year that passes on the industry and his markets are more competitive between them. This competitiveness appears with the increase in difficult in acquiring new clients or maintaining the actual ones making the costs associated with it increasing every year. Some studies refer that a bad service provided to a customer can create a damaged brand which can cost a lot to repair. This is mainly because of the passing of word from that experience that can lead to possible customers to think twice into trying that service from the experience that was reported by that specific customer.

With this market competitively enterprises are forced to be more severe and competitive in the publicity or strategies to approach the clients. From new studies in this century new economical ideas appear such as consumer loyalty to a company, customer relationship or market value per customer. This are now used to help on the strategies to increase the market value and the value of a final consumer. [15] [1]

This vision on improving the service given to client is a huge step into improving the overall satisfaction transmitted to the clients. There have been several improvements on this new way of thought always looking to increase revenue for the company. For that the employees providing that support need to be in the best shape possible. [1]

For instance the creation of Customer Relationship Management (CRM) applications in order to improve the relationship between the company and the client try to fix part of the problems. This applications facilitate in getting data from either clients and employees if the ideas traced previously are getting accomplished. However since this applications try to replace manpower companies reduce their staff and with the increase of number of clients using this service the flow gets bigger for that same number and it creates a constant flow of critical moments for those employees to answer. [39]

Using this kinda of data can not only help increase the overall income of the company by analysing it from a statistical point of view but also to understand if the productivity of the workers in on point. [4] From this point of view it is possible to evaluate from our

perspective if performance and mental fatigue is related to stress problems caused by the jobs that employees have.

This situations put at stake the health of the employees creating the probability of mental stress, blood diseases or even burnout so its important to raise awareness for this matter. [29]

There are also studies that indicate that poor management on the company along with overload and complexity of the tasks can reduce the performance of the employees. [50] This can also lead to less job satisfaction that have influence is the work performance. [16] Since the performance of the employees have significant importance towards the company performance [50] it is of some severity to adopt strategies that can reduce those factors and improve the overall performance of those two parts.

In some situations where it is important to have a fully alert state to have awareness of our surroundings an increase on mental fatigue can create problematic situations or in a worse case fatalities for example in the aviation industry. [28]

The same happens for instance in the gaming industry. Even thought E-Sports a diminutive for electronic sports is a trend at the moment in society and there is now more concert into creating a health environment for the whole structure that exists in this industry its common sense to understand that players face a high degree of stress on this job. It is considered now a normal sports even thought there is not a lot of physical activity it requires a lot mentally to execute the tasks this players have. The average life job for this players situates between sixteen and twenty five years old with some exceptions. Players are subject to up to 14 hours of play per day to train for the actual games on the stage. This amount of time played can lead to problems from the physical and mental forum. From the physical side it can lead to back injuries, carpal tunnel syndrome or pain in the muscles. This kind of problems can be prevented with regular exercises to fortify the muscles and avoid problems in the posture of the player. On other hand, a high amount of hours in front of a computer without breaks to clear the mind can lead the mental forum problems on a human being. In extreme cases can lead to mental fatigue, stress or conscious lose. In a more extreme way they were occurrences of severe problems and even death for players that played for more then 24h straight. To avoid this situation teams now have physical coaches to help players recover physically from the long hours of sitting in from of the computer, mental coaches to support them on after a lose or to put get all the team in the same direction and analysts to evaluate the performance of the team or just one player in question. This structure helps players reach their maximum performance in the right conditions when they perform in stage against other teams. Obviously there are other factors that are important in order to make the team success like cohesion of the team, good environment and the skill of the players. Finally the training itself its important towards learning and succeeding and that's why players train so much.

Analysing performance of the individual in this situations of stress on the players represent extreme importance towards helping this situations and similar ones into increasing their performance without sacrificing the health of the users. With that in mind this thesis is gonna focus on predicting mental fatigue based on metrics gathered from the games. These means that we are not looking only to increase performance and the success of the players but preventing in the future diseases from the mental forum that is becoming common in the current society.

2.3 VIDEO GAMES ENVIRONMENT

Video games are usually associated exclusive with negative effects on the life being of the humans with special attention for children. As the video game industry gains strength with popular franchises that develop games close to reality and with mature content teenagers get addicted to them [19] [20], they tend to be more aggressive [18] or have problems from the social behaviour forum[17]. In other articles it is being done the comparison between gaming addiction and pathological gambling [49]. Finally proven research show a relation between excessive gaming and some health problems such as obesity, sleep anomalies , stress, depression and anxiety. [45] [23] The investigation around this concept is on a early stage but is starting to be taken as a serious matter by the health community when it was proposed in the past to be considered as a new pathological illness in the society. [22] There was also related in a earlier study the correlation between arcade games addiction and television addiction. [43]

In the most recent studies it was noticed that in subjects that have the background of being addicted to video games were more impulsive towards giving a answer when failed a lot more times rather then the control group. [26]

Meanwhile video games in moderate amount can effect us in a positive way. Its easy to understand that video games can be used to escape reality from our daily problems or in some situations to join a community inside of it. [44]

In certain conditions video game can be educational by training a certain skill or to be used to face a specific issue. From the past it is said from previous researches that playing computer games reduces the reaction times, improve hand-eye co-ordination and increase the players self-esteem. [27]

When used properly video game can be a powerful tool that can be beneficial to society. As an example video game can be used for research being the perfect simulation to recreate a environment that wants to be studied or to use that simulation to teach a specific target of people a new skill that requires certain parameters. For teenagers or children there is the possibility of creating goals for them to archive in order to succeed. Video games are generally interesting creating a sense of loss of reality and focusing on excitement for the

player. This type can also be used for every age and used with technology creating the possibility of post analysis in terms of performance of the player and their characteristics, goals achieved and feedback for the subjects. This said video games not only can help improve a person but also are a excellent tool for new iterates on new cases that need evaluation and approval. [27] [25] [46]

2.4 MONITORING MENTAL FATIGUE, ATTENTION AND PERFORMANCE

In this section we will present the state of art to the concepts of the values we are looking to deliver as output doing this thesis. Some considerations that we find relevant during this section is that this three metrics have a relation between them and are very important towards the health and performance of the user. We will divide in each subsection and explain why this aspects are important for this dissertation and how can they be measured presenting some examples for better understanding.

2.4.1 *Fatigue*

Human cognitive functions such as perception, attention , memory or decision making are constantly present in our daily activities. So it is even more important to understand the relation that the activities we performance and our cognitive systems are connected to accomplish the maximum performance during the exercise of our tasks.[33]

When though when talking about fatigue we consider it a very subjective matter it is related with the previous point. The increase on the interest from the civilisation on having good habits towards the well being of themselves makes a concern on the importance towards the direct relation between fatigue and the role it develops during their own health.

This concept surges as a limit capacity that affects the human being on the realisation of their own tasks caused by symptoms that are associated with this status. Some of those manifestation can be loss of attention, low productivity and performance or even less quality on the task at hand. This ones are not as visible as others such as somnolence or tiredness that come when the individual has long periods of time of work without resting or breaks during the job time. [33]

So this concept can be wide being most of the times associated with low performance and diminish of attention. This two can lead on the worker the surge off new errors that were in normal conditions considered unnecessary and drive to less capacity on executing activity that in an ordinary way would be enough. In some extreme cases this failures can less to fatalities such as piloting a plane full off passengers. [33]

Another example is a flight controller that needs to have the capacity to react and to observe lots of planes coming and departing from the airport he is surveying.

When the extreme cases happen regularly during lots of days it can cause to the individual severe mental issues , constant humour changes that will require medical treatment later. Some diseases that have a big relation to this are depression, stress and chronicle fatigue.

Fatigue is an aggregation of mental fatigue and physical fatigue with direct association a problems related with sleeping, stress and some other health diseases. There is also a known relation with psychological problems such as depression or humour changes.

Mental fatigue affects the individual brain power reducing its power of reasoning, decrease in attention and increase on the reaction time during the execution of their own tasks.

Fatigue can also be classified with physical fatigue when it involves muscular tiredness or resistance limitation from the man associated with physical effort involved in the activity developed.[33]

We can also categorise fatigue into chronicle fatigue when it occurs persistently in the user even when there was resting associated. Ordinarily there are rare diseases associated with reasoning losses related with mental and physical exhaustion. This requires special treatment mainly because their own life is very affected by this health problems especially limiting the activities they can perform.

Finally we can classify the fatigue into sharp fatigue when it is felt in a instant way usually associated with rapidly and intensive physical effort or during several days with a big level of efforts performed on that daily basis.

2.4.1.1 *Detection For Mental Fatigue*

As an example for intrusive methods that can have some good results into detecting fatigue we got smartCap, a hat device that looks into gathering cerebral information from a electroencephalogram (EEG). If it detects the imminence of somnolence emits sound warnings. [42] [47]

Fatigue can be also measure with the help of questionnaires from the subjects that are being tracked, by tracking its performance while performing a specific task or using eeg tools to detect the changes while doing a job. [33]

On the revolutionary side we got a start-up called Performetric that detects mental fatigue based on the interaction between the user and the input devices present on the computer such as the keyboard and the mouse. We will explain with more detail in some sections ahead but what this company does in a brief explanation is collection data from that interaction as biometric data and after a proper trained network it returns a numerical number of fatigue from 1 as absent of mental fatigue to 7 as completely exhaust. It is a non intrusive approach without having any gadgets attached or looking at the user while

he is performing his tasks delivering a more natural state removing the influence that could be caused otherwise. [3] [30] [6] [8]

We look to attend some possible flaws that can occur during the usage of this application such as being too generic for all situations. With that in mind we look into a specify case to find more metrics that can reveal metric towards the optimisation of the network. We also look to find some patterns in stress events that can happen during a period of time and look in more detail for a brief interval shortly before happening and the same after the event happens. If we prove to be successful we can improve the results of Performetric software and improve the detection of the mental fatigue for the users that use this kind of software.

Currently measuring fatigue is of extreme importance towards the success of improving the health environment of the human being. However this measurement is on its early stages as companies are developing or improving its application to be more reliable.

2.4.2 *Attention*

The attention concept is based on the capacity of an individual performing a certain task without having interrupting caused by him or by the environment. It can be classified in direct or secret attention. In the direct capacity we have the capacity of redirecting several sensory parts for a unique stimulus that we pretend to have. On the secret we can the power of focus to a single stimulus.

Monitor this value is commonly studied from a scientific point of view where it used image detection devices such as cameras to detect the movements of the head or the eyes to detect patterns during the execution of one single task. There are also studies involving the usage of sensory devices such as EEG to detect sensory patterns that involve brain usage during the same procedure that involves making a simple task. Both this methods look forward into finding out how the brain and the user behaves on full attention or when it lacks it.

From a economical point of view this is considered a important point for the business. It is key to see the behaviour of the employees doing a daily basis work to check if they are doing their tasks on the best way and with the maximum focus possible. This can get extremely important when we are considering jobs that have some interaction with the final consumer where making a failure can reduce the maximum profit taken for the business.

During the work flow of this dissertation we look into find patterns that detect the decrease of increase of attention during the course of the work during the hours.

2.4.3 *Performance*

In society performance is usually related with the act of performing. It is commonly used in arts, sports to represent on good the individual performed on a certain task. For instance when a sports player has a not so good game we can say that he performed poorly or the below his normal expectations. In science performance is a field of research for every kind of jobs that relate the capacity of performing a certain task. This is used to test out of most of the times conditions that can be related to the job characteristics such as a stress environment and uses a set of methodologies to understand the mechanics or skills associated with those experiences. Some studies related that mental practice can be used in some cases to enhance performance. [21] Performance can be measured by comparing their development with others that are on the same conditions or using a set of tools that can properly measure how well the job was develop. To end this its usually a metric that is more taken into account a short period of time.

2.4.4 *Productivity*

Productivity is associated nowadays with a concept close to economics. In a generic way productivity is an association between the amount of product of product we can deliver per industry capacity. The industry capacity can have lots of factors associated with it, from number of machines, workers or the amount of resources we have. In this case we are talking about delivering a product but this concept can be also related with supplying a service to the user. In this thesis we are focusing on the second part, where we consider the concept of productivity related with the amount of work a employee can do on a daily basis.

Productivity is usually a metric that is used to evaluate a worker during the course of this work. One of the reasons is that there is commonly linked to the quantity of product or service the collaborator provided per time. Since this is very similar to the economic part of the business its easy for someone from marketing to analyse. Also it can be used to continuously to compare the productivity between collaborators. Both this ideas can be considered wrong if the analysis is made from a outside perspective or considering the fact of everyone having a different work method where more work doesn't mean necessarily a better one so it can be considered a difficult metric to calculate for a unique employee.

There are hundreds of applications, ad-dons or extensions that can be used to increase productivity in a individual or collective way for the tasks in a daily basis. Some examples are:

- Any.do - Managing app for individual or group tasks

- Asana - Project manager for development teams
- Boxer - Management of mail service app

There are also applications that block certain websites or apps that are considered a productivity breakers. Finally there can be found some that just provide information on what have we done over the day.

In a work perspective this applications can act indirectly to the productivity of the user based on the sense of being watched creating an unnecessary stress disorder that can be transmitted physically or emotionally. [5] [36] This stress can lead to mistakes that in other circumstances would not be committed. In certain situations this failures can lead to more serious concerns for example while driving a car. This intrusive way for monitoring can lead also to distractions or failure in the capacity of dealing a response in an acceptable time. [31]

For this reason having a application that monitors metrics that can be obtain in a non intrusive way help to employee to behave in a normal way during his work time reliving him from the emotional or physical stress associated with him empowering his maximum potential. The necessity to warn the user to rest from time to time or on a mental fatigue spike can help increase the productivity of the employee, reduce the probability of mistakes made and increase his mood and health during the week.

Considering a quick example with a online call center we can get certain metrics to evaluate his productivity and to understand if he is doing the job on his max efficiency. As for that we can look at some of the metrics that are used nowadays in order to evaluate the productivity within a single collaborator:

- First Response Time
- Medium Response Time
- Total Resolution Time
- Satisfaction Rating

In this case of study we look into attributes related to the concept of gaming where we are gonna analyse. Up ahead in this document will be a section related to the case study , the metrics and all the decisions taken in order to accomplish the results.

2.5 SUMMARY

In this chapter it is possible to have a perception from the basics that cover performance and attention monitoring and from this point start to work on the objective to this dissertation.

It is necessary to understand the mechanics that are at the moment used to track this metrics and from that be clear when creating the simulated environment to obtain the conclusions that we are looking for. From that creating a smart application that allows us to monitor the data that pretended in order to favour the targets that are being analysed. This examples and structure presented above is essential for the success of this dissertation. [37] [38]

3

SIMULATED RESEARCH ENVIRONMENT

This chapter describes the proposition for the simulation that is pretended to reach our goals. It will described the technologies existent for some cases that were previously described shortly. The simulation pretends to simulate this type of situations and in case of success, to describe the data and characteristics given as output, in order improve the detection tools into detecting fatigue by analysing and unifying each situation as its own. It will be taken into consideration all the concepts explained in the previous chapters as for the state of art and also introduced new ones that describe the simulation itself.

In a summary we want to analyse data from a simulation environment that can have critical situations during that interval and compare it with real mental fatigue data that was tracked in the same interval and understand what are the metrics that have influence on the mental fatigue during that simulation. The simulation will be recreated using a video game that contains loots of variables for analysis providing an exceptional tool for the pretended project. In this settings will also be considered the different difficulties present on it to reproduce different quantities over similar intervals of time. The success of the simulation will also be taken into attention providing extra feedback about the correlation between each of the metrics. Video games are easily one of the best tools at our disposal being easily adapted for any kind of simulations especially for research purposes. The existence of a great variety of games with very different specifications from fast paced to games that require a bigger thinking process allows in a quick way to analyse the effect of those in the subjects.

Discovering major differences between a less stressful interval to another is one of the expected conclusions. Finding a correlation between status of mental fatigue and all the findings can help increase the accuracy on any mental fatigue application providing a better profiling of a user to help increase his performance reducing the fatigue over the week and decrease the probability of health related issues such as burnout as a consequence of it.

In the following section we will talk about the Performetric application is implemented at the moment and what is the potential that this dissertation plans to take.

3.1 SIMULATION ENVIRONMENT

Considering the previous section it is now key to present the simulation that is gonna be used for this investigation. As for it all the ideas behind it will be presented during this part. Some choices had to be taken into account when of the implementation of the system. Starting to explain the environment and their details as well as some important facts that can be relevant for a better understanding of this work. This simulation will use a game that provides a lot of metrics available to calculate generic data from it as well as the performance of the player. It will be in more detail in the next sections. The idea of choosing this concept is to create the possibility in further investigations the opportunity to use similar concepts in real life situations using real data. After this research the same thought process can be used into finding the similar or new correlations in real job situations where for example dealing with customers can be stressful and reduce the overall performance of the employee.

As said previously games can be used not only to have some leisure time but also there are very commonly used in investigation for some particular cases with an objective on each test. This will prove a worth fact because we can exploit every possibility that can be evidence as a proof of concept in real life situations or as a base for another simulations.

Also there are some assumptions that have to be taken but will be explained on the reason behind them.

For example the performance of a player in a single match can be measured with the final statistics that appear in the end of each match. In a long term with lots of matches is possible to start to understand how a player is evolving generally in terms of skills. On a single match it is near impossible to predict if a player is breaking down from fatigue for example unless there is a lot of data analysed previously for the matter.

On other hand it is interesting on a single game to understand how the player is reacting to everything as the game progresses and in what way the user behaves to a event that occurs within the course of the game. Some of this concepts will be explained in the next section.

3.1.1 *The Environment*

The description of the environment can be of severe importance towards what is pretended as a result of each simulation. Some simulations require a fast paced reactions while others require some strategy forcing to be a more thinking environment with less moves per time as a consequence of the thinking process. It is important to consider the type of game that we are going to analyse, a shooting game requires precision and reaction times while a strategy requires some logic, actions per move and a lot of coordinating. Being a team

game is also important for the matter because you may be reliant of your team mates to be willing to perform in some cases when providing for example a action to be made. With all this choices we find out of interested targeting what can be considered as essential to this document. Finally some games protect their own data during the instant where it happens only giving on the end game its statistics which even though it can give some useful information most of the time is not providing the whole story. All things considered we are gonna use game that is currently a top hit for the players.

The environment where we are gonna record the metrics to be studied and classified is a game called World of Warcraft which is a Massive Multiplayer Online Role Play Game (MMORPG). This game was launched in 2004 and ever since has been getting content to keep their players entertained. Even thought the game has a lot to offer on the players we are only going to do our investigation on a small part of it which is the raiding.

Raids are considered the late content of this game and the games that are related to the same category. It consists in a sequence of mobs, bosses or events that require coordination, focus as well as the proper level and equipment in certain cases to have a chance to manage it. It is an optional part of the game because players can still reach the max level without needing to participate on this section of the game.

This part of the content is included on a section of it called a player versus environment as Player versus Environment (PvE) where players fight against computer based mobs or computer driven events. There is also in this type of games late game context that involves player versus player and in WoW it is no exception. Both of the two modes are challenging for the players in certain conditions.

The reason why we are opting for the player versus environment instead of the player versus player as Player versus Player (PvP) is that we want to contain and control the data for a simulation purpose where the data is more specific and more predictable then in a player versus player situation where every match is different because of the human side of it. It should be an interesting investigation as checking in further studies the reaction to what the other player or players are doing in a certain moment. For this purpose we will concentrate our focus on the PvE meaning the raids that are available in the game that provide some challenge during the investigation period.

3.1.1.1 *Raids*

We explained briefly what is the concept of an player versus environment. In this subsection we will talk with detail about raiding and how can we simulate an environment for investigation.

As we said before a raid is part of the late content of the PvE part of the game and it requires some specifications to be considered a raid. As for gaming experience the player passes most of his time alone doing objectives or quests to success on it. As you level up

you can add players to help with those objectives and in some cases participate as a group of five users in a dungeon that increases the difficulty of the game unbeatable alone in the same level range.

In case of the raids the main idea is to defeat bosses and mobs where the challenge is even higher so you need a bigger group to face those challenges. As a rewards you can get some of the best equipment available in the game if succeeded. A raid consists of at least a group of ten players that number being scalable up to thirty players in order to accomplish that. There are three difficulties as for this expansion that can be acknowledge and tried by the players each one more difficult and challenging for the group as it follows normal heroic and mythic difficulties as each level adds up new challenges. This challenges can be a bigger boss health pool increase of damages taken by the players or new spells or phases that require mechanics to be passed on. Adding up the mythic difficulty required a minimum of 20 players to be contested.

Each subsequent level adds up better loot that can be used if the challenge has passed over. For the competitive side WoW challenges teams to be the first worldwide group to finish all the content in the mythic challenge. Usually the ones finishing this kind of objectives are professional guilds where the players spent an average of ten to twelve hours a day playing this specific video game.

We can consider the normal difficulty for casual players , the heroic for semi-professional players and the mythic for the professional players or the ones seeking a high competitive challenge.

Finally it is important to mention that on a raid that are several bosses and mobs each one different from the others requiring specific ideas and strategies to beat them. Adding up each subsequent difficulty adds up to more cons why addressing the boss. Can be new abilities to be dodged, more damage to be avoided and sustained and a bigger health pool on the boss itself.

So as a team there is the necessity of coordination and communication for all the members as a whole for the attempt on the success but there is also the individual challenge on dodging abilities or dealing the maximum output of damage or healing. We will enter this part in the next subsection.

3.1.1.2 *Composition of a group*

On the previous section it was explained the concept of a raid and the biggest challenges for the players trying to succeed on it. On this section we will break down some of the ideas behind the usual composition of a raid group in theory. This section is relevant to understand some of the decisions behind the data to be collected.

We can divide the players that participate on a raid in three different groups. First we got the tanks that are responsible for sustaining most of the damage.This doesn't cover the

whole damage that is done to the team but it is a considerable amount. Secondly there are the damage dealers that are responsible to give the maximum damage possible into boss during the fight and finally we got the healers that are responsible to keep everyone during the encounter safe from dying by healing them.

Each of three groups are important for the success of the encounter and each job is well defined and needs to be address properly for the favourable outcome. Frequently the composition of ten players squad is consisted of one or two tanks depending on the fight mechanics, two or three healers depending on the fight difficulty towards the healing process and the rest as damage dealers. As it scales the composition can vary leaving the constitution of the group somewhat flexible towards the fight.

As simple it looks we will enter in more details in some of the generic mechanics that will be taken in consideration as for this dissertation.

3.1.1.3 *Enrage*

The enrage can be also describe as berserk or frenzy being the ability for the boss or Non Player Character (NPC) to be extremely powerful during a period of time. There are two types of enrage , hard enrage or soft enrage. The hard enrage is a generic timer often is most of the encounters the player experience and gives the boss the ability to wipe out the group if it doesn't die within a specific time assigned to do it. This mechanics counter the possibility of adding up as much healers possible to keep a small part of damages alive for the boss encounter. This mechanic tries to balance out amount of healers and the damage necessary to be dealt before the time runs out and the enrage happens. The hard engage translate into giving the boss a big increase in damage and attack speed resulting in the incapacity of holding off the damage output as well as defeating it unless the target is close to be defeated. [12]

This narrows the data collected from the game of each fight to a few minutes for each attempt. Even though that data can be referent to that short period of time it can be measured in a performance way for the player as well associated to the mental fatigue of the user during that interval.

As for the soft enrage they are usually present in encounters without a hard engage. This kind of enrage can come in several forms. Some of this enrages can happen when a group makes a mistake on a specific mechanic present on the fight creating a situation that an lead to out of control for the players or when the boss reaches a certain percentage of their health and it is induced a new mechanic that needs to be addressed. Even though this are just some examples you can see how this can affect the gameplay and the success of the encounter. [12]

3.1.1.4 *Aggro*

Aggro is a jargon word originally derived from the English words "aggression" or "aggravation" and denotes the aggressive interest of a non player target as NPC to a player. This mechanic is super important towards the tanks because they have to control this mechanic. It is measured in percentage and counts as the percentage of attention the boss has into you. Every incoming damage from the group creates a threat towards the boss that ranks up the aggro meter towards them. There are spells to reduce the amount of aggro for the damage dealers and spells to turn attention from the boss to them increasing the aggro towards them. This is frequently important mechanics of some encounters on holding aggro from the tank side. Usually the last players of the group dying are the healers cause of the amount of target they gave to the NPC. [11]

3.1.1.5 *Addons*

An addon is a piece of code that is implement outside of the game by the community in order to achieve an objective. This modifications can be added to the game in order to enhance the gaming experience for the players. Each addon has his own functionality going from improving the user interface of the game by cleaning the default interface to add new buttons with new functionality. Some advanced addons can help the player perform on certain tasks inside the game. For the raids it can warn the player when a event in about to happen in a encounter. [10]

As for support on this dissertation we are using a program called WarcraftLogs which comes in a two part set. The first one is a addon which can be used in game in this case in the World of Warcraft game and transform the game recorded data into structure data. The second part is a platform where you can upload that data for later analysis. The data is recorded into the operative system by the game and transformed by the addon.. [51]

There are some other ideas will be shown during the development chapter in more detail.

3.2 METRICS

Having explained the concept of the simulation environment for this dissertation in this section there will be here now a brief analysis of the metrics that will be used during this simulation. During this phase is expectable to look just the main concept without going into much detail to get the core to keep all the possibilities open. Its important to get a perception on how to measure mental fatigue and performance and how can we related them to each other. The metrics that we looked are gathered considering three aspects. First aspect is metrics that are related in a general perspective to the simulation itself describing it or the user. After we look for values that can be related to the performance of the user. To

complete using a specific software gathering metrics that describe the fatigue of the user. All this metrics can be related to each other using it to characterise the scenario that is created on each iteration. Because the objective of this dissertation is to gather new possible metrics that can be used to either be connected in some way to the mental fatigue detection or used into creating a performance output with them it is important to understand how effective them can be used from an outside perspective as well to comprehend some decisions that had to be made during the continuous work. For this gathering the metrics in the same time interval and associating them becomes key for the outcome of it.

As for the game itself the metrics will be explained in more details in the development chapter because of the decisions that had to be taken into account during the development phase for further analysis.

3.2.0.1 *Performetric Metrics*

The behaviour of Performetric[32] software is very simple and effective. The general concept can be divided into a two step process as the first one gathers behavioural metrics information from the usage of the computer by the user and the second the algorithm interprets the data that was previously gathered. There are small details that are not relevant for this work in cause but are also important for the success of their application.

Considering now the biometric data information gathered on the first instance we can divide it in two pillars. The first is related with the movements that the user makes while using the mouse or touch pad. The second main pillar is the data is related with the way the user presses the keyboard. Both types of data are recorded and stored when the user is actively performing their day on day tasks. With the data stored the algorithm works with that data and returns a classification of their mental fatigue representative of that time interval as a scalar value between one to seven as one representing a fully alert status and seven with a high level of fatigue.

Some of the metrics that can be measure during a time interval with the Performetric application are: [2]

- Key Down Time
- Error per Key Pressed
- Mouse Velocity
- Mouse Acceleration
- Time Between Keys
- Time Between Clicks

With this procedure Performetric is capable of detecting the mental fatigue during the workday of the user and to add up detecting a spike or a abrupt alteration of their mental state over a period of time alerting the user to take a break or rest for a while.

Figure 3.1.: Performetric application

3.3 SUMMARY

There is a close association between the output mental fatigue, productivity and performance for each user. The main point of this thesis is to prove this connection on a specific situation and this particular case how effective can it be. This concept is most of the times discussed between performance and fatigue mostly on situations that require physical activity. Adding up the mental piece can be sometimes helpful into understanding this matter. If the metrics that we're gonna analyse are proven to be worth into adding onto the mental fatigue algorithm they can be added in a later stage to the actual software, proving that for each situation there should be software variations to the calculus of the mental fatigue state.

As an example a call center where the collaborators of the company try to solve customers problems improving the feedback of the business. When the company uses those kind of software to help creating their online footprint on the market there is the necessity of having feedback on what is happening during the client support. This kind of software provide metrics that can be used to read the productivity of the support as teamwise or individually. Some metrics used are such as how many tickets are not being solved , the satisfaction rate of the customers or time for answering a ticket. The employee responsible to figure out this metrics can see if the company is satisfying customers as intended and if not identify the problems that are decreasing that satisfaction. Since this type of job is considered a

stressful one there should be taken preventive measures that can reduce this situations of a a lot of stress that can rapidly increase the mental fatigue of those workers. Preventing this situation is always more cost effective then reacting to poor executed situations from making a error that cost money unintentionally. [40]

4

DEVELOPMENT

This chapter represents all the decisions that were made the work flow of the project. On the first sections we will explain the thought process of the dissertation and how it evolves to its development. After the concept presented the next sections will explain the process in order to prove the pretended results.

4.1 ACTUAL CONCEPT OF PERFORMETRIC APPLICATION

Currently the Performetric system can be described on theory as a simple and very effective application that can detect the mental fatigue of the user for the last minutes. [35]

The application can be separated in two distinct parts in terms of function but they need to be connected in order for the application to work. The first one is related with gathering data from the interaction that the user has with his device. There is an time interval containing all the information statistically that was gathered during that interval. There are some other rules associated for this part related for example with the away status but they are not relevant for the objective of this dissertation. The metrics collected on this distinct system will be explained in some level of detail in a further section.

The second distinct part is the core of the application. It's here where the data is filtered, worked and classified into a fatigue state and then returned to the user. When the system detects that you are getting tired or when there is a sudden spike on the fatigue status the system alerts the user the necessity of a break of his current functions. This alerts come as a notification. [33],[3]

Even though it looks like a intrusive system from an overseer perspective, it is only trying to guide the user to reduce his bad habits that can lead to a worse mental fatigue and less health diseases related to that. [34] This is being possible from the profiling that is intensively done during each iteration of calculating the mental fatigue of that interval.

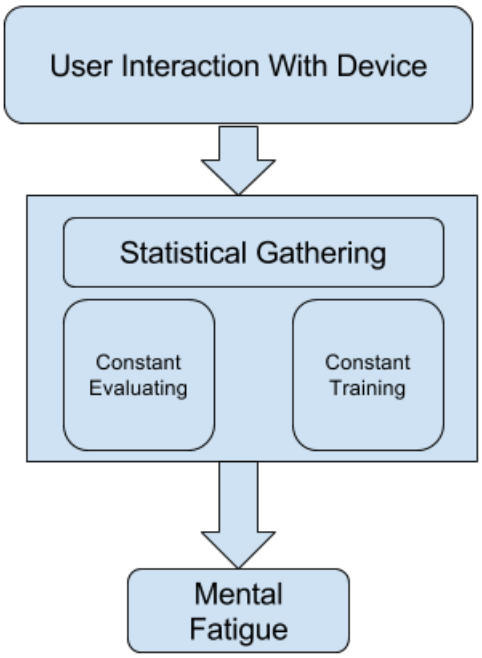

Figure 4.1.: Theoretical behaviour of Performetric application

It has been proven a better health style from the users of this application as well as increases of performance during work with a day on day from the usage of this application.

4.2 CONCEPT FOR THIS DISSERTATION

Performetric application currently works exclusively with biometric metrics that are referent to each user and their own interaction with the electronic device while they are performing any kind of task. Even though it detects the fatigue successfully it opens the possibility of being too generic in specifying and characterise every situation into the same logic leaving some hidden concepts and metrics that are explicit to each circumstances. With that Performetric considers the perspective of trying to find new metrics that can suit in different situations and proof to be useful into helping the current algorithm improving their results even more. Lets consider the following example: an employee has daily, weekly and monthly objectives that has to accomplish in order to keep his job stable. While facing this the employee faces a degree of stress to keep himself on the same level as the company desires. This metrics not only are used to evaluate the employee performance but the company itself from an economic perspective against their most direct competitors. So currently bosses guide themselves by this metrics to check how well the business is going. This values should not be only used just for the financial view but

also can have significant purpose into the computation of the mental fatigue on the interval desired for the business. From another perspective there is also the possibility of using the Performetric application to try and produce as a final result the performance of their employees. If the performance mental fatigue association exists it can improve the overall performance of the company and their associates as well improving the happiness or health of the same.

In conclusion it's important on a first instance to find out how related this two types of metrics are and in which circumstances this relationship between exists. When properly interpreted the most relevant and influential variables can be included onto applications such as this one.

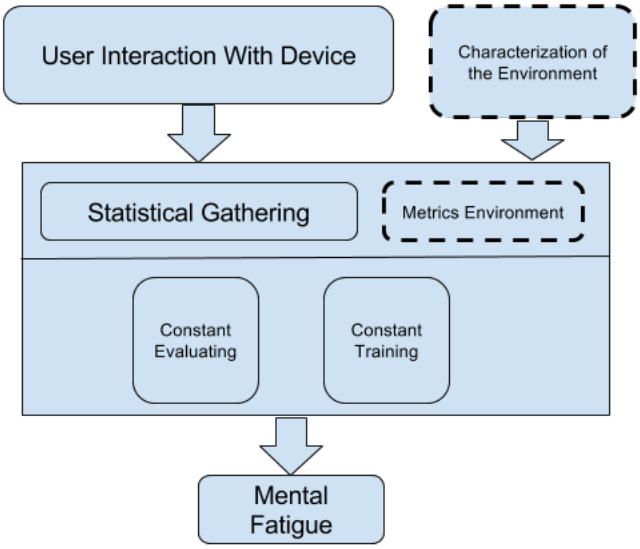

Figure 4.2.: Architecture of the dissertation proposition

In case of success there is the possibility of not only adding new variables on the simulation but creating the premise of using the same concept into real life scenarios where performance or productivity of the user are most of the times evaluated opening further studies for each scenario described.

Presently the Performetric application collects biometric from the user that has the application installed on his device. In a simplistic way the statistics of the interaction of the user are recorded and sent to the Performetric server for analysis returning the mental fatigue correspondent to that time interval that is being recorded. Since the writing of this dissertation the mental fatigue tracked with the Performetric application, is being done from a generic perspective. This means that even though every time interval that is being tracked is considered as a unique moment when the application is online, the

characteristics of it are similar to each other. This can be understood by the capture of the same metrics no matter the situation in question. That excludes the fact of different actions on the computer represent different perspectives of understanding how the user behaves to each perspective. In a way we can say the characteristics from a work environment differ from time of the day, the specification from the work that the user is performing or for example the need for physical effort. Also a work environment can lead to stress situations that can get overload on the subject. On another perspective if we compare a work environment to a leisure time such as playing a video game or watching a movie can lead to completely opposite misconception of the user bio metric statistics. A quick example studies indicate that playing certain types of video games lead to faster reaction times but with the cost of accuracy or performance on it. On other hand a more strategic game lead to less reaction times due to more thinking process reducing the number of keys pressed or mouse movements. Even though this happens video games show a bigger typing speed or more movements towards while performing it to a work task. [41]

In the future jobs will be moving towards gaming oriented perspective. For instance currently there are drones being controlled with joystick by the soldiers in order to reduce the number of fatalities when performing a mission. [48]

It is necessary to take conclusions and assume that certain tasks require different sets of behaviour to be successful. Finding new ways to track down and catalogue each unique situation would be considered of great value in terms of tracking the mental health of users.

4.3 PROPOSED APPROACH

Having shown on the previous section the challenge found in the mental fatigue detection and with it established the concept around that its on this section that its shown the proposed approach to complete the gap found on this application.

Since its risky to work on a first instant to work with real time data the simulation environment will help get results that can be proof of concept for the critical situations that can happen in real jobs. Also it was said before how can a game environment has advantages into research and analysis of the scenario itself.

On this proposed approach the focus will be in three key aspects. The first one will be detecting the mental fatigue while performing the tasks for this simulation. The second aspect will be the success of not of the task at hand. That way we can analyse and understand the influence of certain parameters towards the objective. Finally the performance of the subject at hand since this a video game it is key towards the understanding for the success of the job and to related to the mental fatigue status of the time interval analysed.

This proposal will be worked on a two step process considering the first one the data gathering of all the values that are considered relevant for the second phase that involves data science around all the metrics gathered.

4.3.1 *System Architecture*

In this subsection we present the architecture that will support our proposed approach. This section will be structured in two parts. Starting by a timeline approach considering all the steps needed for the success of this dissertation. Then we go into the details for each step explaining all the choices as well as the problems found during each part of this project.

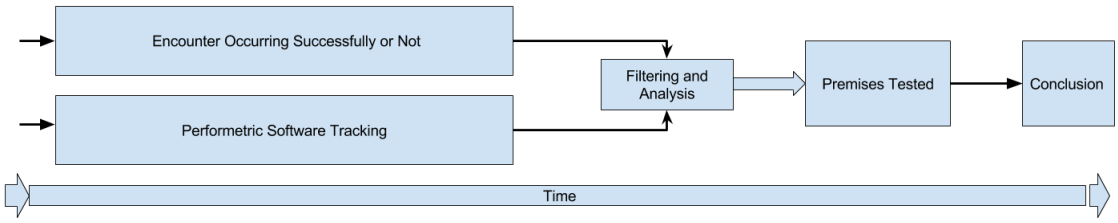

Figure 4.3.: Architecture for this dissertation.

The above image represents the main steps that involve the proposed solution during the development of this dissertation. The first part gathers metrics from the both the Performetric application and the WarcraftLogs platform. The second stage is use data science and machine learning techniques that can give us conclusions of some value for the pretend results.

For the first phase it will be needed for the player to be using the Performetric application during the simulation and for someone from the party to be recording the encounter events using the WarcraftLogs addon. The time interval needs to be the same for both the different application recording the data in order to have a common trait. There is also the possibility of analysing the data from just one of the group if necessary. For Performetric this analysis has been previously done in past research. As for the gaming environment there could be relation between some metrics that could provide interesting feedback in some situations.

After the data is gathered the second phase comes into play with its analysis. This analysis will be looked upon from a statistical point of view that can correlate both groups. In the best case this analysis can provide a specific correlation between the mental fatigue that is detected from the Performetric software and the performance from the player.

4.4 DECISIONS

All the decisions that were made during the development of this dissertation will be present on the following section. It will be divided in small subsections to explain all challenges or doubts that were faced during the implementation of the system. Some of the decisions are associated with the simulation environment while other are linked with the system and the analysis that was made in the second phase of architecture.

4.4.1 *Simulation Environment*

From the previous chapters there was a lot of mentioning the environment where we were gonna simulate the critical situations. Before the gathering it was necessary to understand how could we benefit from the environment for the objective of this thesis. Each video game has their own core of game play that is easily understandable by the players on what is the objective of it. This can be used for our advantage as what to expect. As an example on a shooting game its expectable from the best players good reaction times as well as accuracy. On this case its acceptable to say that teamwork and the realisation of the mechanics needed to be successful are the most important aspects for the accomplishment of each boss encounter.

The analysis will try to capture the big picture of the encounter while obtaining the metrics pretended.

4.4.1.1 *Time Interval*

When trying to get the big picture of the encounter we need to understand how can the time interval of each recording can be of influence to the matter. In this case there is a specific time interval that is recorded by Performetric for the matter. In this case since the most of the encounters have an average timer of ten minutes or less then its not necessary to reduce the timer to a reduced interval. The analysis and comparison will occur for the whole encounter period where the critical situations will be analysed from a different perspective. In another perspective reducing the time intervals could be key for the objective at hand if the whole encounter doesn't prove to have anything of value. The characterisation of small period of time can be more effective into get to results specially if there are events that will create critical situations.

4.4.1.2 *The Subject*

On this scenario its imperil to look on the player that we are going to inspect for this thesis. As referred before we have types that can be grouped in three different classes as tanks, healers and damage dealers. For the damage dealers the job can be fairly understandable,

dealing the maximum amount of damage possible during the encounter. The tanks have to mitigate most of the damage while holding aggro of the boss during the entirety of the fight while healers they have to keep everyone healthy. Consider also that all the players are trying to avoid damage that can be avoidable from performing as intended or that can be mitigated in some way. In each of the types there are different classes that can perform the same type of job but in a different way. There are healers for example that can heal in a area of effect being effective to recover several members at the party at the same time while other classes have a bigger variety of spells that intended to heal a single target for each time. Considering this it is good for our knowledge to know in advance that even in the same class the values from the metrics on the same type can return huge differences. Finally it should be mentioned that the healer class is more dependant from the team performing or not unlike the others two.

All this facts got us into attention so we took the decision of analysing two different players that play divergent types. One of them plays the healer type and the second a damage dealer. Each one of them plays on a different server meaning that they don't play on the same team. Some facts behind this decision are mentioned on the following paragraphs.

The healer is very dependant on the team as said before. This means this type is an indicator on how overall the team is performing during a encounter. If the team being effective during the scenario the number of stress moments for the healers and the team in general is reduced. Meanwhile when the team commit so many errors the number of critical moments raises and in some situations the response capacity of the healers is insufficient to keep use the pace.

Another aspect that is important for the healers is the resource management. While keeping everyone safe the healers have to measure another aspect of their game play which is mana management.It's a resource which is a numeric value that quantifies the sum of mana that player has of it. Each spell spends that resource that starts depleting their mana pool on a percentage value. When the resource gets on critical levels the caster is unavailable to cast any more spells including healing ones. There is static mana regeneration from the traits of the player and spells that can help recover part of it depending on the class. So if the team gets to much damage continuously on themselves the healers have have to spend a lot of resources to keep up the pace creating a stress situation. Along side this there is an idea of prioritisation. As one or two healers per a squad of ten people you should prioritise the players that matter the most for the success of the encounter, per example, if you let a tank die the probability of not succeeding the encounter increases.

So healers represent a critical part of the team during the fight. Letting a healer or tank die is more concerning then letting a damage dealer die. Contradictory this idea the damage dealer is not so vulnerable to the team but the performance of himself. The performance in

a damage dealer is based in how much damage done can he put on a boss and how much damage taken can he reduce during each fight. Calculating performance on a damage dealer is for the community of this game easier to evaluate unlike the performance of a healer. One of the concepts that allows this belief is that each class on each specialization has certain rules or in gaming language combos that allow the maximum output to be dealt. A combo is a set of spells or attacks that need to be dealt in a specific order that can maximise that damage. This means that an error while carrying out this set can reduce substantially the damage done. Also in some classes there is the necessity of keeping a constant debuff to deal extra damage. This is easier to track using the application that record the same.

On a damage dealer the metrics analysed will be slightly different to try see the difference that can exist in each case.

For the healer we are gonna use a priest class with the specialisation in holy that grants most of spells as single target ones and the damage dealer a paladin with specialisation in retribution providing tools for this melee damage dealer.

4.4.1.3 *Amount for players to be recorded per party*

Since in one of the cases the subject is dependant to the team itself it maybe be would be for the best to analyse the whole team specially in higher difficulties. For this work we decided not to include that analysis considering it for posterior investigations. Usually while facing this encounters teams are communicating with voice chat applications to help them go thought the challenges.

4.4.1.4 *Type of Fight*

Each encounter can vary depending on the boss they are facing. As an illustration some confrontations require two tanks that need from time to time to switch aggro because of a debuff that increases their damage taken by a percentage which stacks indefinitely reaching a point that is not sustainable by the healers. So switching the tank allows the other tank to wait until the debuff disappears to get back into mitigating the damage from the boss again. When analysing the data gathered it could be ideal to evaluate that filtering by boss to understand the changes. On the first iteration it was included all the encounters from all the difficulties that were gathered for this test.

4.4.1.5 *Metrics for analysis*

With some much possible data that can be analysed from the game simulation it is key to choose what information is meaningful for this dissertation. While part of the data can be representing the scenario and its fundamental for the analysis some chunks of it are instance of the performance of the player.

As for evaluating performance its important to follow some standards presented on the performance websites for this particular game and find out which metrics are the most relevant towards the performance and mental fatigue at the same time. As an example the website *WoW Analyzer* evaluates reports and analyses where the player could have performed better during each encounter.

For this particular dissertation this are the metrics that we are gonna analyse. There will be explained in more detail in the results section.

1. Damage Done
    a) Total Damage Done
    b) Active Time Doing Damage
    c) DPS
2. Healing
    a) Total Healing
    b) OverHealing
    c) Active Time Healing
    d) HPS
3. Damage Taken
    a) Total Damage Taken
    b) Active Time Damage Taken
    c) DTPS
4. Spell Usage
    a) Number of Casts
    b) Active Time Casting
    c) Types and Targets of the Casts
    d) CPS

We are gonna enter in some detail for each case explaining what is the real importance behind it and the challenges for each case. The idea here is to find a established relation between them are the influence they have in the individual performance and mental fatigue of the subject. The list that was detailed previously has some metrics that can be most related with the healer performance during fight occurrence while others are related with the damage dealer.

Damage Done is only relevant to the damage dealers and can be subdivided in three key aspects. Total damage done is an absolute value of all the damage that was do during the fight, active time is the total time that the subject was dealing damage to the target and Damage per second (DPS) which is dependent from the total damage done.

Healing: Healers have the function during a encounter to keep everyone alive including themselves. Since it's their main function we should analyse the metrics associated with healing intensively. There is three metrics that have absolute values and on that is a dependent on one of them. Total Healing is a number representative of the amount of effective healing that was given during the time measured. Over Healing is the value of healing that is wasted when healing a target. Heal per second (HPS) is a common metric to analyse how much healing was done per second and its dependent on the total healing done. There are more metrics associated with this healing that are used in the analysis but this are the most relevant to explain the decision being it. This type is just relevant for the healer.

Damage taken is all the damage that lowers the health or is enough to kill the player. On this list we will consider three types, total damage taken which is the amount of damage the subject took during the encounter. The active time is the time that the subject was taking damage from enemies and the the Damage taken per second (DTPS) is a metric that is conditional from the total damage taken and total time the encounter took. This group of metrics are relevant for both subject that are gonna be analysed.

In the spells usage category we can follow to paths. Primarily we can just work with the metrics correspondent to the whole encounter and that are absolute such as total spells casts, time spend casting and casts per minute. This is the path we are gonna take and it is relevant for both subjects. In another perspective it could be interesting especially for the healer to analyse the choice of spells used by that player. As a quick example some spells take longer to cast or spend more resources needed instead of other options. The targets can also be a interesting idea to analyse due to the prioritising that the healers have to make in order to increase the success of the encounter. Lastly checking how many casts per minute is also important specially to set a range between a success and a failed encounter. One thing that can be also added for future is to check how many casts were cancelled during the simulation. It can be a interesting factor that could be added to understand the behaviour of the subject being analysed.

Some categories were left off for this dissertation. It includes buffs, resources, combos and the position of the player during the encounter.

As for positioning there are no records of the actual movement of the players but there is in some records the actual position in the map where the player is standing on a specific time stamp specifically when the game decided to record into the disk the information. Even thought we can try to predict the movements that the user made that can create some

incoherence on the data. This is a challenge that can be easily faced when the application goes intrusively recording the actual keys that were pressed during the encounter and not just the statistical information about the keyboard interaction. Since there being intrusive can lead to some degree of stress the decision to not track this metric was made. This was also a problem for the combos. Since the analysis is from a overall perspective it is not relevant to try and get at first instance the combos of the damage dealers. For later investigations this can be relevant when understanding for example the perspective of a sequence of moves to be done for the maximum output. The buffs revealed from a gaming perspective a not ideal metric to be tracked at first glance. It has to many dependencies to the composition of the group as the classes that are on it. Some classes can provide buffs while some don't. To end this section the resources are important but reveal some inconsistencies for the objective of this dissertation. The most obvious is the mana that was explained early. The values given are in random time stamps during the encounter interval because of the limitation of the system which records when it feels it is the best moment and not in a specific interval. For further investigation it would be interesting to see in some cases not only from a individual perspective but also for all the team since the records are given as a team perspective with individual records inside of it.

4.4.1.6 *Queries*

Presently on the WarcraftLogs API there are ten possible queries that can be used to get data. The two most relevant are the overall information that is provided as table or all the events that were recorded during that encounter. The focus will be on the first one leaving the second one as future possible work for a more detailed analysis.

The main objective of this queries is to find values that can be related to the fatigue measurement used on the Performetric software and the variables that are present on the data collected from the game statistics. If we can find a correlation between both platform we can find new ways to increase the analysis of both performance and mental fatigue detection during a period of time. This can help for example the Performetric software to increase the accuracy of the detection by creating specifications for each case being a gaming simulation or a real time job.

While using this API to get the needed information there should be taken into consideration duplicate or similar reports appearing from several users from the same raid encounter having uploaded each ones reports into the platform.

4.5 IMPLEMENTATION

The following section will be explaining all the implementation that was done for this dissertation. As said before this architecture can be divided in two phases. The first one is

the system that gathers all the metrics for its analysis. The second related its posterior analysis. For the objective it was helpful to have the Performetric application for comparison of the data. Since the game simulation is about a particular game there was the necessity to do some previous research on tools that could provide us help to understand how performance was measure for each player. There are several websites that provides this kind of feedback that players can use to inspect their performance. Most of this websites require reports that are collected using a tool name WarcraftLogs. It contains a in game addon that structures the data that is recorded by the game and when upload into their service can be used for inspection on their website or by other tools that require the id representative of the entire raid encounter. There will be explained here also the usage of the WarcraftLogs API to obtain the metrics necessary.

4.5.0.1 *Data gathering*

As explained earlier all the gathering data for this simulation that contains information about the game will be extracted using a platform called WarcraftLogs. This platform provides to the World of Warcraft players the possibility to analyse their own raid progress and performance individually or teamwise on it. It is necessary to do two steps in order to use this platform. First at least one member of the raid group (usually the captain of the guild) downloads their addon and includes it on the game so during the encounter the data of all events that are recorded into the system are structured for the second step. After the end of the session is over the user has to upload the logs that were recorded into the platform. After that they are accessible to the users on a interactive platform for a limited amount of time where the statistics for all the details are presented being accessible in a general overview or by filtering what is pretended to see. There is also the possibility to access graphs and check the performance of a specific player in that report from the overall performance of players in the same encounter. This performance is a comparative value between that player and to all the others where there are reports submitted with them on the team. [51]

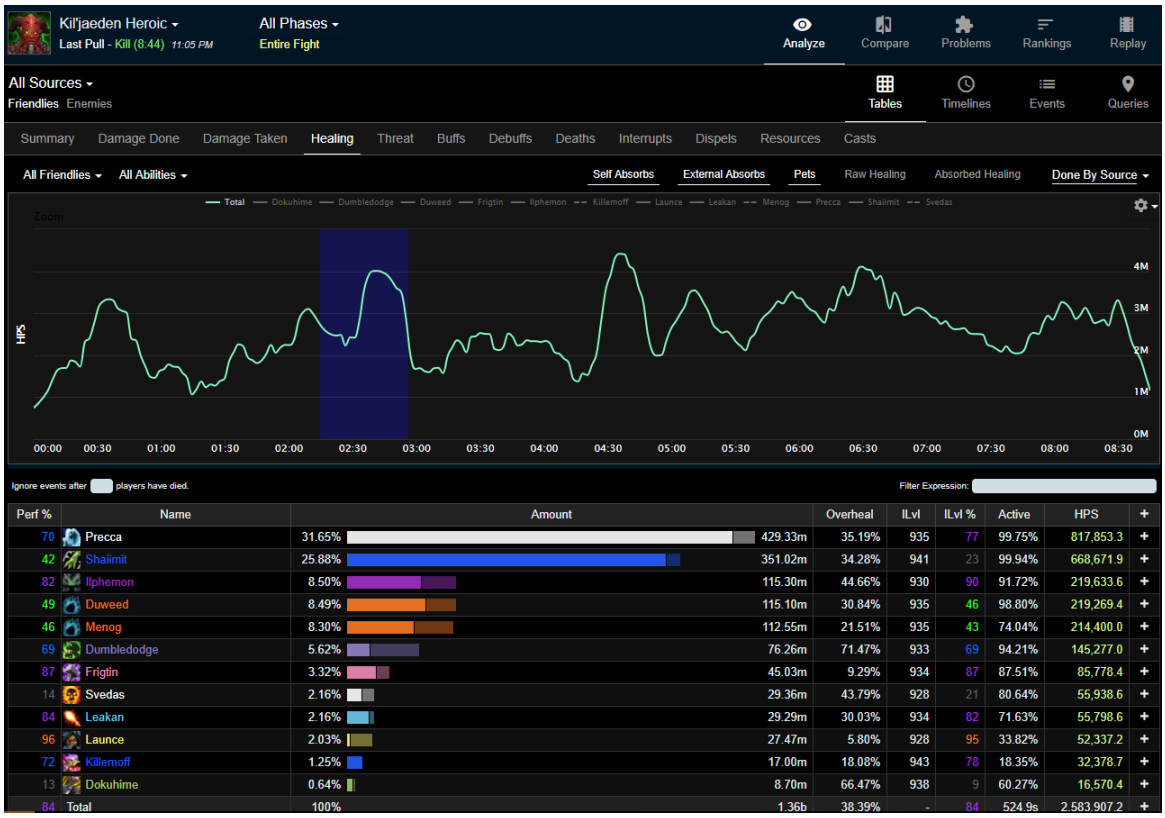

Figure 4.4.: Interface of WarcraftLogs Platform

For this thesis we are gonna use the data available on this platform that is relevant to us from two specific guilds that have each one a single player using the Performetric software. Both of the guilds use this platform to check the data after. Also it is relevant to mention that each guild have different objectives when doing raiding. One is more casual oriented because the majority of the members work daily and just want to play the game for leisure. Even though on the other guild there are workers too the second guild tries harder into having progress. To download the the metrics we will be using the Representational State Transfer (REST) Application Programming Interface (API) from this platform. The API provides us several queries that can be used to gather the data. All the information given is returned as in JSON format. Initially we obtain all the information about all the single calendar reports that were uploaded by the guild. The data returned would be giving just the zone, the start time and the end time where the raid occurred. For each of report we have to query the server for more information related to each report. So the next query that needs to be done is to general information about all the fights that occurred during that report.

When using other query to get the information about each report we receive a JSON file having all the fights and the information associated about which boss was fought and the times that can be used from the whole report to calculate the interval where that occurred.

There is also information about if that fight was successful or not as long as difficult. Finally a array of all the members that were present during the whole encounter informing in what encounters they were present.

From this file then we would filter the id of the fights where the tracked subject was there and just use that data for this investigation. From here the need to query the server for the information about each category for each fight is the next step to be taken. The types of data that could be requested are:

1. Damage Done
2. Damage Taken
3. Healing
4. Casts
5. Summons
6. Buffs
7. Debuffs
8. Deaths
9. Survability
10. Resources
11. Resources Gains

This final query has several parameters that can be added to reduce the amount of data that is returned. As default its response comes with all the information from all the party members. In some cases it's better to obtain all of that information for some studies.

In the web platform there is also the possibility do check the performance of the player during each fight. This performance is comparative between all the players from a specific class and their specialization considering only the following characteristics for the fight, the boss itself and the difficult in which that fight was addressed. This *performance* can come in two ways, the first one comparative to every single report that have that specification or being more selective and comparing the players that have similar item level. Exemplifying a holy priest subject can be compared against all the players that play that same composition.

This performance from a statistical analysis is optimal but is not delivered in the queries of the platform. Using the programming language get iterated every fight for each report and got for the healer those performance percentages using a ruby gem to simulate a user navigating and using that gem and with some code we were able to save those metrics in a

local file for analysis. We took advantage of this and saved additionally the percentage of damage or healer the subject made. On a side note the information that we recorded was unique for each user meaning that for a healer the importance was given exclusively to the healing type and for the damage dealer for the damage type.

To end with this section we asked the two players to be using the Performetric software during the entire raid encounter specifically and advised them to leave that open during most of their time spent on the computer to let the application work and provide credible results.

Finished the gathering phase we had more then forty metrics at our disposal for the next phase which was the data analysis.

4.5.0.2 *Data analysis*

Before using the data for analysis its required to clear the data that can be influential for the analysis at hand. On a first instance we are excluding all the fights that contain null values in each fight. That will reduce our data for evaluation. That can have a negative effect in our research but that was a decision to be taken into consideration on the first iterations. This values are non existent due to the fact that in some cases the fight takes only a few seconds as a result of a wipe per example causing in some cases that there is no data associated to that player.

The following image is an example of fight that last a few seconds and there was no healing information for our subject. The values seen are the results of the element present in the row while using a ruby gem finding the pretended values. This kind of data had to be filtered and excluded in order to create the best possible scenario.


```
{
  "id": "3",
  "p Type": {"ELEMENT":"0.43631354773848363-3"},
  "p ILvl": {"ELEMENT":"0.43631354773848363-4"},
  "p Overall": {"ELEMENT":"0.43631354773848363-6"},
  "ilvl": {"ELEMENT":"0.43631354773848363-5"}
},
```


Figure 4.5.: Example of data from the gaming performance

From this point the next step is to establish the interval for the values from the metrics gathered to reduce their discrepancy. Now using Pearson correlation we calculate the correlation between each set of metrics to find how direct and how strong the correlation is. Depending on the results the analysis will give us for each subject that was analysed what is the major factors to take into account while measuring his fatigue. In another perspective we want to measure the effects of the entire encounter to the intervals that followed it. So using only the Performetric data we calculated the average fatigue for the

entire encounter and compared it with intervals immediately after to the raid. This can be added up to other situations that are reported on the results chapter.

4.6 OUTCOMES

During this investigation there were tested two raid instances that were being played in its majority by the wow community. The first, Tomb of Sargeras which was release and unlocked during the patch 7.2.5 on 20th June 2017. The second, Antorus the Burning Throne was unlocked on 28th November 2017 during the patch 7.3.2. As for this most of the data for the healer player was recorded during the first raid. As for the damage there is only data exclusive to the second raid. Both the players presently raid in two separate guilds in two different servers. Healer raids in a guild named *Unavailable* present in the Kazzak server. This guild does this raids from a casual perspective where there the data gathered only includes normal and heroic difficulties. In other instance the damage dealer plays in a guild denominated *Team Hazard* playing in a Portuguese server and plays in a more serious level. In this case there is data from all the difficulties present in the game. Both the guilds operate in the European WoW servers.

The initial results show us an existing correlation between the performance of the player and the mental fatigue measured during the recording sessions. This association differ from the subject but seem more evident from the data in the damage dealer. This can be associated with the independent state that the player can have other the rest of the team while the healer is more dependant to the performance of the player. Considering the other premises the overall data from the comparison between the intervals show an differentiation after the raid encounter happened for both of the targets. For the healer the results show a minor decrease in mental fatigue after all of the fights were over and in a opposite direction there is a considerable increase.

The results will be presented In more detail on the results section as along as all the premises explained in more detail.

4.7 SUMMARY

In summary the system had to be developed considering all the facts that were valuable to the success of this project. Even though we only analyse a single individual per team its comprehensive to say that every role is important during the encounter with some roles being more vital then other. As an example a healer is incredibly reactive to what the other players and himself are doing and his job has to be consistent during the whole duration. If his performance decreases, even if caused by other members, the success of the fight are

diminish. The amount of variables that are present to be gathered present a good point in following this implementation for review.

It is expectable that during the analysis the results given to the subject that has the role of a healer will be different from a damage dealer while associating variables that can prove this concept. The system implemented during this dissertation is very vulnerable to the challenge of this simulation especially to the first step where we need to obtain all the metrics that characterise the scenario and define the performance of each subject that was analysed during each encounter. This volatility can be explained by some errors that exist from the game platform that gives us some values that cannot be used for analysis and in the worse case forces us to remove a entire line of values because of it. Either way there are enough data for a specific analysis where lots of different filters shine and will be used for a better understanding of the different situations at hand. The initial results proved to be effective and in the directions pretended when founding some connection between the performance and the mental fatigue of each subject but with different perspectives for each one of them.

5

CASE STUDIES / EXPERIMENTS

This chapter will be focused on the study cases that were tested after the development of the system. It will be shown the results of the experiments from the outputs and the possibles failures for some associations.

5.1 EXPERIMENT SETUP

The next step after developing the architecture that gathers, filters and prepares the data for this simulation is to analyse that prepared information to a degree where we can correlate metrics from the game and the Performetric software to reach conclusions that can help improve the detection of mental fatigue or add a new output value the performance to this application for this specific simulation.

The analysis will vary from case to case depending on the encounter at hand and the player that is being analyzed. There are generic values that are independent of the boss itself such as the Performetric metrics that are always being recorded during the sessions, the outcome of the fight , duration and so on. As for the player itself we had two subjects with different roles one a lot more dependent then the other from the performance of the whole team. Considering this fact it is possible that the results may vary substantially between them. We will explain in more detail the expectancy for both players and the reasons behind it. One of the players plays this game casually as for the data being centered only in Normal or Heroic runs while the other plays it more professionally having a lot of encounter on the worse difficulty Mythic and a few runs in Heroic and Mythic.

We will get in more detail in the section where we explain the study case.

5.1.1 *First Hypothesis*

As a first study case we consider the data from the game and Performetric that was gathered and start the analysis considering the whole encounter from the moment it was started to the moment it ended successfully or not. This will permit on a first instance to have

perception of the importance of each variable into the success of the encounter and to understand the association that can be taken into account between each set of variables. This will be a two step process to reach this goal. First investigating the correlation between the variables available from the statistics of the game.

This first analysis will permit to see if exists a correlation between the statistics that are present in the logs of each encounter and with each correlation find how much of interest it can have on fatigue and performance. This performance can be established in two ways first by comparing the performance metrics that are present in the Performetric application and secondly by comparing the game results with everyone else players that use that platform by certain requisites such as having the same class, same spec or similar equipment.

On a first instance we are gonna use all the reports that we have at our disposal that include data from both applications. This will permit a faster knowledge of all the possibilities that can be made.

As for the healer we are using data from a player named in game SamHodor that plays on the guild Unavailable in the server Kazzak. On the time that we started the investigation there were raiding Tomb of Sargeras a raid that was added into the game and unlocked for the players in the patch 7.2.5. On this raid there are nine bosses present that players can be challenged with.

As for the damage dealer we track the data from Dødheimsgärd a player that is in the Team Hazard guild in the server Aggra. We work with this player on a later stage of this investigation. The player in question plays on a higher competitive level and having on the moment of this investigation some of the highest performance reports for the kill encounters.

Having all the reports in question the analysis should be made from a bigger perspective to a narrow one. On the first analysis there should be included all the reports and in each iteration changing a small perspective of what can be included for analysis. This can result into relevant conclusions. i

A small example is the understanding every boss encounter has his own specify abilities and mechanics making it difficult for analysis on a whole raid perspective. We might need to narrow our choice to a single boss fight and prepare the data just for that unique simulation. Narrowing all the possible information from all the different encounters to a single one creates a limitation towards the data as for the number of reports to be analyzed while on the meantime it reduces the complexity and the dispersion of values that can emerge during the analysis. This can be due to the fact that some encounters during the game can have a mechanic that for example amplifies the heal received and given towards the party or where the damage taken builds up during the encounter not being consistent towards the rest of the events. Lastly there should be some considerations towards what kind of boss encounter needs to be analyzed. There should be present on

boss encounter mechanics that require team effort in order to be successful during the same without forgetting variation for the time the encounter lasts. Finally we can look for encounter that have a lots of attempts from a successful and unsuccessful run. This can be also be applied to kill only situations or difficulty levels and so other relevant choices.

Finally acknowledging the fact that the healer and the damage dealer have different perspectives for analysis and having that in mind the results can't be generic for both of them.

The following table shows the number of attempts that were uploaded in the server as well as the success rate for each type of encounter on the most recent raid:

The metrics in question will be shown in the metrics section with more detail.

5.1.2 *Second Hypothesis*

After analysing the whole encounter and associate the metrics that prove their significant it would be relevant to understand the aftermath from the effects caused by this critical situations in the the user. So the second hypothesis just works with the mental fatigue of the subjects during the whole raid period and not only a single fight and compares the average value of it to the average value of time intervals that occur after the raid was finished.

The intervals that are going to be analysed are between zero and fifteen minutes, fifteen and half an hour and half hour to one hour posterior of raid being finished. This will be only comparing time interval where the user was using the computer after finished all the encounters.

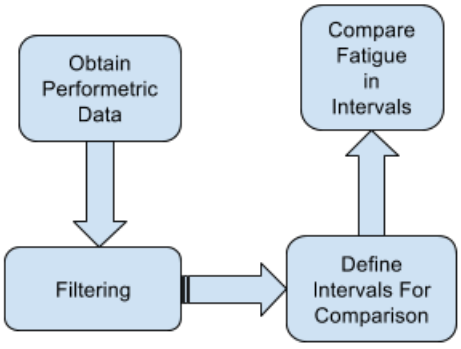

Figure 5.1.: The intervals compared on the second premise

With this hypothesis we look into understanding for both subjects the effects that can happen for each for them on the mental fatigue value difference from being in a crucial situation where it is required a lot of focus to a moment that doesn't contain so much critical situations to be dealt.

5.1.3 *Third Hypothesis*

The third hypothesis tries to understand if there is an accumulation of fatigue during situations from the whole raid encounter. For this matter we will measure each encounter with his subsequent by comparing the difference between the average mental fatigue for both fights that are compared. In this premise it will be also considered some different possibilities that can occur from this investigation such as the difficult or if it was succeeded the previous encounter in comparison to the next one.

Unlike the previous premise that considers the average mental fatigue for the entire encounter including trash fights or moments with no shown activity as a small break in the middle of the raid or when the group is discussion the mechanics for the fight. In this case the premise will only evaluate the actual fights itself considering only boss fights. Trash encounters are group of mobs not as challenging as the main content but that need to be addressed because they exist between each boss fight. Since the challenge of this small encounters is not relevant it will be excluded for this premise.

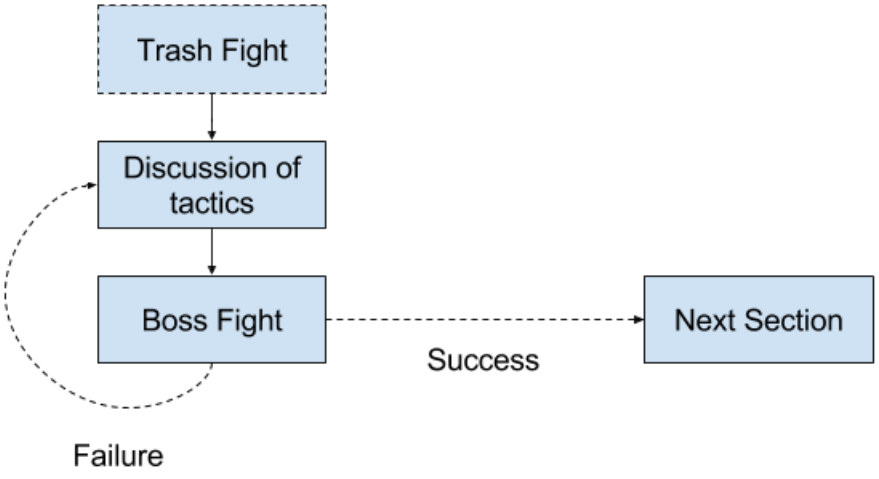

Figure 5.2.: Scheme from a boss fight

The previous scheme shows how can the encounter go. Even though we are only gonna analyse the boss fights itself it is necessary to understand that there are some previous

analysis that the guild does before going to face the boss specially on the first iterations where the guild never experienced the fight. When facing a failure it is recurrent for the teams to analyse what went wrong and to adapt that failure. When evaluating the difference in fatigue from this two situations we can look into understanding how effective that change can have on the performance of a player.

5.1.4 *Metrics*

On this subsection we will approach all the metrics that we gathered to be used for the analysis as well as the ones that were excluded during this dissertation. This section will be divided in two parts. The first part will be used to specify the metrics by describing in more detail what they represent, the target and the range of values that it can get. This metrics will be used in clustering and classification algorithms to gather conclusions for the dissertation objective. The second part component will be to explain some of the decisions that were taken into account for the selection of variables that were picked up from a wide range of possibilities.

The metrics that were considered for the study can be grouped in three different groups. The first group are values that correspond to actual features of the game encounter that characterise the encounter itself. This first group includes ideas like time taken on the encounter or the difficulty of the simulation as well as metrics that related to the player performance

The second group is related to the actual performance of the player that is being analysed. This group takes into account the some of the metrics that were gathered during the encounter and compares then from any other player that has the same characteristics from him (being of the same class, specialization or having similar equipment level) and tags that comparison as a generic performance from all the reports that were saved and upload into the platform.

The third group are the metrics that are related with the mental fatigue detection application Performetric that involves the actual mental fatigue of the user on that instant and mouse and keyboard performance metrics.

Bearing this the table that follows describes all the metrics that were used during this investigation.

Metric	Description
Time	Time in milliseconds of the encounter
Size	Number of members present in the raid from 0 to 40
Difficult	Difficult of the boss fight being 3 correspondent to normal difficulty, 4 to Heroic and 5 to Mythic
Kill	Outcome of the fight
Healing	Total Healing done from the player in absolute value (Exclusive to the healer role)
Overhealing	Total Overhealing done from the player in absolute value (Exclusive to the healer role)
Healing Per Sec	Total Effective Healing done divided by time of the encounter in absolute value
Active Time Healing	Percentage of time that there were spells healing targets during the encounter (Exclusive to the healer role)
Percent Healing Reduced	Percentage of time that there were spells healing targets during the encounter excluding pets (Exclusive to the healer role)
Overhealing Percent	Percentage of healing that were wasted during the encounter (Excess healing when target was already at full health, Exclusive to the healer role)
Total damage done	Total damage done by the player into the boss. (Exclusive to damage dealer)
Active time damage done	Percentage of the encounter where the player dealt damage to the boss and adds (Exclusive to the damage dealer)
Active time damage done reduced	Percentage of the encounter where the player dealt damage to the boss only (Exclusive to the damage dealer)
Damage per Second	Damage per second done by the player during the fight. (Exclusive to the damage dealer)
Casts Per Minute	Number of spells done per minute by the player.
Percent Cast Time	Active time the player was actively casting spells
Percent Cast Time Reduced	Active time the player was actively casting spells except his pets
Total Damage Taken	Total ammount of damage that was taken by the player
Damage Taken Per Sec	Damage taken per sec from the player
Percent Total Damage Taken	Percentage of time that the player was actively receiving damage

Metric	Description
Percent Total Damage Taken Reduced	Percentage of time that the player was actively receiving damage excluding his pets
Item Level	Level of equipment for the player
Performance Item Level	Comparison in percentage with all the reports related with that boss for all the players with all the class and specialization associated on the same range of equipment level
Percent Healing Done	Percentage of healing done on that specific fight from the player from all the team (Exclusive to the healer role)
Performance Overall	Comparison in percentage with all the reports related with that boss for all the players with all the class and specialisation associated
Fatigue Level admslMean aedMean admslVar aedMean aedVar ddcMean ddcVar dmslVar dmsLMean kdtMean kdtVar keysPressed leftClick Mean mouse acceleration Variance mouse acceleration	Performetric mouse and keyboard metrics

Metric	Description
Mean mouse movement Variance mouse movement mouse Distance mouse Excess Distance mouse Precision rightClicks tbcMean tbcVar tbkMean tbkVar wvMean	Performetric mouse and keyboard metrics

Table 5.4.: Description of the Metrics

It is expectable to have correlation between the variables of the three groups. We look to find association between the first and second groups and the third group. If we find a correlation between them we can find relation between gaming performance and mental fatigue.

5.2 RESULTS

In this section we will pretend the results obtain for all the premises that were tested during this course of this investigation. Some of the tables are shown on the appendix in the end of the document for a better reading of this section.

5.2.0.1 *First Hypothesis*

The core of this premise centres itself around finding correlations between the simulation environment and the performance of the subject and mental fatigue metrics gathered via the Performetric application. There will be excluded correlation that involve the same type of group metric such as healing and over healing which are directly associated. There are still shown on the tables on the appendix. Even thought there are more correlation that could be presented we only considered worth mentioned correlation that are over an abs value of 0.5.

The first set of results are referent to the Pearson correlation with all the data from all the reports excluding null values. From the healer correlation table is possible to see a strong mutual relationship between the healing and the spells casts with absolute values from 0.7 to 1. This is comprehend by the necessity of casting spells in order to heal players. On a reverse idea when item level increases, healing and the number of casts get reduced mainly because of the improvement in equipment from the whole team making them able to sustain more damage and not forcing so much the healers to cast so much. Considering now game metrics with the Performetric metrics, healing and casts are negatively related with distance between clicks, mouse movement and precision while on other hand it is positively associated with the mouse acceleration. The reason behind this is the usage of the UI from the player to maximize his performance. On this first iteration there seems to have no correlation between fatigue or other game metrics. The following image shows this explanation. The clicks are mostly done on the green squares where each square represents a player. A full green square means the player with its full life and it gets grey the less health it has.

Figure 5.3.: UI screen from the healer

The damage dealer has also a strong link between damage done and spells cast. The character the damage dealer plays relies a lot on spells to increase their damage output. When dealing more damage the player also takes more damage, suggesting more focus shown on his task at hand without splitting that concentration also to avoid the damage and ease the function of the healer team. His performance gains credibility from a overall or item level perspectives when he performs more damage and casts more. While with healer there is a lot more correlation obtained between mouse and the player game play,

the damage dealer provides adds up with keyboard. As the difficulty increases the subject performs less left and right clicks and takes less time pressing the keys which implicates faster typing to perform when casting spells. This is also seen by getting the correlation between keys pressed as the player deals more damage. The size of the party matters for this subject as it increases the mouse distance and the mouse excess increase as well and there is less precision from the player. Finally the mouse acceleration and distance between clicks are inverse associated to the percentage of damage done from the player to the enemies during the encounter.

When analysing all the reports from the damage dealer it is found the first relation related with the fatigue level. On this subject as the difficult rises the fatigue tends to increase too. The correlation between this two metrics is situated in 0.43 which average association but worth mentioning.

From both players it is obtained the significance between overall performance and performance limited by the equipment level. The better the equipment the easily the subjects are able to give better heals or provide a higher damage output. Results differ when gets we compare item level and percentage of heal or damage dealt. When looking into the healer perspective it is observable a strong correlation unlikely the damage where the association is almost nullable. Both the players produce more damage done or healing while receiving more damage as time passes by during the encounter.As time increase players have inverse relationships with mouse distance from each other while increase on the healer it decreases on the damage.

From this point of view we start filtering the data from difficulty to get more precise results. From the damage dealer perspective there is a problem associated with it which is the spectrum of values. From 70 fights analysed in total previously 67 are referent to heroic leading to not enough data to be analysed when in normal mode and very similar results from heroic to all reports. So we filter and divide on the healer into two big groups, normal and heroic difficulty having a similar size of data for analysis. Since most of the correlation from the game metrics were displayed from all the data due to the similarity of the type of function performed in both difficulties we are only gonna look into strange correlations that can appear on this first case or new associations that can appear related with the fatigue level. Comparing normal and heroic difficulties from this player the correlations are stronger and more easily identified on the normal difficulties so we are gonna focus on those ones. In the following graph it is possible to see that fatigue level seems to have influence from healing and casts made by the player on normal difficulty. There is also a positive correlation between more keys pressed and the healing and casts done by the player.

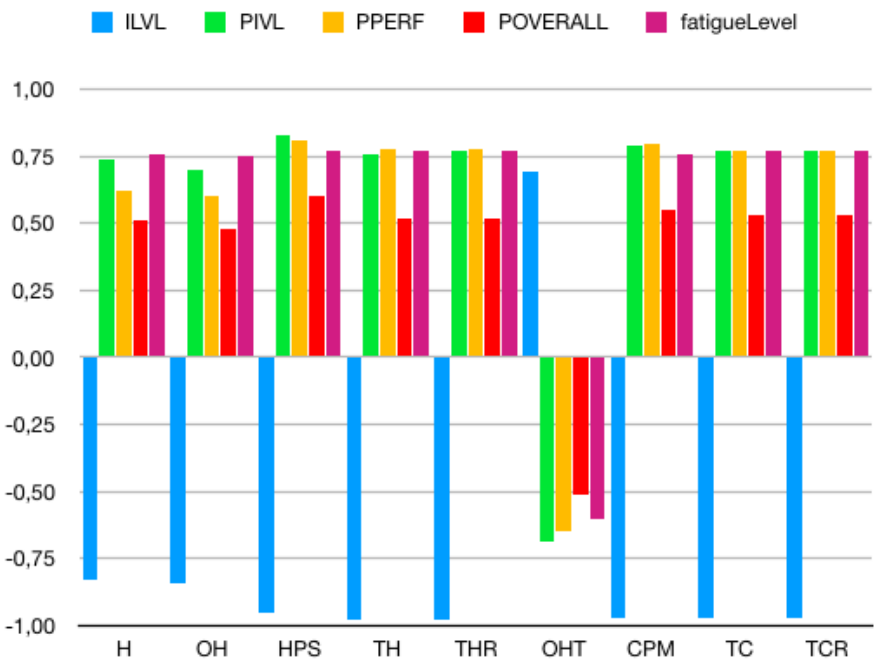

Figure 5.4.: Fatigue and Performance important correlations

Keys Pressed can also be correlated with the percentage of healing done by the player as well as his performance from a overall and ilvl perspectives. The size of the team is negative related with the fatigue level. The higher the item level of the player is the less tired the player due to the fact of the fight getting easier for the entirety of the team. When the players performs its fatigue level is highly to rise up too explained by the percentage of healing done from the whole team and the performances. Mouse precision and velocity decreases as the main game metrics related to the healer increase while in a opposite way acceleration and writing velocity increase while it increases. To end this as the percentage of over healing increases the fatigue level of this subject is likely to decrease. Damage taken seems to have no correlation from either between any performance from the game or the Performetric metrics. So it is required a bit more investigation on this matter.

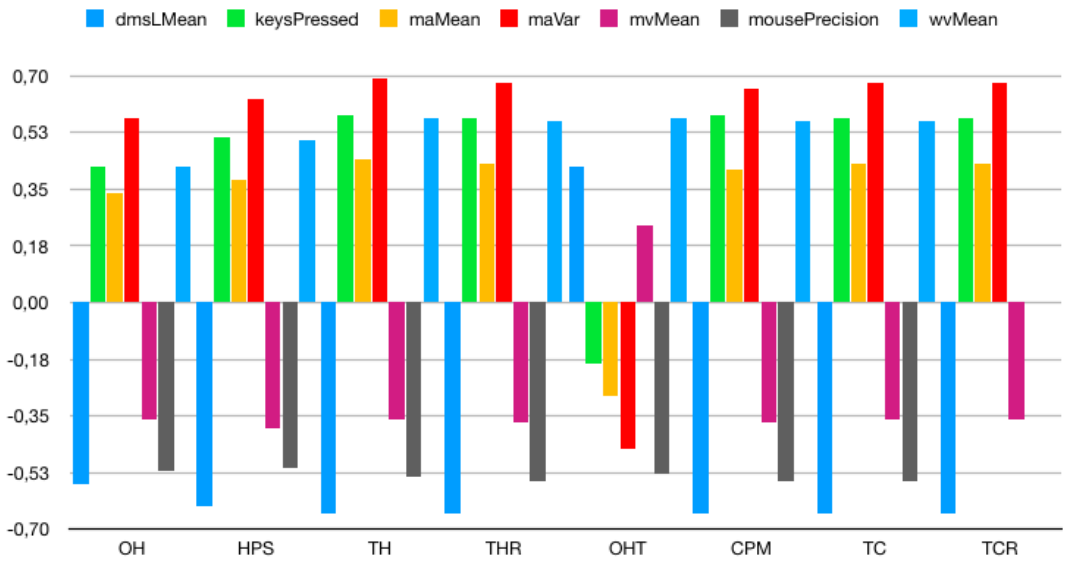

Figure 5.5.: Performetric correlations from healer data

As for the damage dealer we can find similar correlations to mouse, keyboard and game characteristics as the following graph shows.

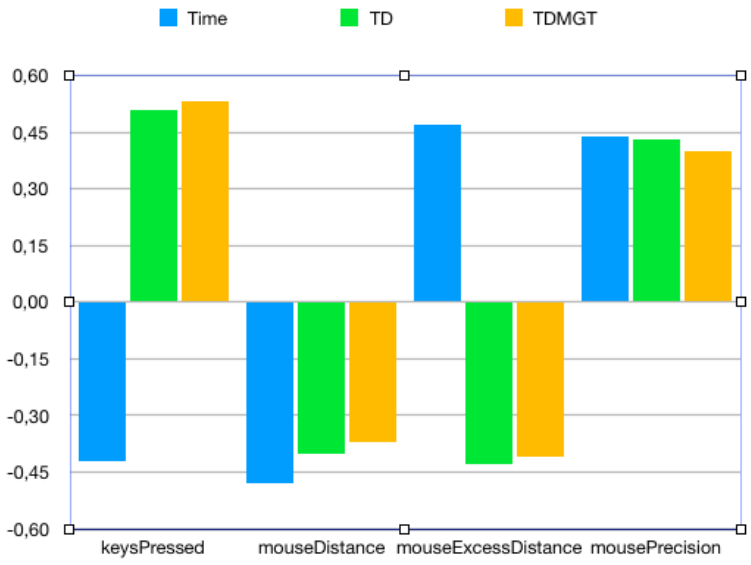

Figure 5.6.: Performetric correlations from damage data

For a more detailed perspective the tables with correlations are presented in the appendix.

5.2.0.2 *Second Hypothesis*

The second premise focuses on understanding the effect that playing consecutively during the duration of the whole raid run has prior too it. As said before a full raid run consists of several fights successful or not that last on average two to three hours. The conclusions from this investigation come in two different directions depending on the subject that was observed. When looking at the healer data we can see that there was a small decrease until the half hour section returning after to the average fatigue that was being felt during the raid encounter. In either case the difference was not significant suggesting the fatigue of this subject remains the same after ending the raid run. Meanwhile when looking at the data related to the damage dealer its observable a substantial increase on the fatigue level in all the intervals tracked with special attention to the interval correspondant between fifteen and a half hour to the raid ending. To finish this premise the average raid encounter is higher on the damage dealer indicating that it this stress situations have a bigger effect on him.

The tables supporting the data are shown below.

Difference on Average Fatigue on Time Intervals	Value
Between 0 to 15 minutes prior to ending	-0.97%
Between 15 to 30 minutes prior to ending	-6.57%
Between 30 to 60 minutes prior to ending	0.91%
Whole raid encounters analysed	40
Average fatigue level during raid encounter	2.6

Table 5.5.: SamHodor (Healer) second hypothesis statistics

Difference on Average Fatigue on Time Intervals	Value
Between 0 to 15 minutes prior to ending	14.39%
Between 15 to 30 minutes prior to ending	23.47%
Between 30 to 60 minutes prior to ending	15.23%
Whole raid encounters analysed	10
Average fatigue level during raid encounter	2.8

Table 5.6.: Dødheimsgård (Damage Dealer) second hypothesis statistics

5.2.0.3 *Third Hypothesis*

The objective of this premise was to try and understand the influence from a previous fight when going into the next one from a whole report encounter.The questions we were trying to answer were:

- What is the difference in fatigue from one fight to the next?

- Is the influence more felt from an unsuccessful encounter?
- Has the difficulty influence to the fatigue increase?

The results for the first topic show us that there is a residual increase on average when going to the next encounter. We also perform on a study to check what was the highest increase and decrease from each player. On the damage dealer there isn't a lot of oscillation between this two values that were looked into. In other hand on the healer case there is a huge increase on fatigue which suggests there was a spike detected during the fight encounter.

When grouping the data into previous successful encounters or not there was no found evidence from the influence of the last encounter into going to the next one. In terms of difficulty the outcome leads to believe that the two subjects have similar fatigue level when going into normal mode for the healer and heroic mode for the damage dealer during the duration of the raid encounter. The spectrum of data obtained for the normal difficulty for the damage dealer is small (four fights) and should be ignored.

The tables to support this results are shown below. They are separated by player because of the function they perform during each of their raids. The discussion about this results will be on the next section.

Average Difference on Fatigue	Value
Every consecutive fight (All Fights)	1.02%
Previous fight was a successful encounter	1.15%
Previous fight wasn't a successful encounter	0.98%
Highest Increase from a previous fight	28.57%
Highest Decrease from a previous fight	-9.15%
Previous fight was on Normal Difficulty	0.14%
Previous fight was on Heroic Difficulty	1.05%
Consecutive fights analysed	337

Table 5.7.: Healer third hypothesis statistics

Average Difference on Fatigue	Value
Every consecutive fight (All Fights)	1.27%
Previous fight was a successful encounter	1.01%
Previous fight wasn't a successful encounter	1.06%
Highest Increase from a previous fight	5.33%
Highest Decrease from a previous fight	-1.27%
Previous fight was on Normal Difficulty	3.94%
Previous fight was on Heroic Difficulty	0.36%
Consecutive fights analysed	68

Table 5.8.: Damage Dealer third hypothesis statistics

5.3 DISCUSSION

It is evident from the three premises shown before that exists a correlation between mental fatigue from the user and his performance. However we need to analyse with more detail some situations some of this traits. The associations that were found relate Performetric metrics with the characteristics of this simulation and the performance from the player. The two subjects analyse gave similar results in some correlations while in other complete opposite ones. We were expecting very strong relations , over 0.5 in absolute value. However there was not a lot of correlations that proof that expectancy. In fact most of the pretended correlations in both subjects are situated between 0.35 and 0.5 as absolute. Should in other simulations be necessary to look into a combination of multiple metrics gathered from this kinds of software, and be compared with the characteristics of the performance of the player in order to find a strong complement? The answer seems likely yes but subject to discussion depending on the objective of that research since in this case the relationships were moderate to strong. A few more questions rise on top of this. Is the fact of the data missing the maximum difficulty as Mythic from either subject a flaw on the data mining? Are the variables not only dependant to the subject that was tracked but also the team present itself? Is the usage of the Performetric software got a different effect on the players from expected? The answer is maybe for all of them. The lack of the maximum difficulty was a challenge into defining a critical moment but easily identified. It was identified an increase of mental fatigue when the difficulty of the simulation rose so it's likely to have the same effect on the maximum difficulty. It forces the player to be more focused and to be more willing to respond to more dangers from the game as bosses get more abilities that need to be addressed as the encounter progresses.. When looking into the team it might be easy to identify the dependencies when looking at the effects of mental fatigue on the healer. The more spells he used the more tired he would become. Either way it looks from a research perspective to analyse a whole team and look how the performance of a player can damage or improve the rest of the team. When questioning the guild of the healer it was given the same idea. Especially in the fights that were needed a lot of communication and teamwork when a player under performed the negative effect was immediately felt most of the times resulting in a unsuccessful encounter.

About the usage of the Performetric software changing behaviour was maybe felt on the initial days but easily surpassed. When questioning the players around the second and third premises, the healer used the breaks to pause for a smoke while the damage dealer didn't stop hanging in the computer at all. This could influence the average fatigue level felt during the course of the raid encounter and the higher increase felt on the damage

dealer prior to the raid. This doesn't excludes the characteristics of the user that in future research can be used to define the performance of the player in a more expressive way.

Even though gaming is on the present days starting to be considered a job, enterprises are more interested in the effects on real jobs that could contain this critical situations, and if the correlation that was reached on this research is gonna have and be felt with the same effect. One of the causes is the user having different reactions when he is observed where side effects such as induced stress creating the possibility of limitations on their performance. Some research needs to be investigated in real life situations in other to associate their productivity to this environment that can be linked to fatigue and performance. The same applies in a opposite way for this simulation. Since the simulation used a video game to support the objective for this thesis, the sense of a critical situation that we wanted to evaluate could not be achieved as pretended on the players especially on the healer which plays the game more casually. This fact could be related on the usage of video games by users as leisure, to escape the problems from reality or just for fantasy creating the possibility of transforming what could have been a stress moment into a challenging one creating a new set of characteristics for this situation.

Meanwhile in subsequent research there some be created different simulations with this same perspective, that created different scenarios. For that there should be used other genres of games in order to fulfil the research objective having this thesis as starting point. Also since e-sports is now a trend and there are now professional players a critical situation can be on stage playing against other players of other teams.

Even though this research didn't have the main concept to target to the gaming industry this can be used for this business. Targeting the players to reach their maximum performance while taking care of their mental health should be addressed accordingly in order to benefit both sides.

It is noticeable that there is the necessity on realising more studies in order to prove with more specification in more simulations that can prove this concept in a generic way. For that more types of games and further investigations should use this research as proof of concept to move further in more complex scenarios.

5.4 SUMMARY

With this chapter it is possible to understand in much detail the existence of an association between the mental fatigue and performance of the player. Between on the subjects the results differ for the type of job they are perform during this simulation.

There could be hidden variables that can be influencing either the mental fatigue and the performance of each user. In order to find this hypotheses it might be needed to look for additional hypotheses that can complement this evidence. On the damage dealer case since

he is the most independent of the three types that were presented earlier, the performance is more individual oriented and is more affected by his own behaviour. When facing high degrees of fatigue his performance is affected more intensively. In other hand the healer is more focused on the task that he has at hand. In a generic way the healer spends most of the time avoiding incoming damage while looking at the health of the team. This task requires a lot of focus that is evident with the increase of difficulty of the encounters.

When analysing the mental fatigue after an raid encounter it was also found a dispersion on results. In one case it had no significant effect on the user while in another case it was found an increase of mental fatigue found during the intervals that were considered. This increase can have lots of influence starting by the nature of the person to the difficult of the challenges.

With this evidence its safe to say that in every situation that differs with some significance there should be taken into some consideration variables that can be related to the atual environment, person and type of task.

6

CONCLUSION

6.1 PRESENT WORK

This present research is the starting point into redefining the potential that can be associated from analysing the mental fatigue of the players and associate it to their performance. The system created provided with success the evidence that performance and mental fatigue are correlated in depending from the characteristics of the user, the specification of the environment and the performance of several individuals. There is also evidence that can related the type of task during that simulation that can characterise the mental fatigue of the subject. Depending from the class played by the user different associations are created between the Performetric metrics and the game metrics that were gathered during this investigation. Considering this matter and some of ideas that are explained in the results there is a window to add into this kinds of applications the sense of singleness for each unique situation that there are faced, or at least grouped into a more specific set of characteristics specially the ones referent to the interactivity of the user to the device. Mental health is a serious concern that if not taken care of can lead to worse problems in the human being and that why the mental fatigue detection applications such as Performetric come into play. Finally even thought the system created is not in production it can be used as an API into the game from a addon point of view in order to help the players on their health.

6.2 PROSPECT FOR FUTURE WORK

As for future work there are a lot of paths that can be taken from a investigation perspective. Using this dissertation as a proof of concept to prepared some work into by measuring real life situations instead of just making a simulation. There is also the opportunity in a gaming scenario to establish the association between mental fatigue and performance to reaction times and decision making for other types of games like shooters or strategy games for each of the metrics specified. There is the potential to find hidden behaviour on short

periods of time that can reflect into signals meaning less productivity and instant increase of fatigue on that moment in jobs as find less performance while playing a video game. Lastly, for this dissertation there is the possibility to analyse the whole team to create a bigger understanding on the players and their communication, how reliable the team is when performing and to see how can a decrease on performance on one of the subjects can have effect on the encounter and the team itself.

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A

DETAILS OF RESULTS

A.1 TABLES RELATED WITH THE DAMAGE DEALER

A.1.1 *All Reports*

Metric 1	Metric 2	Correlation Value
TAD	TADR	1
	TC	0.94
	TCR	
	CPM	
TADR	TC	
	TCR	
TC		1
PILVL	POVERALL	0.98
Fights analysed		70

Table A.1.: Correlation > 0.9 All reports Damage Dealer

Metric 1	Metric 2	Correlation Value
TIME	TD	0.86
	TDMGT	0.81
TD		0.83
DPS	DTPS	0.7
	PIVL	0.77
	POVERALL	0.79
TAD TADR	CPM	
CPM	TC TCR	0.81
	PILVL	0.71
	POVERALL	0.73
TDMGTK	TDMGTKR	0.74
Fights analysed		70

Table A.2.: Correlation > 0.7 and < 0.9 All reports Damage Dealer

A.1.2 *Summary of Heroic difficulty reports*

Metric 1	Metric 2	Correlation Value
DPS	CPM	0.95
TD	TDMGT	0.9
TC	TCR	1
TAD	TADR	
	TC	0.94
	TCR	
CPM	TC	
	TCR	
PILVL	POVERALL	0.98
Fights analysed		67

Table A.3.: Correlation > 0.9 - Heroic Difficulty Damage Dealer

Metric 1	Metric 2	Correlation Value
TIME	TD	0.88
	TDMGT	0.83
SIZE	PPERF	-0.83
TAD	CPM	0.78
TADR		
CPM	TC	0.81
	TCR	
DPS	DTPS	0.79
CPM		0.75
TAD	TDMGTK	0.74
TADR		
CPM	TDMGTKR	0.72
DPS		0.73
TDMGTK		0.76
DPS	PILVL	0.7
CPM		0.79
DPS	POVERALL	0.72
CPM		0.98
PILVL		
Whole raid encounters analysed		67

Table A.4.: Correlation > 0.7 and < 0.9 Heroic Difficulty Damage Dealer

Metric 1	Metric 2	Correlation Value
K	TD	0.5
DPS	TAD	0.62
	TADR	
	TC	0.65
	TCR	
CPM	TDMGTK	0.56
TC		0.69
TCR		
TAD	TDMGTKR	0.65
TADR		
TC		0.66
TCR		
DTPS		0.52
TC	PILVL	
TCR		
TDMGTKR		0.59
ILVL	PPERF	0.55
TC	POVERALL	0.53
TCR		
TDMGTKR		0.61
SIZE	maMean	0.63
	maVar	0.64
	mvMean	0.67
	mvVar	0.6
	mouseDistance	0.5
TD	keysPressed	0.51
TDMGT		0.53
DTPS	mvVar	0.51
PPERF	maMean	0.61
	maVar	-0.58
TDMGT	mvMean	0.53
Whole raid encounters analysed		67

Table A.5.: Correlation > 0.5 and < 0.7 Heroic Difficulty Damage Dealer

Metric 1	Metric 2	Correlation Value
mouseDistance	Time	-0,42
	Size	0.5
	TD	-0.4
	TDMGT	-0,37
mouseExcessDistance	Time	-0,48
	Size	0.46
	TD	-0.43
	TDMGT	-0,41
mousePrecision	Time	-0,47
	Size	0.44
	TD	-0.43
	TDMGT	-0,4
wvMean	Time	0,45
	Size	-0.43
	TD	0.46
	TDMGT	0.52
keysPressed	Time	0,44
	TD	0.51
	TAD	0.39
	TDMGT	0,53
Fights analysed		67

Table A.6.: Performetric correlations - Heroic Damage

A.2 TABLES RELATED WITH THE HEALER

A.2.1 *All Reports*

Metric 1	Metric 2	Correlation Value
HPS	TH	0.93
	THR	
	CPM	
	TC	
	TCR	
TH	THR	1
	CPM	0.97
	TC	0.99
	TCR	
THR	CPM	0.98
	TC	0.99
	TCR	
CPM	TC	
	TCR	
TC	TDMGTKR	1
TDMGTK		0.9
PILVL	POVERALL	0.9
Fights analysed		336

Table A.7.: Correlation > 0.9 - All Reports Healer

Metric 1	Metric 2	Correlation Value
H	OH	0.81
	HPS	0.75
	TH	0.72
	THR	0.74
	CPM	0.76
	TC	
	TCR	
OH	TC	0.71
	TCR	
Fights analysed		336

Table A.8.: Correlation > 0.7 and < 0.9 - All Reports Healer

Metric 1	Metric 2	Correlation Value
TIME	H	0.55
	TDMGT	0.63
SIZE	THR	-0.5
	PPERF	-0.6
H	OHT	-0.55
	ILVL	-0.57
	dmsLMean	-0.52
OH	HPS	0.61
	TH	0.68
	THR	0.69
	CPM	0.68
	dmsLMean	-0.5
HPS	OHT	-0.69
	ILVL	-0.79
	PIVL	0.57
	dmsLMean	-0.65
TH	OHT	-0.59
	ILVL	-0.85
	dmsLMean	-0.68
THR	OHT	-0.58
	ILVL	-0.85
	dmsLMean	-0.68
OHT	CPM	-0.6
	TC	-0.58
	TCR	-0.58
	ILVL	0.67
	PILVL	-0.52
CPM	ILVL	-0.83
	PILVL	0.52
	dmsLMean	-0.67
TC	ILVL	-0.83
	dmsLMean	-0.67
TCR	ILVL	-0.83
	dmsLMean	-0.67
ILVL	PILVL	-0.55
	dmsLMean	0.58
PILVL	POVERALL	0.54
PPERF		0.53
Fights analysed		336

Table A.9.: Correlation > 0.5 and < 0.7 - All Reports Healer

A.2.2 *Normal Difficulty*

Metric 1	Metric 2	Correlation Value
TH	THR TC TCR	1
THR	TC TCR	
CPM	TC	
	TCR	
TC		
TH THR	CPM	0.99
HPS	TH THR CPM TC TCR	0.97
H	OH	0.92
	HPS	0.9
OH		
HPS CPM TC TCR TH THR	ILVL	-0.95
		-0.97
		-0.98
Fights analysed		67

Table A.10.: Correlation > 0.9 - Normal Difficulty Healer

Metric 1	Metric 2	Correlation Value
Time	TDMGT	0.83
H	TH	0.85
	THR	
	CPM	
	TC	0.86
	TCR	
	OHT	-0.76
OH	TH	0.88
	THR	0.89
	TC	
	TCR	
HPS	OHT	-0.73
H	ILVL	-0.83
OH		-0.84
PILVL		-0.78
	PPERF	-0.77
SIZE		-0.76
H	PILVL	0.74
OH		0.7
HPS		0.83
TH		0.76
CPM		0.79
THR		0.77
TC		
TCR		
HPS	PPERF	0.81
TH		0.78
THR		
CPM		0.8
TC		0.77
TCR		
Fights analysed		67

Table A.12.: Correlation > 0.7 and < 0.9 - Normal Difficulty Healer

Metric 1	Metric 2	Correlation Value
TDMGTK	TDMGTKR	0.82
PILVL	PPERF	0.81
	POVERALL	0.89
PPERF		0.7
H	FatigueLevel	0.76
CPM		
OH		0.75
HPS		0.77
TH		
THR		
TC		
TCR		
ILVL		-0.77
ILVL	maVar	-0.71

Table A.13.: Correlation > 0.7 and < 0.9 - Normal Difficulty Healer

Metric 1	Metric 2	Correlation Value
maVar	HPS	0,63
	TH	0,69
	CPM	0.66
	TC	0.68
	PIVL	0.5
mvMean	HPS	-0,39
	TH	-0,36
	CPM	-0,37
	TC	-0,36
mousePrecision	HPS	-0,51
	TH	-0,54
	CPM	-0,53
	TC	-0,55
	PIVL	-0,51
wvMean	Time	0,5
	TH	0.57
	CPM	
	TC	0.56
	PIVL	0.5
keysPressed	HPS	0,51
	TH	0.58
	CPM	
	TC	0.57
	PIVL	0.52
Fights analysed		67

Table A.14.: Performetric relevant correlations - Normal Difficulty Healer

A.2.3 *Heroic Difficulty*

Metric 1	Metric 2	Correlation Value
TC	TCR	1
TH	THR	0.99
TH	TC	0.98
	TCR	
THR	TC	
	TCR	
CPM	TC	
	TCR	
TH	CPM	0.96
HPS	TH	0.91
	THR	
	CPM	
	TC	
	TCR	
TDMGTK	TDMGTKR	0.93
PILVL	POVERALL	0.92
Fights analysed		269

Table A.15.: Correlation > 0.9 - Heroic Difficult Healer

Metric 1	Metric 2	Correlation Value
TIME	H	0.74
H	OH	0.78
	CPM	0.71
	TC	
	TCR	
OHT	ILVL	0.72
HPS		-0.77
TH		-0.8
THR		
CPM		-0.76
TC		
TCR		
Fights analysed		269

Table A.16.: Correlation > 0.7 and < 0.9 - Heroic Difficult Healer