Understanding User Interaction in a Video Game by using Eye Tracking and Facial Expressions Analysis

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Abstract

The increasing importance and employment of usability testing has heightened the need for a careful and extensive study of usability evaluation methods and tools available. Usability testing provides a means for understanding the real picture of the product being used in a context.

The aim of this Master's thesis is to understand user interaction in a video game by using the two data collection methods, eye tracking and facial expressions analysis. Usability testing in video games is one of the important factors, if carried out consistently and timely it can significantly make the video game more enjoyable, playable and provide a quality user experience to the gamers. Overall, the usability testing efforts contribute to the enhanced effectiveness, efficiency and satisfaction in the gaming experience.

The eye movements and facial expressions provide data which is useful for researchers to understand the user interaction of players' while playing a video game, as what objects capture their attention, what objects were ignored or didn't get attention, difficulties in progressing through the game and also players emotional state when interacting with video game elements.

Total eight participants were recruited including one pilot participant to perform the usability testing. The participants were asked to play Call of Duty: Modern Warfare 2 and progress through the game by completing the objectives. Data collected by using eye movement tracking and facial expressions analysis. Data analysis performed to generate results from usability testing, questionnaire and interviews.

Key words and terms: Usability testing, usability evaluation, eye tracking, facial expression analysis, video game.

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1. Introduction

The importance of usability of a product has been acknowledged in all kind of works and actions in our daily life, basic action of opening a door, using light switches, using a coffee machine or working on a computer application. To complete a certain amount of work or an action efficiently, the basic and essential need to understand the product's usability has become key. Aspects of usability vary differently from tangible products to intangible products, in terms of their applicability [Taylor, 2013].

The concept of usability is not very old, it emerged in the 19th century from the fundamentals and principles of scientific management, to increase the extent to which products were easier to use and met the requirements of users [Taylor, 2013]. From the 1980s onwards [Norman, 1988], the concept of usability received increased attention in the field of Computer Sciences, especially when the tutorials for the first time computer users were launched [Al-Awar et al., 1981]. Since then, different methods had been designed and developed to ensure the efficient usability of products. By utilizing those methods, a product's usability can be evaluated, to ensure positive and satisfactory results [Spencer, 1985].

Usability evaluation of a product is significant to assess its characteristics in order to ensure its efficiency, effectiveness and satisfactory level. To perform usability evaluation, we need the usability evaluation methods. There are various usability evaluation methods available such as focus groups [NY Times, 2003], heuristic evaluation [Nielsen, 1995], interview [Gubrium and Holstein, 2002], questionnaires [Gault, 1907], cognitive walkthrough [Wharton et. al., 1994], think aloud [Nielsen, 1993] and usability testing. For this study, usability testing has been chosen as usability evaluation method followed by questionnaires and interview.

The increasing importance of usability testing has heightened the need for a careful and extensive study of usability evaluation methods available. Usability testing provides a means for understanding the real picture of the product being used in a context. Dumas [1999] describes, the concept of usability testing is evolutionary in nature. Significant constructive and productive efforts have been carried out in the field of usability testing which makes it a suitable method for measuring usability of a product [More solid ref].

The challenges that are normally faced in the usability testing are; choosing a suitable data collection method, providing satisfactory comfort level for testing participants during the testing. If the usability testing is tiresome and complex for the participants, then participants are dissatisfied. The outcome of this situation for the participants is that, their productivity starts to lose; they often lose the control during the testing, they lose their concentration and in some cases start paying less attention towards the tasks given in the usability testing [Norman, 1988].

Usability testing in video games is one of the important factors, if carried out consistently and timely it can significantly make video games more enjoyable, playable and provide improved user interaction to the gamers. Overall, the usability testing efforts contribute to the enhanced effectiveness, efficiency and satisfaction in the gaming experience.

Video gaming is one of the fastest growing sectors worldwide with estimated 1.2 billion gamers worldwide and increasing, as described in Figure 1 [SuperData, 2015]. Gamers demand of playing entertaining and playful video games have led the companies to produce more video games. As the video game production increases, the competition in the video gaming industry becomes intense. The game industry growth can be recognized by the global games market report for the year 2014, as shown in Figure 2. This report estimates the game industry revenue for 2014 as $81.5 billion and lists the top 100 countries in the world with game revenue [Newzoo, 2014].

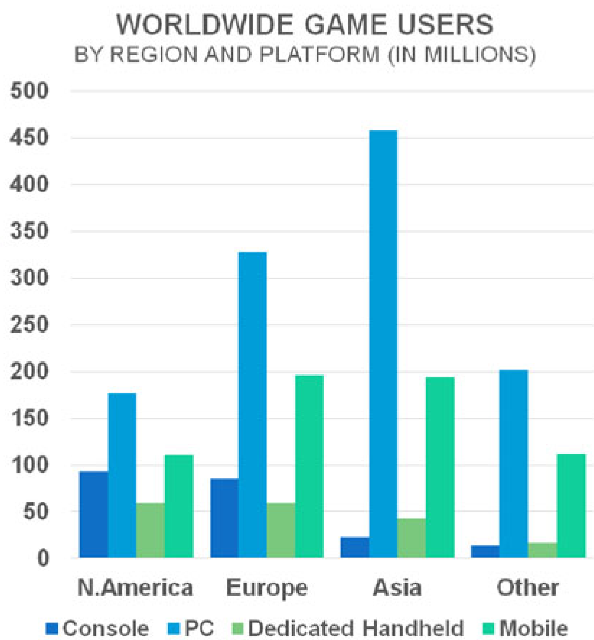

Figure 1: Worldwide game consumers in 2015 (in millions).

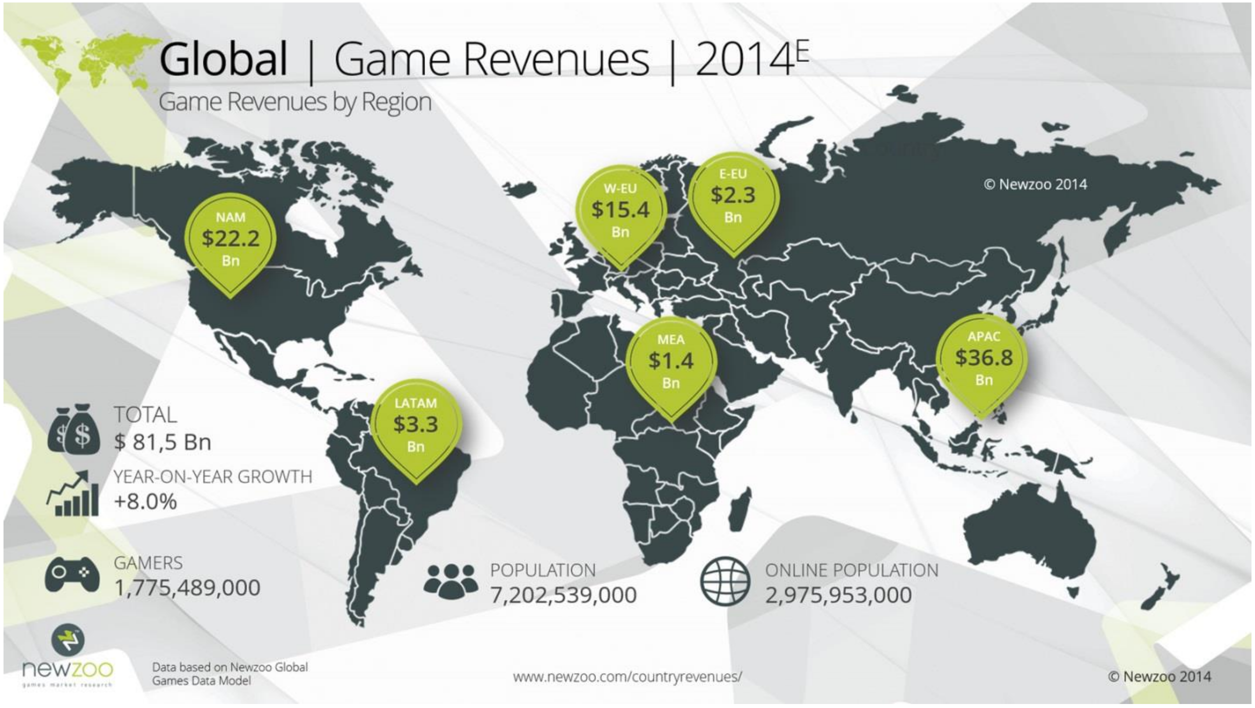

Figure 2: Global game revenues by region in 2014.

The competition in the gaming industry has made the companies to work consistently towards the efficient and satisfying usability of video games. Video gamers’ requirements and wishes are the priorities for the companies, to produce high quality video games with higher usability ratings and provide satisfactory user experience to the video gamers [Mital et. al., 2008].

As mentioned by Laitinen [2005], the gaming industry is experiencing a rapid boom; numerous games are being developed and launched every year. There is a serious competition in the gaming industry, if the video game lacks the qualitative elements; it is possible that it can drive the player towards frustration, less exciting and less engaging experience. The unsatisfactory performance and interaction with the video game can make the player to choose different and a better video game.

The aim of this Master’s thesis is to perform usability testing for a video game. To accomplish this goal, we need data collection methods to collect data during the usability testing and later perform data analysis on the collected data. For this purpose, eye tracking and facial expressions analysis are utilized to maximize the usability testing efficacy for video games. This approach will provide a basis to understand the deep insights in usability testing by utilizing the capabilities of both methods.

The eye tracking can provide participants' eye movement data during the video game, data related to the efficiency and effectiveness of each task in the video game. Also, by analysing the participants' eye movement data will provide the details such as the game elements that captured participants' attention, important elements that were ignored or unattended. The data collected from all the participants using eye tracking will provide us insights to look at the usability problems faced by the participants throughout the game.

Facial expressions analysis can provide the data for participants' facial expressions such as Joy, Surprise, Sadness, Fear, Anger, Disgust and Contempt to understand the emotional state of the participants. The data collected from all the participants using facial expressions analysis will provide us insights about the participants' emotions based on their facial expressions, when they are performing tasks during a video game. It will be useful to understand how participants' feel for different (easier, medium, difficult) kind of tasks during a video game.

Combining the functionality of eye tracking and facial expression analysis is useful to achieve the aimed results of this study. Correlation of both methods can provide insights such as when a participant is facing a difficulty in performing a task, what insights does the eye movements reveal and what is the emotional state of the participant.

It seems like a lot of work required to carry out the usability testing. Considering from the participant's viewpoint, the participant has to focus on each task and follow the instructions from the moderator during the test. In contrast, the usability tester and the moderator have to perform the testing carefully by keeping the comfort level of participants, observing the participant's behaviour and helping the participant as required. The work can be challenging and provide productive results.

This master's thesis can benefit the usability testers and researchers to understand potential benefits and limitations of eye tracking and facial expressions analysis in the context of video games. So, they can understand when and how to apply them. These methods both generate some data as opposed to monitoring and interviews and more structured data then plain video. Also, how they relate to standard usability testing methods.

This thesis has six chapters. Chapter 2 discusses the concept of usability, usability testing, eye tracking and facial expressions analysis in more detail. Chapter 3 explains the procedure of this experiment. Chapter 4 presents the results and their analysis. Chapter 5 presents a discussion of the results obtained in relation with the existing knowledge present in the literature. Chapter 6 concludes the work and presents some of the future research opportunities in the field of usability testing in video games.

2. Background

In this part, previous work with relevance to the current study is reviewed. This includes studies that explain the concept of usability, usability evaluation methods, usability testing, current trends in usability testing and two powerful techniques; facial expressions analysis and eye tracking. The recent work which has been done by the researchers and the practitioners concerning the enhancement of usability testing is reviewed as well.

2.1 Usability

In the early 20th century, the concept of the usability was initially discovered. The "Father of the scientific management", Frederick Winslow Taylor [2013] published his outstanding work in the form of a monograph, explaining the fundamentals and principles of scientific management in order to enhance and the aspects of usability in almost all kind of works and actions in the day to day work [Taylor, 2013].

In 1943, the "Founding Father of ergonomics", Alphonse Chapanis was the first person to uncover the hidden details of "pilot error" in the aircraft cockpit, which could be reduced by enhancing the usability of the aircraft safety instruments [Homewood, 2002, Vicente, 2004]. Later, in 1981, "Tutorials for the first time computer users" was published by the Alphonse Chapanis and his colleagues, which reflected usability as a formative rather than summative activity [Al-Awar et al., 1981].

The 1980s has been considered as the birth of the usability as a profession [Dumas, 1999]. The concept of Usability evolved greatly in historic references; it was the time when the term 'Usability' had to be described. According to Eason [1988], the term Usability is described as "*the degree to which users are able to use the system with the skills, knowledge, stereotypes and experience they can bring to bear*".

This definition is broad enough to encompass a wide range of activities.

In 1990, it was the first time that the description and full definition of the concept of usability was published. Usability was described as a function of efficiency, effectiveness and satisfaction as "*Human Factors and Usability*". This also became an ISO standard [Shackel and Richardson, 2008]. The concept of usability matured in the mid of 1990s, but the beginning of the 21st century, took the usability a step ahead.

Now, the concept of usability has become a principal reference point in usability research, as explained by the ISO (the International Organization for Standardization). According to ISO 9241-11 [ISO/IEC, 9241-11, 1998], the term usability has been defined as, *"Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."*

2.1.1 Usability Evaluation Methods

The usability evaluation of a product is significant to assess the product characteristics in order to ensure the efficiency, effectiveness and satisfactory level. To perform the usability evaluation, we need the usability evaluation methods. There are various usability evaluation methods available:

- Focus groups are usually formed by multiple participants involved simultaneously, to describe their feelings about the test and they provide general information [Rubin & Chisnell, 2008].
- Heuristic evaluation involves Nielson's ten heuristics, whereas usability problems are assigned a severity rating and this method is performed without users [Nielsen, 1995].
- Interview is a face-to-face discussion carried out with the participant, to collect useful information regarding a usability test.
- Questionnaires collect the data about user's background, preferences and experience. Both interviews and questionnaires provide subjective information.

Wharton et. al. [1994] describes cognitive walkthrough as a task specific approach, an evaluator or a group of evaluators accomplish the set of tasks, each task is a sequence of actions, a user has to perform. Evaluator(s) walk through the system by questioning themselves as if the actual user would follow the same sequence or not. This method can also be applied at an early stage such as a design phase of the system and it is cost effective as compared to the usability testing.

Among the various usability testing methods, 'Think aloud Protocol' is one of the, effective ones, as this method allows the usability testers or evaluators to get into the thought process of the participants, by allowing them to speak aloud whatever they think during the usability testing. Nielsen [1993] defines think aloud, as a method which allows the participants to use the system and simultaneously verbalize their thoughts during the test. It provides the deep insights of participant's thinking process, as what they actually think while performing any action.

The method which is selected to perform usability evaluation is a key factor, to make use of the capabilities of the usability evaluation method to achieve aimed results. It is dependent on the target user group, contextual use, product under evaluation and the product development phase.

Usability testing is discussed in detail in the following section.

2.1.2 Usability Testing

There are certain methods available that can be employed to measure the level of usability, so that it passes the criteria of effectiveness, efficiency and user satisfaction. One of the available usability evaluation methods is, ‘Usability Testing’, which is explained as, *“The process that employs people as testing participants who are representative of the target audience to evaluate the degree to which a product meets specific usability criteria is referred to as Usability Testing”*, [Rubin and Chisnell, 2008].

Alshamari and Mayhew [2009] assumed that the factors affecting the performance of the usability testing process and its results could be numerous and include usability measures, users, usability testers, tasks, usability problem report, environment and some others. The developer of Pure, a racing car game developed by the Disney’s Black Rock Studio, got the Metacritic score improved by 10% because of usability testing [McAllister & White, 2009].

In recent times, the study of the usability testing has gained significance [Dumas, 1999]. It is extremely important to ensure that the factors affecting the application’s usability are well designed and effectively incorporated into the design of the application, before the application is launched. The usability testing process involves recruiting participants, selection of testing environment, selection of techniques, usability experts, tools for analysis for measuring the efficiency and effectiveness of an application’s usability. The process involves usability testing environment, usually a laboratory or a field, usability evaluation methods, moderators and observers, participants to perform the usability testing, interviews of participants and questionnaires filled by participants.

The nature of the testing environment can be a laboratory or an open field; such as a public place. Meanwhile, for certain devices and applications there is a greater need for open field testing [Benefits of field testing]. In contrast, the laboratory environment is comfortable and more productive in uncovering, discovering and learning the factual information. If usability testing is carried out in the open field then there is a higher risk of human factors, systematic factors and environmental factors affecting the usability testing process of an application and thus causing errors.

The selection of usability testing environment plays a key role in uncovering usability problems, discovering factual information, learning deep insights into the usability testing process and enhancing the usability testing efforts.

Once the usability testing environment is finalized, the usability testing method is selected for optimal performance of the test and bringing the best possible results for the overall study.

The selection of participants depends on the nature and the target audience of the application, their educational background, and computer handling skills or device handling skills.

Participants should be told beforehand the actual usability testing is carried out, as what they are supposed to do during the usability testing process. They should be thanked in advance, their consent should be recorded that their information will remain confidential and will not be distributed publicly without their consent.

The usability testers often face the difficulties in finding the desired facts during the usability testing process. There can be several factors affecting the usability testing process of an application such as inconsistent usability testing plan, unprofessional execution of usability test, bad selection of usability testing participants and inconsistent analysis of usability testing results. Usability testing usually will not find detailed problems, but it will certainly find the obvious problems that otherwise escape attention [Zirinsky, 1986].

To achieve better and desired results in this particular research study, two useful techniques facial expressions analysis and eye tracking have been employed.

2.2 Facial Expressions

The facial changes in response to a person's internal emotional activity, intentions or social communications, is referred to as facial expressions [Tian et. al., 2003].

In the nineteenth century [Darwin, 1872], Darwin's outstanding contribution to the investigation of facial expressions provided in depth insights, into the facial expressions in mammals. The answers of the research questions that he addresses in his work became the foundation for the facial expression analysis and recognition. The work includes evidence from anatomical, neurological and physiological points of view.

Indeed, there are solid reasons for citing Darwin's extraordinary achievements in the relevant field. Firstly, he strengthened his work by benefiting from the usefulness of various data sources. Secondly, in his writings he explained the observations made about the behaviour of animals, children, and people from the multicultural, mentally sick and disabled background.

Ekman [2006] discussed that there had been several reasons why Darwin's book was not influential and often condemned by other authors. Mainly, due to the Darwin's concept of evolution of man, the emotions and facial expressions which are observed in man should be observed in some animals as well. Inconclusive evidence was given in the research work such as inacceptable amount of behaviour observation, lack of contextual accounting and methodical factual information in the research. The most critical reason was that, he emphasized the fundamental principle of inherent characteristics, lies in some of the facial expressions. This concept received compelling significance and was refused by the psychologists.

In 1914, Watson refused this concept of Darwin and stated that the actual reason is an environmental effect. Later on, Darwin adopted the theory of Lamarck, which explained that the essential and distinctive elements could be a result of inherent behaviour.

2.2.1 Facial Expression Analysis

Facial expressions and words both are used for communication and conveying the message. But facial expression smoothly reveals, what cannot be explained in words [Ekman, 1994]. Facial expression reveals the information about emotions, mood and interpersonal behaviour of humans. In general, facial expression analysis helps us to better understand the humans, their actions and behaviour [Torre and Cohn, 2011].

The first ever considerable efforts in the field of facial expression analysis were published in the middle of the 17th century [Geen and Tassinary, 2002]. This remarkable work is considered as the corner stone in defining and describing the theoretical concepts of the facial expressions and the emotional elements associated with them. However, the progressive maturity and the evolutionary change in the theoretical concepts of the facial expression analysis were seen as archaic by the authors of the eighteenth and nineteenth century.

Facial expression analysis is based on three steps, which are described in the Figure 3, as face acquisition, facial data extraction and representation, and facial expression recognition [Tian et. al., 2003].

Figure 3: Basic structure of facial expression analysis system [Tian et. al., 2003].

Facial expression analysis is the process of analysing facial expressions using a camera which records the facial expressions, matches them with the predefined facial expressions from a database. Qualitative data revealed by the facial expression analysis, provide deep insights into user’s emotional state of mind.

Facial Action Coding System (FACS) is a research tool, developed by Ekman and Friesen [1978] to represent facial expressions by action units to measure the facial behaviour. Facial behaviour includes for example, eye brow movement, turns and tilt movement of a head. FACS can be used for emotional expressions such as depression, medical context, in computer animations etc. It has the capability to measure any observable human facial expression. FACS describes each facial action or movement in the form of Action Unit (AU). All facial expressions are breakable into their individual action units AUs [Ekman, 2015]. Some example action units for upper and lower face actions are depicted in the Figure 4 and Figure 5. However, complete list of actions units revised by [Ekman, Friesen and Hager, 2002] can be found online.

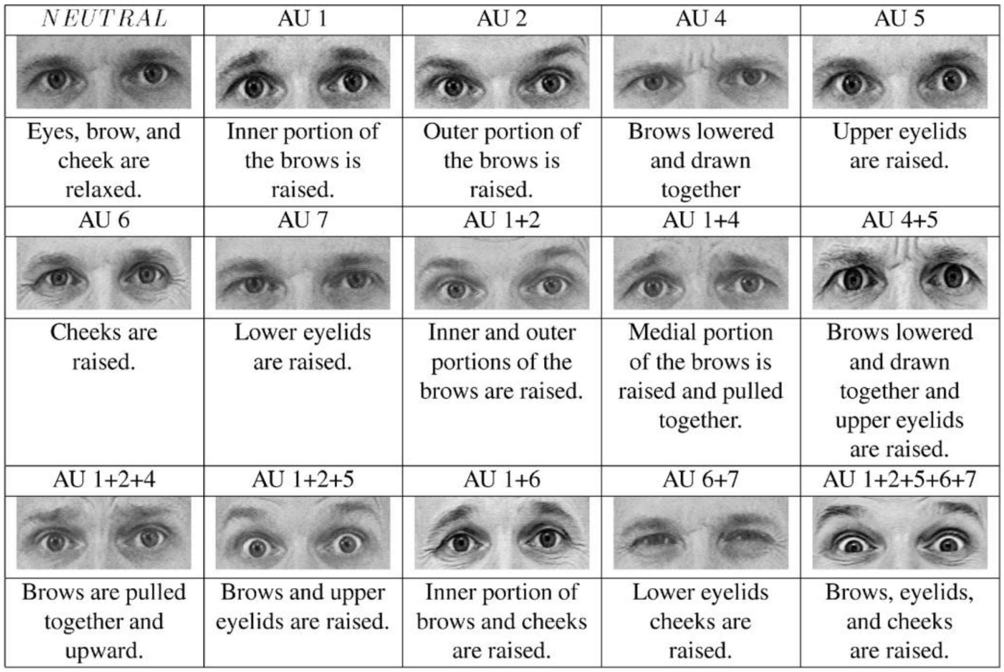

Figure 4: Upper face action units and some combinations [Tian et. al., 2001].

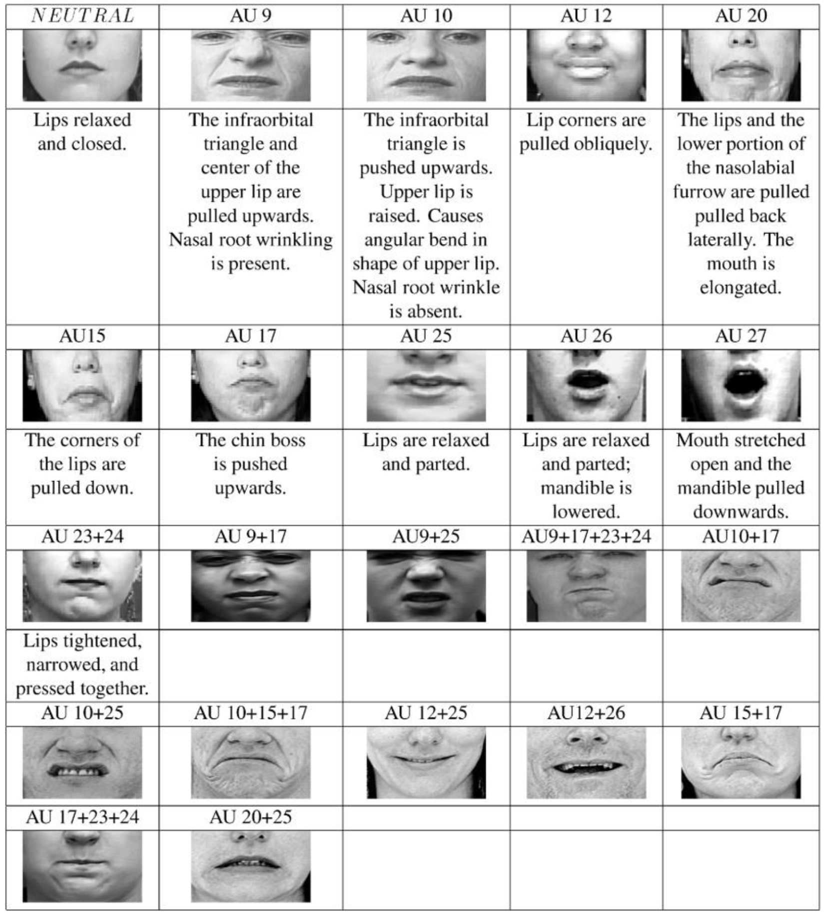

Figure 5: Lower face action units and some combinations [Tian et. al., 2001].

2.3 Current trends in Facial expression analysis

Significant development has occurred in the field of facial expression analysis, automated system have been designed and developed to perform the facial expression analysis and recognition. The software systems like Noldus [Noldus, 2015] and iMotions Emotient module [iMotions, 2015] analyse and recognize universal facial expressions of humans.

2.3.1 Noldus Face Reader 6

Noldus FaceReader 6 is automatic facial expression analysis software [Noldus, 2015]. It supports the six essential facial expression classifications (happy, sad, angry, disgusted, scared and surprised) and also neutral and contempt. It also features head orientation, gaze direction and personal attributes like age and gender classification. FaceReader functions in the following three steps; First, finding a flawless face position. Second, face modelling by synchronizing the active face model over the built-in artificial face model, 500 key points used to define the face location. Third, face classification where the end result is displayed in the form of six basic facial expressions, a neutral state and contempt.

It also recognizes the commonly used action units such as dimpling, eyes closed, raising of cheeks, jaw dropping and many more.

2.3.2 Emotient Analytics

Emotient Analytics is a web based facial expressions analysis tool, hosted in the cloud [Emotient, 2015]. It provides the data analytics for the following categories: attention, emotional engagement and sentiment for the uploaded videos. To analyse the facial expressions of the user, a recorded video of a user is uploaded to Emotient Analytics through a web browser or it's API. The video is processed on the cloud, and the result is available in the form of interactive charts or downloadable data files as shown in the Figure 6. Emotient claims that their technology derives emotions from facial micro expressions, which a user displays in, as small as 1/25th of a second (a single video frame).

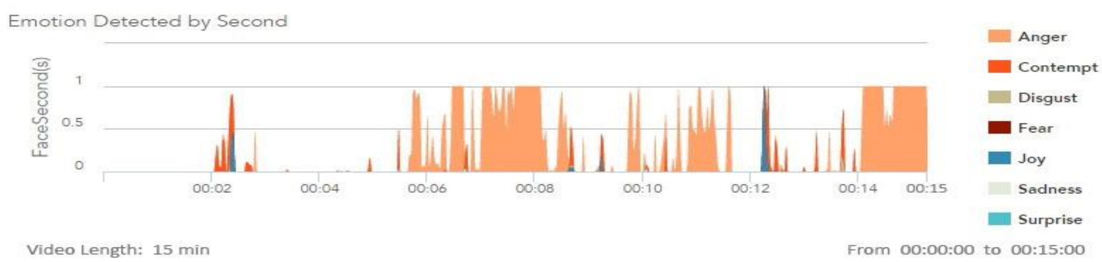

Figure 6 Emotions detected per second.

With 95% accuracy in real world, quick results and the capability of recognizing hundreds of faces in a single video makes it competitive with other face readers. It recognizes seven common facial expressions basis (Joy, Surprise, Sadness, Fear, Anger, Disgust and Contempt), which are analysed on a per-frame basis.

In this study, a free version of Emotient analytics will be used to perform the facial expressions analysis. The following are the key features in the technology:

- Basic emotional states analysis on a per frame basis (joy, surprise, sadness, anger, fear, disgust and contempt),
- Facial data – Action Units plus facial position and orientation to camera in three dimensions.
- Measures attention, engagement, and sentiment (positive, negative or neutral).
- Detects demographic factors such as gender, age group and ethnicity.
- Capable of analysing hundreds of faces at once (if each face is at least 48 x 48 pixels)

2.3.3 iMotions Emotient Module

To analyse the emotional responses from the face and recognize seven basic facial expressions (joy, anger, surprise, fear, sadness, disgust and contempt), 19 action units and two advanced emotions (confusion and frustration), Emotient FACET SDK is integrated into the iMotions Emotient module [iMotions, 2015]. Moreover, optionally the combination of biosensors like eye tracking, EEG, GSR, EMG and ECG can also be integrated with the software.

FACET is facial expression analysis and recognition software, which has been developed after two decades of research. It analyses the emotional responses of users frame-by-frame, recognizes seven basic facial expressions. It provides high classification accuracy in various conditions like gender, age, facial hair, spectacles, head pose and lighting, because of large dataset involved in the backend.

2.4 Challenges in Facial expression analysis

One of the major challenges in the facial expressions analysis which the researchers and the practitioners face is the recognition of instantaneous facial expressions [Bettadapura, 2012]. The research focus has been moved, from recognition of posed facial expressions, towards analysing and recognizing instantaneous facial expressions. However, the situation becomes more challenging when the researchers face difficulty to find the available data for instantaneous facial expressions.

Another big challenge that exists is the low intensity facial expressions recognition [Jia et. al., 2015]. In this kind of situation, there are two alternative ways to deal with this problem. First, the facial expressions with middle/high intensity are recognized and used in the data analysis. Second, users participating in the studies are instructed to generate fake expressions of middle/high intensity, whenever they are supposed to generate the facial expressions with low intensity.

2.5 Eye Tracking

Eye tracking is a technique to follow the eye movement of a person. It involves an eye tracking equipment, which can be integrated into a computer monitor or attached as an external device. The system executes the eye tracking software application that keeps track of the eye movement pattern. This whole human computer interaction can be recorded by using a built-in camera or an external camera, to further analyse the data. [Nielson & Pernice, 2009]

In the late 19^{th} century, the observation of eye movements for reading was initially described by Louis Emile Javal, who founded the ophthalmology laboratory at the Sorbonne, Paris [Javal, 1878].

Later in the same century, the early research and development work by Delabarre and Huey had limitations, as the eye tracking equipment has to be in physical contact with the cornea, which was evidently inconvenient and uncomfortable for the users [Delabarre, 1898 and Huey, 1898]. Thus, the innovative thinking and the redesigning of the eye tracker had to be considered by the researchers and practitioners of that time.

In 1901, Dodge and Cline redesigned the equipment of the eye tracker by utilising photographic devices. It was the first ever eye tracking technique, that was built on the concept of light reflection from the cornea [Dodge & Cline, 1901]. Later on, in the middle of the 20th century, Hartridge and Thompson invented the first head-mounted eye tracker [Hartridge and Thompson, 1948].

In the 1970s the eye tracking research achieved a breakthrough by focusing the technical improvements in the design and technology, to achieve accuracy, precision and make the equipment comfortable for the users. The technological progression of that time became the foundation of the eye tracking technique, and it is still evidently reflected in modern eye tracking [Jacob & Karn]. Since, the 1980s the research in the field progressed to utilize eye tracking technology in human computer interaction. The incorporation of the eye tracking technology in the gaming world has a valuable contribution to build a better and exciting user experience [Isokoski et. el., 2009].

2.5.1 Eye tracking technology

As [Surakka et. el., 2003] described the majority of the currently available eye trackers utilise the pupil-centre corneal-reflection method to define the position of the eye movements on the stimulus. The equipment can be remotely mounted with an external camera or a head-mounted equipment with a camera attached to a headband. A corneal reflection is generated, when the eye is illuminated by using an infrared light emitter close to the camera lens. A software application collects the data, performs the analysis on the recorded information and defines the position of the centre of the pupil and the centre of the corneal reflection. The calibration settings differ for different users, so, before capturing the eye movement data, the equipment needs to be calibrated.

2.5.2 Current trends in Eye tracking

Eye tracking generates both quantitative and qualitative data. The advancement in the eye tracking technology is remarkable. The current technology is available for several fields of studies such as desktop and mobile.

In this study we are going to use the Tobii T60 eye tracker. It is a desktop based eye tracker which uses the onscreen eye tracking technology. The Tobii studio software has been used to capture the participant's eye tracking data.

2.5.3 Eye tracking in Usability Testing

Eye tracking plays a role in usability testing, as it is very useful to understand and discover the participant's eye movements and emotional state during the interaction. It reveals the detailed level of information which verbalization cannot do alone and by utilizing the power of eye tracking in the usability testing, effective results with enhanced user experience can be achieved [Cooke, 2003].

In addition, the scan pattern and eye movements provide the meaningful understanding of user behaviour, to clearly compute the efficiency of task completion and difficulty level of the task. The application of eye tracking in the field of usability testing has indeed a definite potential to take the usability testing to the next level in terms of enhanced usability testing process, and eventually resulting in the effective and satisfactory user experience. The following quote supports the eye tracking technology:

"…[T]he eyetracking system has a promising future in usability engineering" (Benel, Ottens & Horst, 1991, p.465).

Just and Carpenter [1976], put forward an idea of "on top of the stack", which means that a person's thought process is indicated by what he is looking at. This idea was also refered to as the eye-mind hypothesis. This means that the eye tracking can provide the information about the visual objects that grasp the user's attention on the stimulus.

Eye tracking can help HCI researchers to understand the factors that may impact the usability in video games [Ghaoui, 2006], the HCI researchers can define the areas of interest on the stimulus, then track the eye movements falling in those particular areas. Firstly, this approach provides a way to evaluate the visibility, meaningfulness and placement of the gaming elements in the video game such as menus, instructions, dialogues etc. Secondly, the observations made from this approach can help improve the design of the video game. For instance, the gaming elements which were important from the game designer's point of view but the users paid less or no attention to them, can be redesigned to serve their purpose. [Goldberg and Kotval, 1999].

According to Ghaoui [2006], "eye movements tracking represent important, objective technique that can afford useful advantages for the in-depth analysis of interface usability." It seems to be a positive addition in the usability testing techniques for commercial and academic use, and the future for eye tracking in usability studies looks promising. Eye tracking analysis in usability testing opens up many opportunities for HCI researchers.

In the laboratory environment, eye tracking can provide useful data over the conventional usability methods like Think-aloud protocol or questionnaires. There is a potential risk that participant is aware that his behaviour is being monitored. Due to this reason, participant's behaviour can be biased or not accurate in that particular situation, because of social expectations or context awareness. On the other hand, eye tracking reveals the natural eye movements of the participant on the stimulus [Michael et. al., 2003].

Duchowski mentions in his book [2007], to track the eye movements of the users, we can follow the path that users' eye movements make, after analysing the complete path, we can understand the objects that grasp users' attention and get the deep insights of users' areas of interests while interacting with stimulus.

Using eye tracking technology in the usability testing can almost take you into the users' head and know their thinking process. For example, what they look and how long they look can reveal the problems faced by the users' while interaction [Nielsen and Pernice, 2010]. It helps us to understand the users' wasted time, to search a required object or to perform a required action.

2.6 Usability Testing with Eye tracking in Video Games

Video gaming has become a huge industry with some games having budget bigger than movies [Metro, 2013]. [Usability testing in games] In the year 2005, Sony hired a usability testing firm to perform the usability testing for its gaming title EyeToy Play 3 [McAllister and White, 2010]. The observers were Chequer and the other members from the team. The results drawn from the tests were useful in two ways. Firstly, the team members got the motivation as the real gamers were playing to test their game. Secondly, to know the flaws in the game, which were not considered before. Although, the result findings uncovered significant issues in the game, the development team was unable to fix some of the significant issues, as the game was already approaching to the Beta release.

2.6.1 Case Study - Eye tracking Games Research

Key Lime Interactive, a usability research company in collaboration with THQ, Inc. game publisher, performed a usability study utilizing eye tracking for a 3D video game [SMI, 2015]. Usability studies in gaming must consider the following attributes:

- Prior purpose of a game is user experience.

- Overcoming challenges in a game.
- Diverse group of gamers.

THQ perform the usability study by utilizing the Think-aloud protocol and observations. However, they only found out that the players were facing challenges and did not find the insights about why players facing those challenges. So, Key Lime Interactive rerun the usability studies with their own eye tracking technology to collect the eye tracking data and insight of the players' awareness of in-game cues and objects. For instance, what grasped the players' attention in the 3D world, what time they were noticed and what objects were ignored.

The test was conducted by recruiting eight participants (7 males and 1 female), with 3rd person shooter gaming experience. Each session lasted for 60 minutes. The analysis was based on highlighting the areas of interest (AOI), to analyse the number of times the area was visited by the player and how long it was viewed.

SensoMotoric instruments (SMI) RED remote eye tracking system was utilized in the study, to gather eye tracking data. The system was connected to the high end gaming machine. The system provides hardware, External Video Package (EVP) which is used to connect the gaming consoles, MAC or PC. Following are the findings of the study:

- Eye tracking data from the areas of interests was classified based on the visual cues and the 3D objects in the video game as shown in Figure 7.
- Average time spent by the players on areas of interest is highlighted with red colour as shown in Figure 8.
- Eye tracking helped the game designers to relocate and redesign game elements, to make them more effective as shown in Figure 9.

Figure 7: Eye tracking data on visual cues.

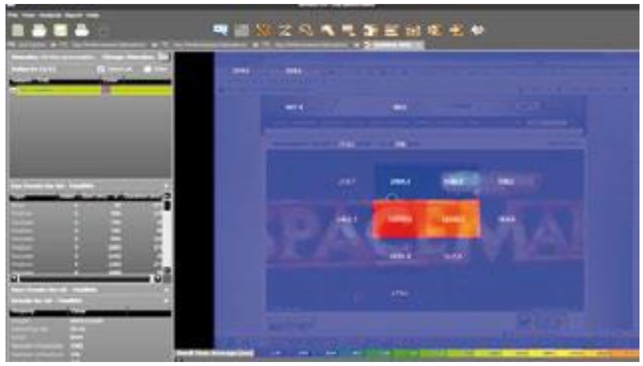

Figure 8: Red colour highlighting dwell time.

Figure 9: Key elements identified for redesigning.

2.6.2 Case Study - Usability Testing with Eye tracking in Video Games

The following case study by the manufacturer of leading eye tracking systems Tobii is the most relevant work for the current study [Tobii, 2015]. This case study is unique of its kind and provides the detailed level information about user interaction in a video game.

A Dutch gaming company, Guerrilla Games released a high budget shooting game, Killzone 3 which was considered as the biggest video game ever developed in the Netherlands. They worked in collaboration with the usability expert firm, named as Valsplat to carry out the usability testing for the game by utilizing eye tracking. The tests were planned in for seven sessions over the game development process, by selecting six to eight participants playing the complete game. Whereas, the usability evaluators or moderators observing the gamers interaction and emotions.

Each usability test lasted for eight hours, divided into three hours play with questionnaires in the end. Tobii T60 XL eye tracker was used for testing, 90% of the participants were males with an age group between 18-30 years including average to expert level gamers.

Both the individual play and the co-operative play was analysed by utilizing eye tracking for data collection during the usability tests.

2.6.3 Findings

The analytical findings of the usability test conducted for the Killzone 3 video game brought forward interesting and useful results that would not be available if the other methodology would have been employed. Below is a concrete list of analytical findings:

1. Finding a right path to progress through the climax is often challenging in video games. Eye tracking provided a means to look into the gameplay of the participants. It allowed the developers to see through the eyes of the participants what they actually look at during the game, instead of what they should be looking at from the game developer's point of view. This finding helped the game developers to modify the elements distracting the participants from moving ahead in the game according to the requirements of the players, to reduce the complexity of finding the path.
2. Fictional world in the game is designed to beautify the game play and gaming experience. The question that is, does the participant see everything in the gaming scene? Eye tracking answers that particular question by providing the elements which grasped the participant's attention, and which did not. It helped the developers to adjust the placement of the fictional world elements.
3. Instructions and hints are displayed on the screen or available in the game menu, throughout the game. Eye tracking helped the developers to design an intelligent method that can sense the participant's interaction and display the helpful messages or hints timely.
4. Observing the participant's interaction in the split screen display during the co-operative game play, to know if the participant looked at the partner's screen, and what elements were looked at.

Figure 10: Player gazing at the objects

Figure 11: Player gazing at the central part of the screen

3. Experiment

This section of the thesis discusses the experiment details such as equipment setup, laboratory, method selection, usability testing tasks and participants.

3.1 System selection

This section describes technical details of the equipment used in the laboratory setup.

3.1.1 Tobii T60 Eye Tracker

Tobii T60 eye tracker has been designed for analysing human behaviour in home and office environment. It operates on the 60 Hz frequency. The hardware components of the Tobii T60 eye tracker include the Tobii T60 eye tracking device, which is connected to an external screen to see the users' interaction and cables and adapters to establish a connection. To configure and use the eye tracker, Tobii studios software is installed on the system.

A Tobii studio is a software tool that enables the researchers to calibrate eye tracker for participants, record screen activities, analyse and visualize recorded data. The calibration has three types of settings Regular (default), Manual or Infants. To capture the complete gaze data for the entire area, the distance between the participant's eyes and the eye tracker should not exceed 65cm (25.6 inches) as shown in the Figure 12. Also, the placement of eye tracker must be appropriate as the gaze angle, should not exceed the 42˚ to any point on the screen.

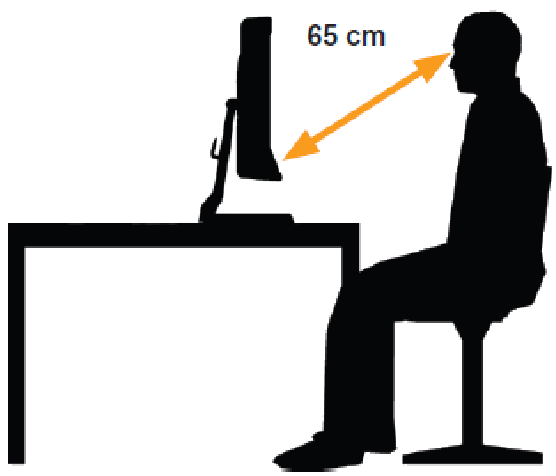

Figure 12: Distance between Eye tracker and participant.

3.1.2 Gaze Laboratory setup

The experiment was conducted in the gaze laboratory of University of Tampere. The laboratory was equipped with the following facilities as shown in the Figure 13:

- Observer room
- Participant room
- One way mirror for separation between rooms
- Tobii T60 eye tracker
- Tobii studio computer with Tobii studios eye tracking software installed
- Live viewer as a secondary screen
- Audio and video recording equipment

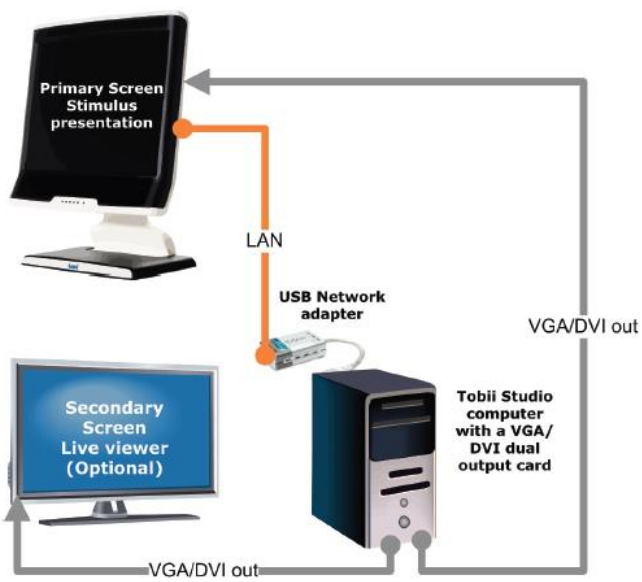

Figure 13: Gaze laboratory setup.

In the given hardware setup, Tobii studio is not capable of capturing both video recording from the screen and eye tracking movements together in a full screen mode, only windowed desktop can be captured. It can only record eye movement tracking whereas the game screen is blacked out as shown in the Figure 14.

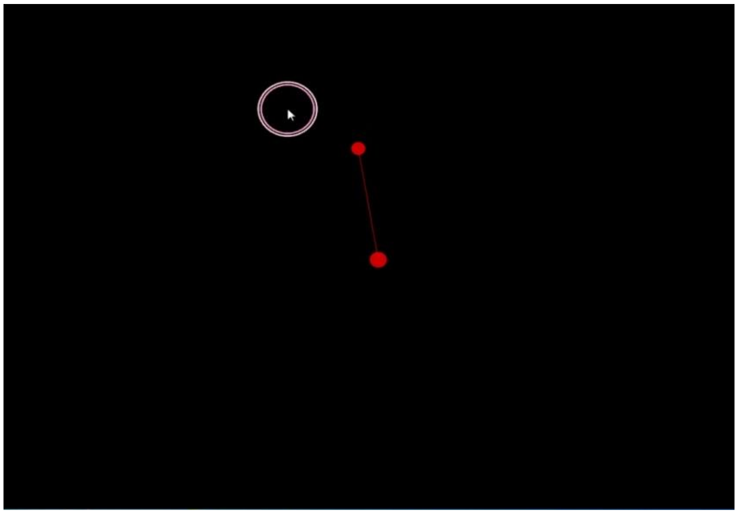

Figure 14: Eye movements with video game screen unrecorded.

Since games utilize full screen mode. Tobii recommends an alternative solution to resolve this problem. To record the full screen mode gaming video, two computers, one with Tobii studio logger and the second with Tobii studio are required. Both computers are connected with the Tobii eye tacker using the VGA/DVI output, both computers and the eye tracker should be on the same network as described in the Figure 15.

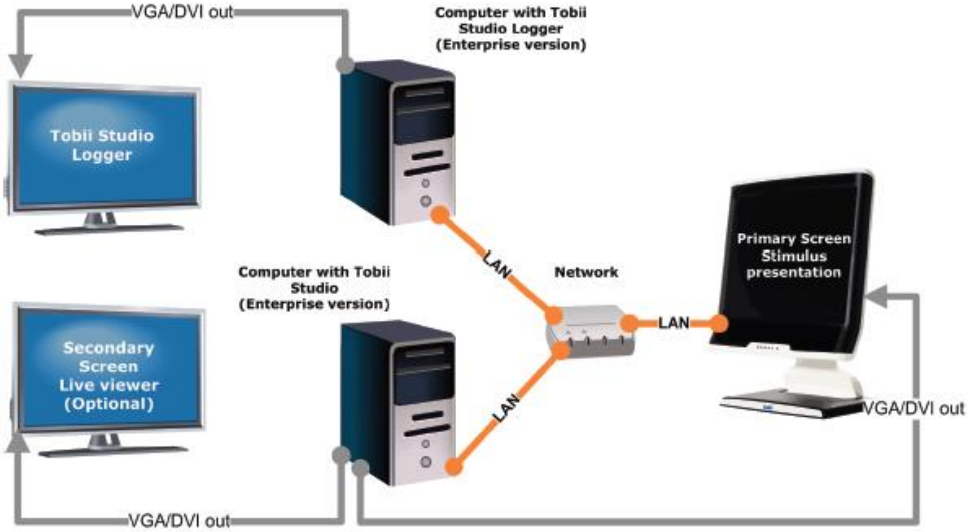

Figure 15: Gaze laboratory extended setup to record full screen mode game video.

Another alternative solution to deal with this problem doesn’t require additional computer. However, external software is required to run the video game in a windowed mode. This solution works and Tobii eye tracker records both video and eye movement data. However, this solution had certain limitations;

Smaller game window

The game window had to be smaller than the full screen mode. If the gaming window is enlarged, close to the full screen, even then the Tobii studios did not record the gaming video. So, the gaming video had to be in the following dimensions (1057x869) for Tobii studios to record it. Smaller game window didn't provide a full screen gaming experience for the participant.

Distraction

The windowed mode caused a bit of distraction during the experiment, as some participants' unintentionally looked outside the gaming window.

Figure 16: Participant's eye movements distracted in windowed mode.

Mouse Performance

Mouse performance becomes slower in the windowed mode. All the expert and advanced gamers reported this problem.

3.2 Application Selection

This study involves the collection of data through facial expression analysis and eye tracking. The application that should be selected for the laboratory usability testing must have an impact on the participant's emotional state; it should change the emotional response of the participant and should be able to generate the basic facial expressions of happiness, sad, anger, contempt and annoyed. Thus, emotional response of a participant can be recorded.

Video games and emotions are connected to each other. As video games have different genres such as sports, action, adventure, violent etc. it has been discussed that playing violent video games extensively develops aggressive behaviour in the personality [Anderson and Dill, 2000] and shooting the humans in a game may provoke more anxiety [Anderson and Ford, 1986] than shooting any other object such as an insect. However, this feeling of anxiety causes a short term aggression in the behaviour.

Bailey and West [2013] describe that playing an action video game, results in the alteration in emotion and visual processing. Action gaming has an impact on the processing of positive facial expressions. Based on the evidence found in the previous work, an action video game was selected to perform the usability testing. The game selected was Call of Duty: Modern Warfare 2, PC edition.

3.2.1 Call of Duty: Modern Warfare 2

Call of Duty: Modern Warfare 2 is a sequel of the one of the bestselling first person action game. It is built on the Infinity Ward IW 4.0 game engine [IGN, 2009]. It was also the most online played game in the history of video games, as mentioned in the Guinness world records [Steam, 2015]. Each game mode has several missions and each mission is divided in several objectives. For this experiment, Campaign mode was chosen. During the game, Campaign mission one S.S.D.D. and campaign mission two, Teamplayer were played. The game saves automatically when a checkpoint is reached. Once, a mission is completed, a story begins before the start of the new mission. The gameplay has three playing modes, campaign, cooperative and multiplayer [IGN, 2009]. The player was Private Joseph Allen. The commanding officer in campaign mission one was Sergeant Foley and campaign mission two was General Shepherd.

To play the game, both keyboard and mouse were used to serve as gaming controls. The instructions during the game appears on the middle region, dialogues spoken by the game characters appear on the bottom part and the mission status such as ‘Objective completed’ appear on the top left corner of the screen.

A ‘white marker’ on the border of the screen points the direction, the character is supposed to follow the white marker to move ahead to the destination in the game. The game map shows the position of the player and the next checkpoint in the game.

3.3 Method selection

According to the Jacob Nielsen [2012], the think aloud protocol has both advantages and disadvantages for finding the usability problems. There are some reasons that makes, think aloud protocol less effective for this study. These reasons include distraction; participant get distracted and lose the focus when practicing think aloud, short time; as the events in a video game happen in a split of a second, participants' don't have enough time to bring out in words what they actually think during the event. Think aloud has some limitations [SMI, 2015] such as, it can find out that the participant faced problems interacting with an interface. However, by using this method it is difficult to get the insights such as why the participant faced the problem.

The good side of the method is that [Jacob Nielson, 2012], it is less costly to implement, flexible in nature as it can be employed at any stage of the development cycle.

There are some points that need to be considered to select a method for the study. Firstly, video game has text and audio instructions, in-game demos, dialogues and other elements that the player is already paying attention. Due to this fact, the participant faces unnatural situation to voluntarily speak whatever first comes into the mind, when playing a video game. Thus, participant will not be able to play the game with proper attention. Secondly, as the participant is expected to speak whatever first comes into the mind, the potential risk that exists in this situation is that, the participant will think and will speak out after modifying the original version of the raw thoughts.

Eye tracking reveals the detailed level of information which verbalization cannot do alone. It provides the eye movement tracking data, which is used to analyse the objects which took participant's attention, how long the participant looked on the particular area on the stimulus, areas of interest (AOI). By utilizing the power of eye tracking in the usability testing, effective results can be achieved [Cooke].

Facial expression reveals the information about emotions, mood and interpersonal behaviour of humans. It helps us to better understand the humans, their actions and behaviour [Torre and Cohn, 2011].

An interview is a face-to-face discussion carried out with the participant, to collect useful information regarding the usability test. Questionnaires collect the data about user's background, preferences and experience. Both interviews and questionnaires provide subjective information.

The above discussed issues of thinking aloud protocol makes it less favourable choice to be selected as a usability evaluation method for the current study. Thus, in this study the most appropriate choice of usability evaluation method is the usability testing, followed by the interview and questionnaires. Eye tracking and facial expressions analysis will be used during the usability testing for data collection.

3.4 Participants

According to Jacob Nielson and Deborah Hinderer Sova [Nielsen & Sova, 2015], one of the key factors that contribute to the success of the research study is to recruit the right participants for the test. Because, the right participants have the required qualities and skills, to be considered as the target users of a system being tested, the validity of the data collected is dependent on them.

Therefore, it is important to know the participants and consider criteria for recruiting them, more specifically profiling the required participants for the study. To understand the goals of the study is also helpful, as it clarifies the focus of the study. According to the study by Jacob Nielsen [2000], testing with a small group of participants such as five participants, can actually uncover 80% of the problems in the system, and see Figure 17. Any additional participants do not contribute to any greater extent.

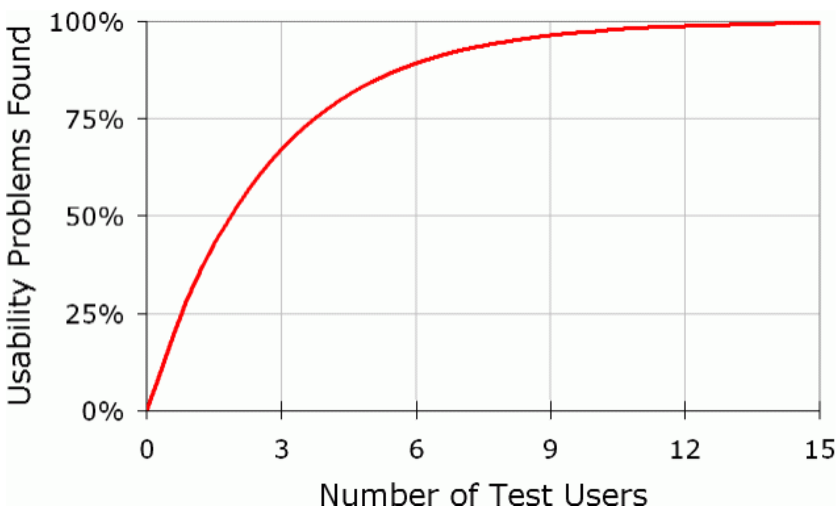

Figure 17: Number of test users vs. usability problems found.

This study involves the video gaming application. This means that the participants selected for this study should be familiar with the computer and computer games. The criterion for the required participants is defined as follows:

- Participant should be a skilled computer user, to control the mouse, keyboard and other equipments.
- Participant can be an expert, advanced, average or a novice gamer.
- Participant has no specific gender requirement.

To recruit the participants, the above discussed criterion was followed. An online participation link was created and shared on the university portal to inform the students about the research study participation. In total, eight participants participated in the study, one in pilot testing and seven in actual testing. The basic background information of the participants is described in the Table 1. All the participants were male students. The characteristics of the selected participants are described in the tabular form below:

Participant Type	Age Group	Gender	Pilot Testing participant(s)	Actual Testing participant(s)	Total participant(s) per type
Expert Gamer	20-30	Male	0	2	2
Advanced Gamer	20-30	Male	0	2	2
Average Gamer	20-30	Male	0	2	2
Novice Gamer	20-30	Male	1	1	2
				Total no. of participants	**8**

Table 1: Participant characteristics for usability testing

3.5 Test tasks

Game has several missions and each mission is divided in multiple objectives. Each objective in the game was considered as a separate task in usability testing. In addition, there was no time limit to complete a task, as the game proceeds only when the task is completed. To play the game, in the allowed time of 15 minutes, total 17 tasks could be accomplished [The Chameleon, 2013]. Task descriptions are listed below:

Task 1: Pick up the weapon from the table.
Task 2: Shoot targets while firing from the hip.
Task 3: Shoot the targets by aiming.
Task 4: Shoot a target through the wood.
Task 5: Pick up the fog grenades.
Task 6: Throw a grenade toward the targets.
Task 7: Use your objective indicator to locate the pit.
Task 8: Pick up the pistol from the table. Switch to your rifle and back to your pistol.
Task 9: Shoot as many targets as you can in the fastest possible time.
Task 10: Regroup with your team upstairs.
Task 11: Protect the bridge layer.

Task 12: Get in your Humvee.
Task 13: Standby for airstrike.
Task 14: Scan for hostile activity. Do not fire unless fire upon.
Task 15: Destroy targets of opportunity.
Task 16: Get your eyes on the school.
Task 17: Terminate the enemy presence in the school.

3.6 Test Procedure

The test was conducted in the gaze laboratory. The tests were carried out using a Tobii T60 eye tracker which as connected with a computer running Windows 7 at 1280x1024 pixels. Furthermore, a webcam with a built-in microphone was placed on top of the Tobii T60 eye tracker screen and its video stream was captured together with the Tobii studios recording feature.

The test procedure started with an introduction of the participant to the laboratory. In the next step, a questionnaire was handed to the participant in order to collect some background information. It was also important to mention the purpose of the test to the participant, followed by an explanation of the test procedure. For legal purposes, permission to record the test was obtained from the participant through a consent form. Then the actual test began. In order to capture thoughts and feelings, a post-test questionnaire was handed to the participant after the video gaming session was finished, followed by a short interview. To give the participant a chance to share further thoughts, the usability ended with a debriefing part.

Then, Tobii studios software was executed to capture the participant’s eye movement data, video game was started and the webcam was turned on to record the facial expressions data. Tobii studios software was used to adjust the eye calibration for each participant and ensured that the eye calibration was well adjusted. It took about 15 minutes of the time. Then the system was ready to record the eye movement data.

The testing began by allowing the participant to play the game for 5 minutes to familiarize with the testing environment and the application. Once the participant played the game for 5 minutes, usability testing session began. The participant was allowed to play the video game continuously for 15 minutes. Usability testing had been employed for this study followed by a short interview and questionnaires. The test took about 45-60 minutes of time to complete. It had been divided into different parts. If the test style would have been task oriented, then it would have created a distraction, participant had to look outside the stimulus to read the task and thus, the participant could also lose the focus in the video game. After 15 minutes of gaming session, the participant was informed to stop playing the game as 15 minutes of time was over.

The moderator sitting close to the participant observed the participant behaviour and provided little help when the participant needed help during the test. However, there was a good distance between the moderator and the participant. So, the participant felt comfortable.

Each participant was interviewed to know how he felt during the test, what the difficulties were and what could be improved. Lastly, participants were asked to fill up post-test questionnaire form [see appendix] to get the subjective data.

3.7 Pilot testing

To ensure the complete setup was working properly for the laboratory experiment, including eye tracking equipment and hardware peripherals, pilot testing was performed. The whole idea of performing the pilot testing was to know the possible challenges and problems that were not taken care earlier and also they might be critical in order to achieve the desired results during the actual usability testing.

Pilot testing had been performed with the novice gamer as a pilot testing participant. The reason for choosing the novice gamer for the pilot testing was that, the game play of the novice gamer would be a beginner level and the gamer was supposed to take more time to understand and proceed through the game.

Pilot testing uncovered some of the facts that were not considered significant before conducting the usability testing. The key findings that came across after the pilot testing were the following:

- The participant should be informed before the testing begins that s/he has to pay attention towards the onscreen instructions and game audio. This would allow the participant to pay attention towards screen and audio instructions. And it would help to progress through the video game.
- To feel comfortable and familiarize with the video game controls, the participant should be given five minutes time to practice the video game controls by trying them out before the testing began.

The key findings from the pilot testing helped to improve the actual usability testing. The necessary changes were incorporated in the actual usability testing.

4.Results and Analysis

This section discusses the results from the usability testing conducted to understand the user interaction in a video game using eye tracking and facial expressions analysis. The results were analyzed to find the effectiveness, efficiency and user satisfaction level.

4.2 Testing

Usability testing was performed in the same gaze laboratory where pilot testing was performed. Seven participants were recruited for usability testing including two expert level, two advanced level, two average level and one novice level participant.

The key findings from the testing were the following:

1. The clear difference between the expert, advanced, average gamers from the novice gamer was that, the novice gamer didn't follow the instructions from the screen even after noticing the on screen instructions and listening to the game audio.
2. For novice gamers it was quite difficult to follow the white marker, pointing towards the path leading to the next checkpoint.
3. For novice gamer, there were a lot of things to pay attention such as game controls, onscreen instructions and audio instructions. Due to this reason the novice gamer did not pay much attention towards the map and white marker.

To measure the effectiveness, efficiency and satisfaction level for the usability testing in the current study, task completion rate, task completion time and data from the post-test questionnaire has been described below in tabular form.

4.2.1 Effectiveness

To find out the effectiveness of usability testing task completion rates for all the participants were calculated. Table 2 describes participant type, completed tasks and task completion rates for all the participants.

Participant No.	Participant type	Tasks completed	Total tasks	Task completion rate (%)
P(pilot)	Novice	8	17	47
P01	Novice	8	17	47
P02	Expert	14	17	82.
P03	Advanced	13	17	76
P04	Average	9	17	53
P05	Advanced	14	17	82
P06	Expert	16	17	94
P07	Average	13	17	59

Table 2: Participant type, completed tasks and task completion rate for all the participants.

4.2.2 Efficiency

To find out the efficiency in usability testing task completion time and task outcome for all the participants were calculated. Task completion time and task outcome are described in Table 3 (a) and Table 3 (b). The following codes are used to describe task outcomes:

A – Task was performed successfully

B – Moderator helped in task performance

C – Task failed

D – Task was not completed (e.g. there was no more time)

E – Task was not tested (e.g. there was no more time)

From Table 3 (a) and Table 3 (b), following observations can be made:

- Both novice level participants P_{pilot} and P01 were at the same level, as they were provided help during “Task 9 - Shoot as many targets as you can in the fastest possible time” but still they could not able to complete the task.
- Average level participant P04 attempted the “Task 9” but failed it whereas the other average level participant P07 completed till “Task 10 - Regroup with your team upstairs “. So, it can be said that both average level participants had the similar level.
- Advanced level participant P03 completed till “Task 13 - Standby for airstrike” and also attempted “Task 14 - Scan for hostile activity. Do not fire unless fire upon” but could not complete it whereas the other advanced level participant P05 completed till “Task 14”. So, it can be said that more or less both advanced level participants had the similar level.
- Expert level participant P02 completed “Task 14” and attempted “Task 15 - Destroy targets of opportunity” but could not complete it whereas the other expert level

participant P06 completed all the 17 tasks. So, it can be said that only expert level participants were through to the task 15.

Task No.	**P(pilot)**		**P01**		**P02**		**P03**	
	Task time	**Task outcome**	**Task time**	**Task outcome**	**Task time**	**Task outcome**	**Task time**	**Task outcome**
Task1	00:56	A	00:11	A	00:03	A	00:06	A
Task2	1:51	A	00:22	A	00:15	A	00:13	A
Task3	1:41	A	00:33	A	00:11	A	00:18	A
Task4	00:07	A	00:04	A	00:11	A	00:05	A
Task5	00:27	A	00:13	A	00:08	A	00:05	A
Task6	00:21	A	00:24	A	00:10	A	00:06	A
Task7	02:06	A	02:38	A	00:46	A	00:26	A
Task8	00:47	A	00:19	A	00:12	A	00:12	A
Task9	03:28	B, D	02:58	B, D	01:04	A	02:54	A
Task10	--	E	--	E	00:30	A	00:23	A
Task11	--	E	--	E	00:40	A	03:00	A
Task12	--	E	--	E	00:30	A	01:34	A
Task13	--	E	--	E	00:31	A	00:31	A
Task14	--	E	--	E	01:24	A	00:04	D
Task15	--	E	--	E	00:29	D	--	E
Task16	--	E	--	E	--	E	--	E
Task17	--	E	--	E	--	E	--	E

Table 3 (a): Task completion time and task outcome.

Task No.	P04		P05		P06		P07	
	Task time	Task outcome	Task time	Task outcome	Task time	Task outcome	Task time	Task outcome
Task1	00:06	A	00:05	A	00:03	A	00:23	A
Task2	03:06	A	00:32	A	00:07	A	00:13	A
Task3	01:04	A	00:09	A	00:10	A	00:23	A
Task4	00:03	A	00:06	A	00:04	A	00:07	A
Task5	00:45	A	00:06	A	00:03	A	00:09	A
Task6	01:05	A	00:16	A	00:08	A	00:35	A
Task7	01:00	A	00:29	A	00:13	A	01:56	A
Task8	00:28	A	00:15	A	00:08	A	00:16	A
Task9	04:04	C	02:50	A	01:09	A	03:26	A
Task10	--	E	00:20	A	00:07	A	00:21	A
Task11	--	E	02:55	A	01:40	A	02:35	D
Task12	--	E	00:27	A	00:21	A	--	E
Task13	--	E	00:31	A	00:31	A	--	E
Task14	--	E	01:20	A	00:21	A	--	E
Task15	--	E	--	E	01:20	A	--	E
Task16	--	E	--	E	00:34	A	--	E
Task17	--	E	--	E	01:02	A	--	E

Table 3 (b): Task completion time and task outcome.

4.2.3 Satisfaction

Satisfaction level for all the participants was observed from the data gathered from the post-test questionnaire, answered by each participant. Data is presented in the tabular form for each question answered by each participant below in Table 4, Table 5 and Table 6.

Q.1 Were you comfortable with the testing equipment?

All the participants felt comfortable except the pilot testing participant, who felt uncomfortable.

Q.2 How do you evaluate your recent experience?

In the post-test questionnaire [appendix], 5 out of 8 participants reported their experience close to very good, 1 out of 8 participants reported his experience neutral, 1 out of 8 participants reported his experience just above neutral, only 1 out of 8 participants reported his experience just below neutral and that participant was novice level.

Participant(s)	Experience	Total
P06	1 (very good)	0
P(pilot), P02,P03, P04	2	4
P05	3	1
P07	4 (Neutral)	1
P01	5	1
	6	0
	7 (very bad)	0

Table 4: Participants experience

Q.3 How would you rate the tasks difficulty level?

In the post-test questionnaire [appendix], 2 out of 8 participants reported tasks difficulty level as very easy, 1 out of 8 participants reported tasks difficulty level as neutral, 4 out of 8 participants reported tasks difficulty level close to very easy, only 1 out of 8 participants reported tasks difficulty level as close to very difficult and that participant was average level.

Participant(s)	Difficulty level	Total
	1 (very difficult)	0
P07	2	1
	3	0
P01	4 (Neutral)	1
P03, P04, P05	5	3
P02	6	1
P(pilot), P06	7 (very easy)	2

Table 5: Tasks difficulty level

Q.4 What is your satisfaction level after playing this game?

In the post-test questionnaire [appendix C], 2 out of 8 participants reported satisfaction level as very satisfied, 4 out of 8 participants reported satisfaction level as close to very satisfied, only 2 out of 8 participants reported satisfaction level just below neutral and one of the participant is novice level and the other an average level.

Participant(s)	Satisfaction level	Total
P04, P06	1 (very satisfied)	2
P(pilot), P02, P03	2	3
P05	3	1
	4 (Neutral)	0
P01, P07	5	2
	6	0
	7 (very dissatisfied)	0

Table 6: Participants satisfaction level

4.3 Results from eye tracking

Tobi studios software generated the eye movement data for all the participants. For each participant a separate video file was generated showing the participant's eye movements. Looking at the video multiple times provided a way to understand the user interaction in a video game.

The general key findings for all the participants from the eye tracking are following:

1. All the participants paid attention to the onscreen text during the cut scenes that appeared on the bottom of the screen, as shown in Figure 18.

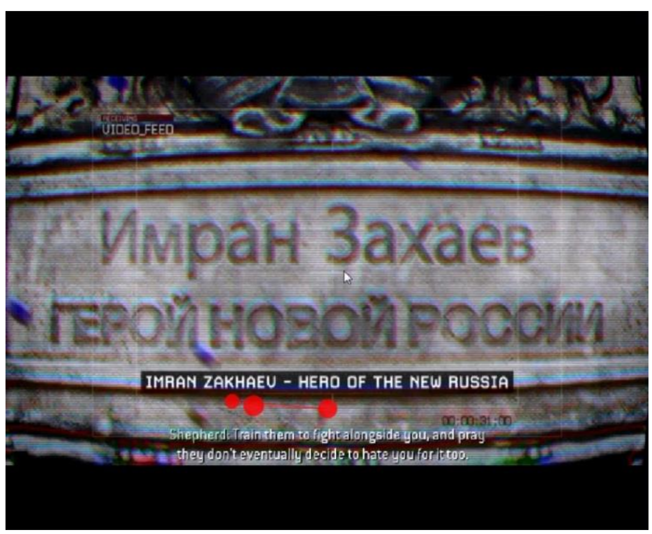

Figure 18: Participant gazing at the onscreen dialogue.

2. All the participants paid attention to the onscreen task instructions and mission status appeared on the top left corner and central part of the screen, as shown in Figure 19. For instance, to complete the “Task 7 – Use your objective indicator to locate the pit”, all the participants checked the objective indicator by pressing the ‘Tab’ button.

Figure 19: Participant gazing at the mission objectives.

3. The participants’ eye movement data shows that, mostly participants were looking on the central part of the screen, as shown in Figure 20. This is because, player moves in the central part of the screen during the mission with weapons in hands and also aims the target from the central part.

Figure 20: Participant gazing at the central part of screen.

The key findings for specific participants from the eye tracking are following:

1. Pilot testing participant's performance in the game significantly improved after paying attention to the screen instructions starting from "Task 6 – Throw a grenade towards the targets".
2. Participant one completed "Task 7 - Use your objective indicator to locate the pit", entered into the pit and completed "Task 8 – Pick up the pistol from table, switch to your rifle and back to pistol". However, after that the participant missed the onscreen instructions and dialogues to proceed inside the pit for shoot out, instead went back to the training base, from where the mission started.
3. Participant two missed the onscreen instructions for "Task 4 – Shoot a target through the wood", as shown in the Figure 21. Game character Sergeant Foley gave audio instructions thrice which also appeared on the screen thrice.

Figure 21: Participant two missing the audio and onscreen instructions.

4. Participant four took 47 seconds to notice the onscreen instruction for "Task 3 – Press C to crouch to fire more accurately". Although, participant was looking through the sights and the onscreen instructions were just above the aim. In addition, the task completion improved after noticing the onscreen instructions since "Task 5 – Pick up the fog grenades". For "Task 6 – Throw a grenade toward the targets", participant was still firing bullets after noticing the instructions to throw a grenade.

Figure 22: Participant not following the onscreen instructions.

4.4 Results from Facial expressions analysis

The automated results generated from the Emotient Analytics have been grouped into three categories Attention, Emotional engagement and Sentiment. A summary of the three categories of results for all the participants is shown in Figure 23.

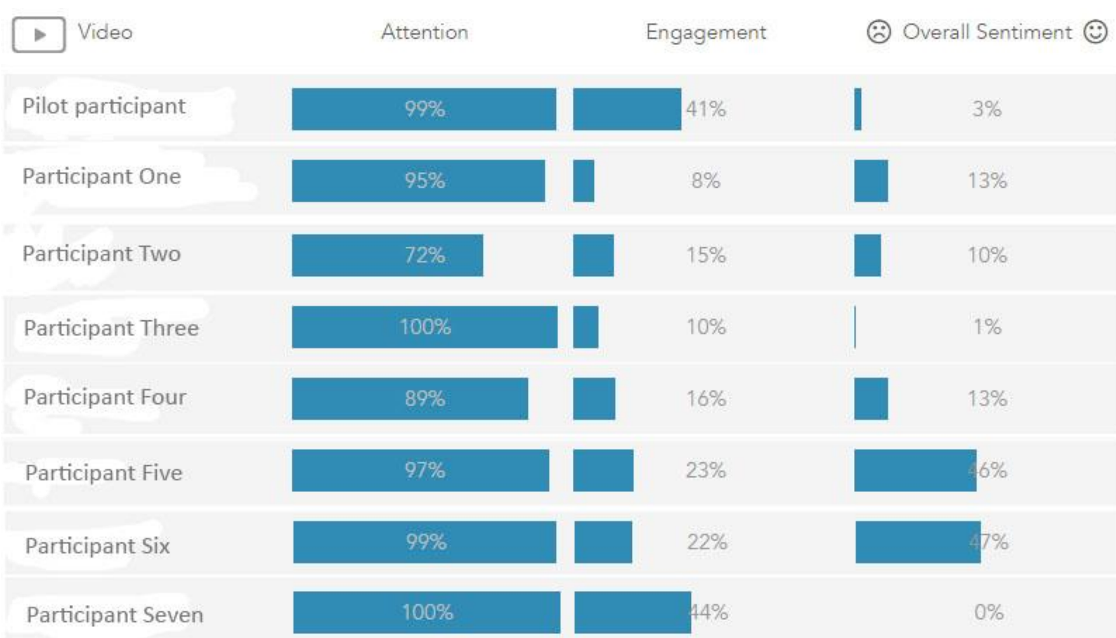

Figure 23: General results from Emotient Analytics.

Furthermore, for each category the detailed results have been generated, to analyze and understand the participant's facial expressions in more detail.

4.4.1 Attention

The attention category showed the following results:

- Least attention paid by an expert level participant which was 72%.
- Highest attention paid by one advanced and one expert level participant was 100%.
- On average, the participants were 94% attentive.

4.4.2 Emotional Engagement

This section provides the representation of overall emotion detected and overall emotional engagement for the participants in the form of pie chart. According to the observations made from Table 3 (a) and Table 3 (b), participants in each (Novice, Average, Advanced and Expert level) category were more or less similar in performance level. So, results from one of the participants from each of the categories had been chosen for further representation.

According to the Emotient Analytics, the facial expressions of the pilot participant reveal that 91% of the time the participant was angry, 5% contempt and only 3% joyful as shown in the Figure 24. On the other hand, the overall emotional engagement is 41%.

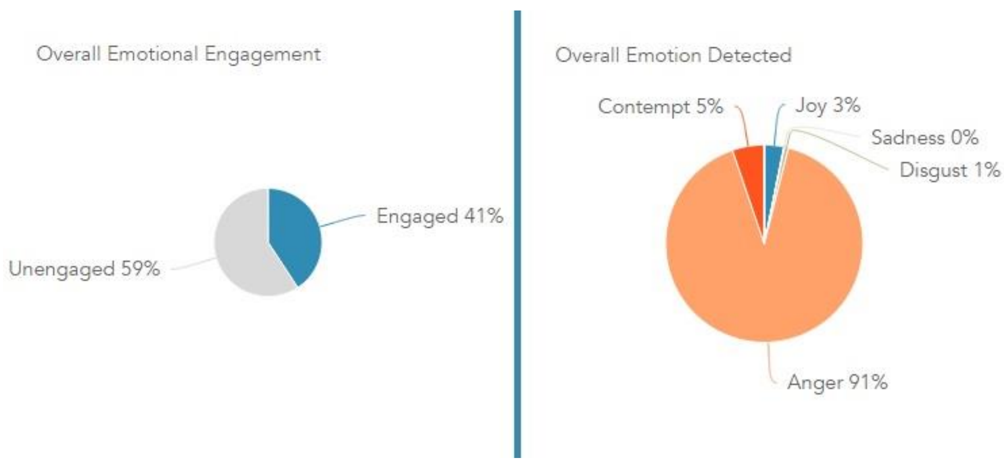

Figure 24: Pilot testing participant results from Emotient Analytics.

For novice level participant, the Emotient analytics has determined that the participant was feeling 82% disgust, 5% joyful, 8% surprised, 4% contempt and only 1% anger as shown in the Figure 25. The overall emotional engagement was only 16%.

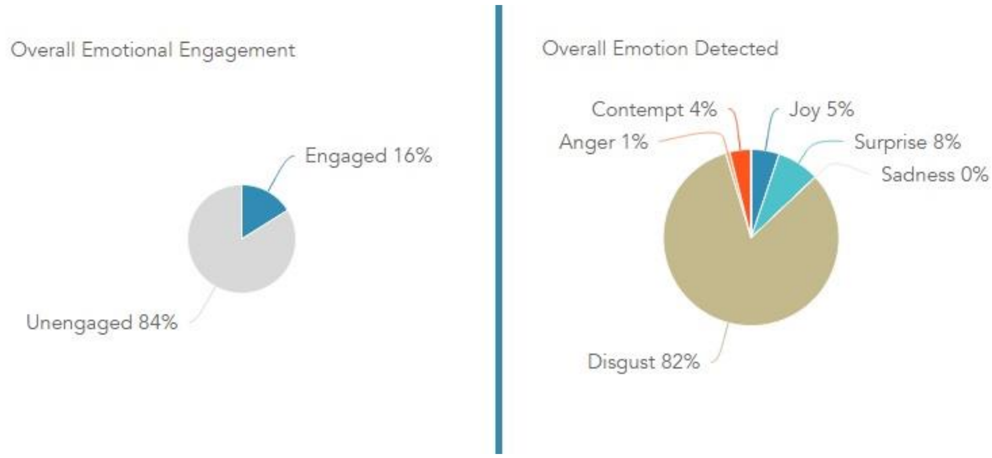

Figure 25: Novice level participant results from Emotient Analytics.

For average level participant, the Emotient analytics has determined that the participant was feeling 46% joyful, 42% contempt, 10% angry and only 2% disgust, as shown in the Figure 26. The overall emotional engagement was only 23%.

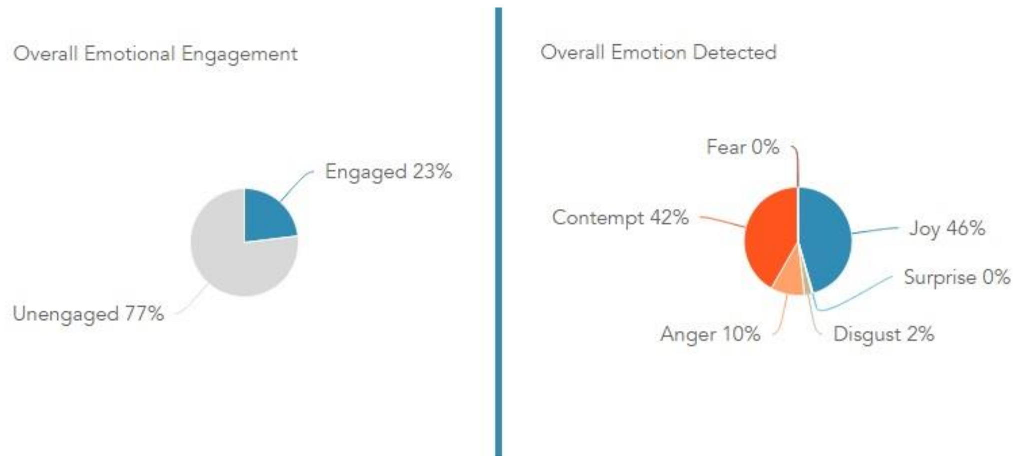

Figure 26: Average level participant results from Emotient Analytics.

For expert level participant, the Emotient analytics has determined that the participant was feeling 47% joyful, 38% contempt, 11% disgust, 3% angry and only 1% surprised, as shown in the Figure 27. The overall emotional engagement was only 22%.

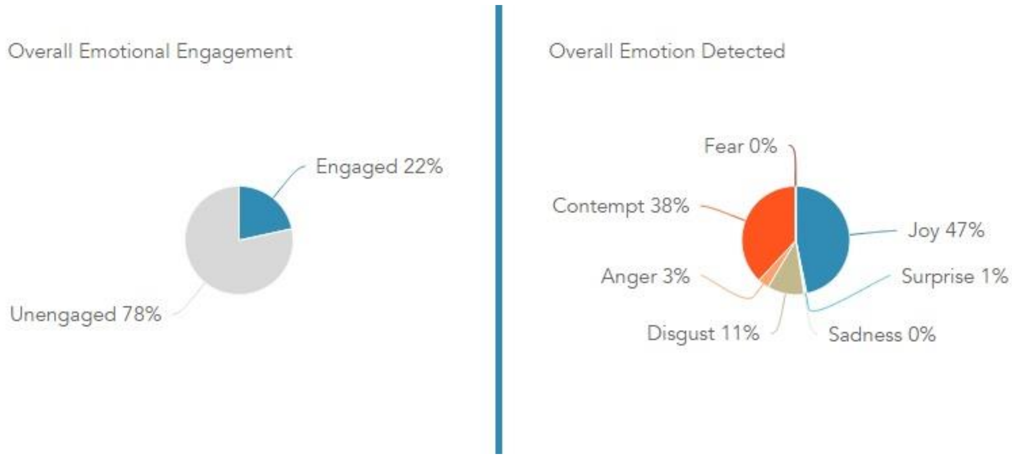

Figure 27: Expert level participant results from Emotient Analytics.

The complete emotions detection timeline as shown in the Figure 28(a), (b), (c) and (d), shows the type of emotions per second, provides the detailed data about the participants' facial expressions. Below is the comparison of the emotions timeline for a novice, average and an expert level participant.

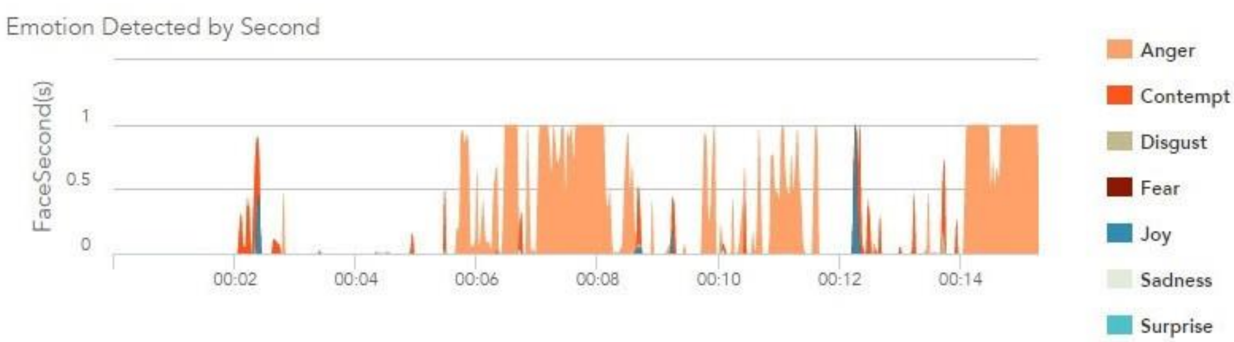

Figure 28 (a): Pilot participant emotions timeline.

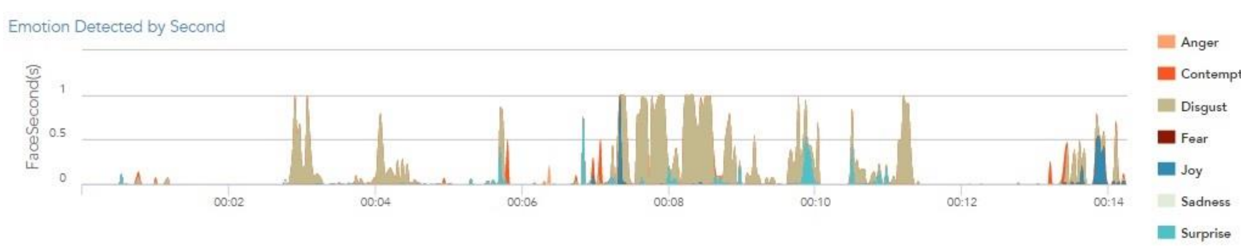

Figure 28 (b): Testing - Novice level participant emotions timeline.

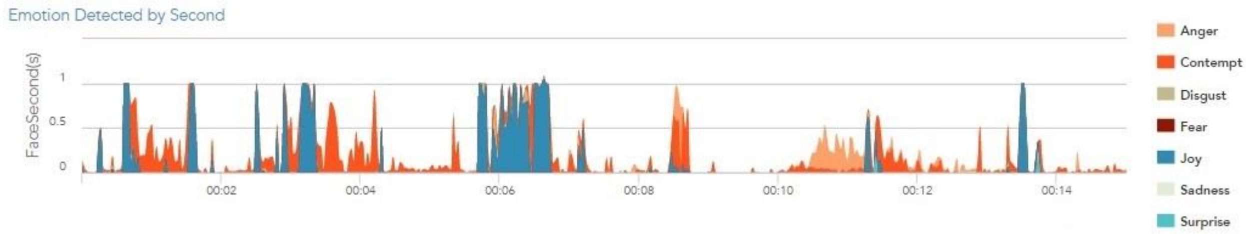

Figure 28 (c): Testing – Average level participant emotions timeline.

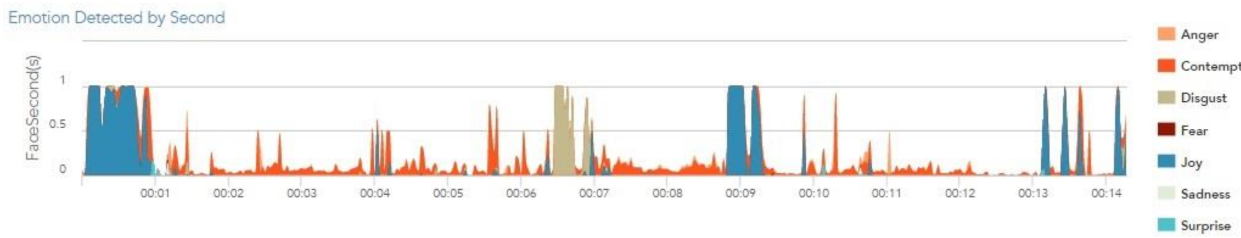

Figure 28 (d): Testing – Expert level participant emotions timeline.

4.4.3 Sentiment

The detailed results for overall sentiment data as represented above in Figure 23, determines that the participant six showed the highest sentiments with 47%, whereas participant seven was the least sentimental with 0%. Below are the pie charts, presented in Figure 29 (a), (b), (c) and (d) of the detailed level data for overall sentiment from each of the novice, average and expert level participants.

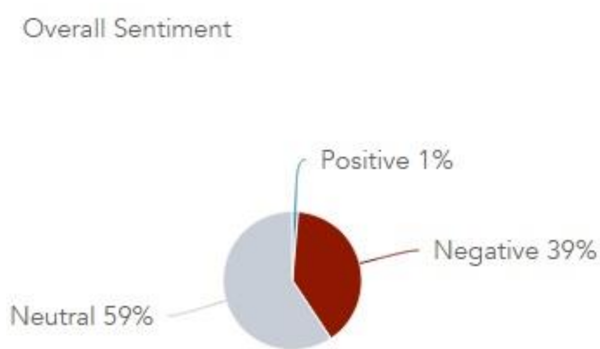

Figure 29 (a): Pilot testing participant overall sentiment.

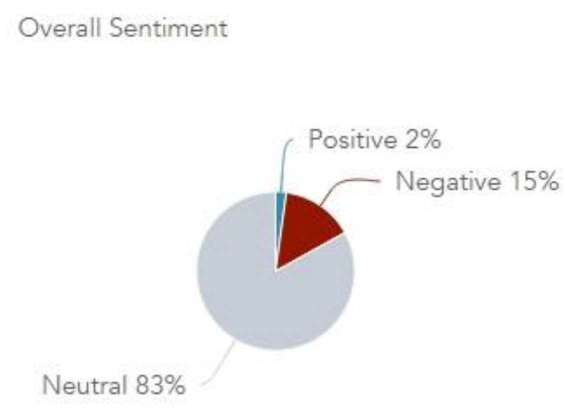

Figure 29 (b): Testing - Novice level participant overall sentiment.

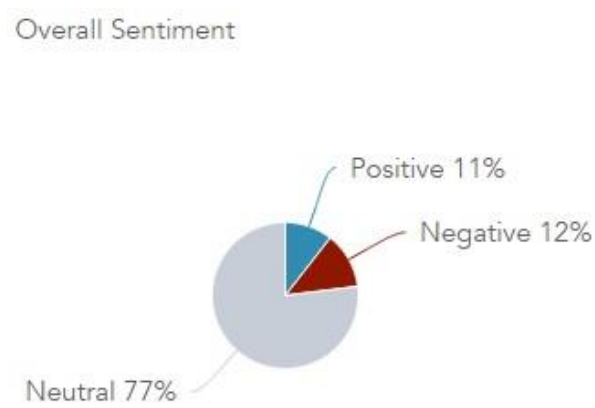

Figure 29 (c): Testing – Average level participant overall sentiment.

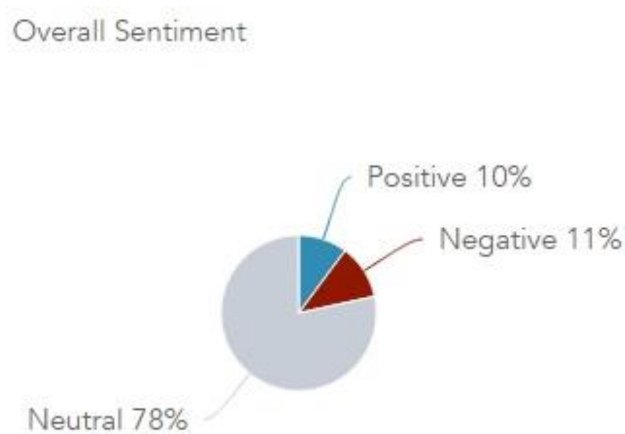

Figure 29 (d): Testing – Expert level participant overall sentiment.

4.5 Results from Interview

Once the usability testing was performed and post-test questionnaire was filled. Each participant was interviewed to get more insights about the experiment. Below were the interview questions with answers.

Q.1 Was it difficult to notice the instructions in the video game?

The novice participants mentioned that there were multiple objects to pay attention to, such as on screen instructions (objective details, dialogues and pressing key instructions), audio instructions, video game controls and controlling the game view in the game. That's why some of the instructions were missed out, and it took more time to complete the respective task.

Overall, the participants said it was easier to notice the onscreen instructions in the middle of the screen such as pressing the 'F' key button to pick up the weapon and the dialogues between the game characters appearing on the bottom of the screen.

Q.2 Was it comfortable to play a video game in a controlled environment such as in a gaze laboratory?

All the participants answered that the laboratory environment had no effect on their performance.

Q.3 Was there any kind of problem you faced while playing the video game?

Some participants other than expert level participants mentioned that mouse wasn't good enough. Whereas, one of the average participants mentioned that it became stressful and disappointing for not progressing through the game.

General comments from the participants were interesting to read. Some of them are described below:

"It was very fast for me, I mean that it required acting very fast in the game and I couldn't come out from the pit in time and sadly I had to perform the pit training task twice. The experience was not bad at all but I still feel disappointed that I did not progress further in the game".

-Novice level participant

"I was expecting an easier game, for me it was little difficult to play, but I enjoyed playing it. I think the graphics were not as good as I expected. Overall, I had a good experience".

-Average level participant

“It was quite interesting study because of the action shooting video game”.

-Expert level participant

“The game was great and I had a playful experience, I think the only factor that affected my performance was the mouse”.

-Expert level participant

5. Discussion

This thesis is a small usability study which differs from the Valsplat usability study for Killzone 3 video game. Firstly, due to time limitations complete Call of Duty: Modern Warfare 2 game could not be played. Secondly, in our case usability study was carried out after the Call of Duty: Modern Warfare 2 had already been released and was available in the marketplace. On the other hand, for Killzone 3 usability study was carried out over the game development process.

To progress through a video game is indeed a challenging work [Myers, 1990]. Similar kind of interaction was observed when participants voluntarily played Call of Duty: Modern Warfare 2. According to the analysis, from “Task 1 - Pick up the weapon from the table” to “Task 6 - Throw a grenade toward the targets”, it was easier for participants to progress through the game but a change in user performance was noticed from “Task 7 - Use your objective indicator to locate the pit”, difficulty level was increased specially for Novice and Average level participants, as their progress became slower.

Those tasks which had greater completion time or required assistance from the moderator or the participant failed to complete them were considered as difficult tasks. Among the difficult tasks in the game, “Task 7” was observed as the first difficult task, in which participants had to locate the pit. The second difficult task was “Task 9 - Shoot as many targets as you can in the fastest possible time”, participants had to go inside the pit to shoot the targets. One of the Novice participants found the pit but he could not able to enter it rather he came out and went towards the training base from where the mission was started. Second difficult task for the participants was shooting the targets inside the pit.

Novice participant took two attempts to complete “Task 9”, but he was too slow to complete the task. Another Novice participant took 2:37 to find the pit and 2:47 searched the way to enter into the pit shoot out but couldn’t found it. He was complaining that he was following the white market but still couldn’t find the checkpoint. Both novice level participants were unable to complete the “Task 9”.

Both average level participants took two attempts to complete “Task 9” as they were too slow. Their completion time for the pit shoot out was 125.8 seconds and 115.5 seconds. Both advanced level participants also took two attempts to complete “Task 9” and their completion time for the pit shoot out was 71.75 seconds and 75.5 seconds, which is better than average and novice participants. On the other hand, both of the expert level participants completed “Task 9” in first attempt. Their completion time for the pit shoot out was 63.3 seconds and 75.5 seconds. Overall, six out of eight participants were too slow they had to perform the “Task 9” again, four participants completed it in second attempt and two couldn’t complete it. Only the expert level participants completed the “Task 9” in first attempt and one of them has minimum task completion time.

To understand user interaction in a video game it is important to know what objects user paid attention to, what he ignored or not paid attention at all. Eye tracking provided eye movement data for the participants. The videos generated by Tobi studios having the eye movement data were analyzed to understand the user interaction.

From the eye movement data, it was observed that initially novice participants only paid attention to the text appearing in the cut scenes and they were not paying attention to the onscreen instructions and mission status. However, when they felt stuck during the game they started looking at different parts of the screen and begin to realize that the instructions were available on the screen. So, they started to follow the instructions and started progressing through the game.

It had been observed, from the participants’ eye movement data that novice level participants took time to become used to with the gaming controls and environment. Thus, they took more time to progress through the video game as compared to the average, advanced and expert level participants. This point is also proved from observing the novice level participants’ task completion time and rate. There were many things to pay attention to such text and audio instructions, gaming controls, controlling game view etc. For the novice participants, the Call of Duty: Modern Warfare 2 turned out to be a complex and little bit difficult game as it was also observed from the participants’ comments from the interview session.

In some cases participants even missed the onscreen instructions to press a certain key or to perform a certain action to proceed in the video game, although the instructions appeared in the central part and participants were also looking at the central part. So, after the analysis it was observed that the participants were concentrating at the gun and aiming to shoot the targets. This was the possible reason for missing out the instructions. However, when the participants noticed that they are not progressing through the game, they started looking on different parts of the screen and noticed the instructions to perform the required action.

Overall, participants paid attention to the onscreen instructions and dialogues, audio instructions dialogues in the cut scenes between the missions. However, it had been observed that some started paying attention when they were not progressing through the video game.

Interview results show that the participants mentioned that there performance was not affected by the laboratory environment. However, the gamers usually explore the gaming world by paying attention to the other elements and characters in the game. This kind of behavior was not observed, even by the advanced and expert level participants.

From facial expressions analysis system, it was observed by analyzing participants’ facial expressions, whenever an objective was completed the participants felt joyful. Participants’ emotional timeline shows the change in emotional activity during the usability testing. Successful completion of an objective, curiosity of beginning of new objective or when the participant died during the mission became the reason for a change in an emotional activity which was reflected in the facial expressions.

5.1 Areas of Interest

According to the data collected through eye tracking, the areas of interest in the Call of Duty: Modern Warfare 2 video game, were the following:

- The central part of the game screen where instructions appeared such as “Press C to crouch” etc. and the other reason is that player holds the gun and aims to shoot at the target.
- The bottom part of the game screen where the dialogues from the cut scenes and during the game appeared.
- The top left corner of the screen where the objective status appeared.

5.2 Future work

With the rapid advances in technology and evolutionary nature of usability testing, effective usability testing has become significant to make the products available in efficient and satisfactory form. To provide satisfactory level user interaction for gamers, video game manufacturers should employ iterative usability testing throughout the development phase of the video games. This iterative approach will keep improving the usability of a video game and increasing the efficiency, effectiveness and satisfaction level for gamers.

In my opinion, to get more insights once the participant is interviewed after the usability testing. The recorded video should be played in front of the participant. All the actions or moves that a participant made during the video game should be discussed in more detail to know more about intentions of the participant.

White marker in the video game that shows the direction to progress through the game should be prominent to be noticed, and a path from the gamers gaze point towards the white marker could be drawn if the gamer is continuously not paying attention to the white marker.

In future, facial expressions analysis and recognition in the video game can provide help to the gamers in the form of hints and repetitive text and audio instructions. When the gamer is stuck in the game and the instructions were missed out. Built-in Facial expression analysis feature would help the gamers. So the gamer could notice the instructions that were missed out earlier.

6. Conclusion

According to the Dr. Murray [Murray, 2015], “Eye tracking allows us to track the players’ visual interaction with the environment. The games have a motivational and a social component to keep people engaged”. The action shooting video game had made the study interesting for most of the participants and it kept their attention for most of the time. As confirmed by the Emotient analytics, minimum overall attention was 72% by one participant, other participants had 89%, 95%, 97%, two participants had 99% and two participants had 100% attention level.

The results analyzed from the eye tracking data concludes that novice and average level participants were only paying attention to the central part of the game screen and they only paid attention to other parts of the screen once they found themselves stuck in the game. Hence, they only focused to progress through the video game. On the contrary, advanced and expert participants also paid attention to the map, mission status right from the beginning of the game and playing safely by saving them from enemies.

Emotient Analytics determined the facial expressions of the participants and represented them in three categories. Emotional engagement category was very useful because it provided the emotions timeline per second as well as an overall emotional engagement and an overall detected emotion data in the form of pie chart representation. Emotions timeline provide important details about the change in emotional activity, which is due to the beginning or end of a mission objective, mission failure or a participant dies during the game.

In the post-test questionnaire, from the participants experience table, we can observe that the participant one checked just below neutral and participant seven checked neutral option. Rest of the participants checked options very good or close to very good. From the tasks difficulty level table, we can observe that the participant one felt neutral and seven felt close to very difficult. Rest of the participants checked options very easy or close to very easy. From the participants satisfaction level table, we can observe that only participant one and participant seven had just below neutral satisfaction level, rest of the five participants had above neutral level experience. After analyzing the data collected through post-test questionnaire, we can we can conclude that the participant one (Novice level) and participant seven (Average level) had faced difficulties while playing the game and their experience and satisfaction level was also either neutral or below neutral level.

The eye movements data generated from the Tobii studios is very useful for researchers to understand the user behavior based on their interaction with the elements in the video game, for game manufacturers to design and produce the games based on the player’s psychology and needs. In this experiment, the eye movement’s data showed that the participants easily notice the objects or text content appearing on the middle and lower part of the screen. Another important factor that became the reason for the participants to easily notice the objects and the content was that the objects were highlighted and the content was appearing in a bright color.

Any object or anything that is usable by people has an interface, which is used to establish an interaction mechanism [Dumas, 1999]. Likewise, video games have an interactive interface that should be developed with usability aspects in the mind, carefully tested throughout the development lifecycle with real games and enhanced according to the usability problems found during the testing, to ensure that a video game fulfills the criterion of effectiveness, efficiency and satisfaction before it is launched or made available to gamers.

References

[Al-Awar, Chapanis and Ford, 1981] Al-Awar, Alphonse Chapanis, Ford W.R. Tutorials for the first-time computer user. *IEEE Transactions on Professional Communication*, **24** (1), 1981, 30-37

[Alshamari and Mayhew, 2009] Majed Alshamari and Pam Mayhew, Current issues of usability testing. *IEEE Technical Review* **26**, 2009, 402-406.

[Anderson and Dill, 2000] Craig A. Anderson and Karen E. Dill, Video games and aggressive thoughts, feelings, and behaviour in the laboratory and in life. Journal of Personality and Social Psychology, 78, 2000, 772–790.

[Anderson and Ford, 1986] Craig A. Anderson and Catherine M. Ford, Affect of the game player: Short-term effects of highly and mildly aggressive video games. Personality and Social Psychology Bulletin, 12, 1986, 390–402.

[Bailey and West, 2013] Kira Bailey and Robert West, The effects of an action video game on visual and affective information processing. *Brain Research*, (1504), 2013, 35–46

[Bettadapura, 2012] Vinay Bettadapura, Face Expression Recognition and Analysis: State of the Art. *Tech Report*, 2012.

[Cooke, 2003] Lynne Cooke, Eye tracking: How it works and how it relates to usability.

[The Chameleon, 2013] Call of Duty: Modern Warfare 2 - Campaign Mission gameplay. https://www.youtube.com/watch?v=Sk6cs6Elkbo&list=PLyp7dNCM6mrNbvmgcDIGraVbaTPdO2Ycq&index=1 [Retrieved, 19.06.2015]

[Darwin, 1872] Charles Darwin. *The expression of the emotions in man and animals*. New York/Oxford University, 1872/1998

[Delabarre, 1898] E. B. Delabarre, A Method of Recording Eye-Movements. *The American Journal of Psychology*, **9** (4), 1898, pp. 572-574

[Dodge & Cline, 1901] Raymond Dodge & Thomas S. Cline, The angle velocity of eye movements. *Psychological Review*, **8** (2), 1901, 145-157.

[Duchowski, 2007] Andrew Duchowski. *Eye Tracking Methodology: Theory and Practice*. Springer-Verlag London, 2007

[Dumas, 1999] Joseph S. Dumas. *Practical Guide to Usability Testing (Human/computer interaction).*University of Chicago Press, 1999

[Eason, 1988] Ken Eason, *Information technology and organizational change*. Taylor and Francis, 1988.

[Ekman and Friesen, 1978] Paul Ekman and Wallace Friesen, *The Facial Action Coding System: A Technique for the Measurement of the facial Movement*. San Francisco Consulting Psychologists Press, 1978.

[Ekman, 1994] Paul Ekman, Strong evidence for universals in facial expressions: a reply to Russell's mistaken critique. *Psychological Bulletin*, **115** (2), 1994, 268–287.

[Ekman, Friesen and Hager, 2002] Paul Ekman, Wallace Friesen and J. C. Hager http://www.cs.cmu.edu/~face/facs.htm [Retrieved, 27.06.2015]

[Ekman, 2006] Paul Ekman, *Darwin and Facial Expression: A Century of Research in Review*. Malor Books, 2006.

[Ekman, 2015] Paul Ekman. Facial Action Coding System (FACS) http://www.paulekman.com/product-category/facs/ [Retrieved, 27.06.2015]

[Emotient, 2015] Emotient Analytics Product Brief http://www.emotient.com/wp-content/uploads/Emotient-Analytics-Product-Brief-May-2015.pdf [Retrieved, 27.06.2015]

[Eurogamer.net, 2009] Games to cost $60 million, says Ubisoft boss. http://www.eurogamer.net/articles/games-to-cost-USD60m-says-ubisoft-boss [Retrieved, 04.07.2015]

[Gault, 1907] Robert H. Gault, A History of the Questionnaire Method of Research in Psychology. *The Pedagogical Seminary*, **14**(3), 1907, 366-383

[Geen and Tassinary, 2002] Thomas R. Geen, Louis G. Tassinary, The mechanization of emotional expression in John Bulwer's pathomyotomia (1649). *The American Journal Psychology*, **115** (2), 2002, 275-99

[Ghaoui, 2006] Claude Ghaoui. Encyclopedia of Human Computer Interaction. Idea Group Pub (E), 2006.

[Gubrium and Holstein, 2002] Jaber F. Gubrium, James Holstein. Handbook of Interview Research: Context and Method. SAGE Publications, 2002.

[Hartridge & Thompson, 1948] Hamilton Hartridge & L.C. Thompson, Methods of investigating eye movements. *British Journal of Ophthalmology*, **32**, 1948, 581-591.

[Homewood, 2002] Michael Purdy Homewood, Alphonse Chapanis, a Founding Father of Ergonomics, Dies at 85. The Gazette Online, The newspaper of the Johns Hopkins University. October 14, 2002, Vol. 32, No. 7. Also available as, http://pages.jh.edu/~gazette/2002/14oct02/14obit.html

[Huey, 1898] Edmund B. Huey, Preliminary Experiments in the Physiology and Psychology of Reading. *The American Journal of Psychology*, **9** (4), 1898, pp. 575-586

[iMotions, 2013] Attention Tool FACET Module Guide
http://imotionsglobal.com/wp-content/uploads/2013/08/130806_FACET_Guide.pdf [Retrieved, 27.06.2015]

[iMotions] iMotions – Emotient Module: Facial Expression Analysis.
http://imotionsglobal.com/software/add-on-modules/attention-tool-facet-module-facial-action-coding-system-facs/ [Retrieved, 24.03.2015]

[IGN, 2009] The 10 best game engines of this generation.
http://www.ign.com/articles/2009/07/15/the-10-best-game-engines-of-this-generation?page=2
[Retrieved, 10.07.2015]

[IGN, 2009] Modern Warfare 2 impressions.
http://www.ign.com/articles/2009/06/03/e3-2009-modern-warfare-2-impressions
[Retrieved, 10.07.2015]

ISO/IEC, *9241-11 Ergonomic requirements for office work with visual display terminals (VDT)s - Part 11 Guidance on usability*. 1998: ISO/IEC 9241-11: 1998 (E).

[Isokoski, Joos, Martin & Spakov, 2009] Poika Isokoski, Markus Joos, Benoit Martin, and Oleg Spakov. Gaze controlled games. *Universal Access in the Information Society*, **8**, 2009, 323-337

[Jacob & Karn] Robert J.K. Jacob & Keith S. Karn, Commentary on Section 4. Eye tracking in human-computer interaction and usability research: Ready to deliver the promises.

[Javal, 1878] Louis E. Javal, Essai sur la physiologie de la lecture. *Annales d'ocullistique* **80**, 1878, 61–73

[Jia et. al., 2015] Qi Jia, Xinkai Gao, He Guo, Zhongxuan Luo and Yi Wang. Multi-Layer Sparse Representation for Weighted LBP-Patches Based Facial Expression Recognition. *Sensors*, 15, 2015, 6719-6739.

[McAllister & White, 2009] Graham McAllister, Gareth R. White, Evaluating User Experience in Games. *Human-Computer Interaction Series*, **23**, 2010, 107-128
Chapter 7: Video Game Development and User Experience

[McAllister and White, 2010] G. McAllister and G.R. White, Regina Bernhaupt (Editor). *Evaluating User Experience in Games: Concepts and Methods*. Springer Science & Business Media, 2010

[Metro, 2013] GTA 5 is most expensive video game ever at $265 million.
http://metro.co.uk/2013/09/09/gta-5-is-biggest-budget-video-game-ever-at-265-million-3955201/
[Retrieved, 04.07.2015]

[Michael et. al., 2003] Michael Schiessl, Sabrina Duda, Andreas ThÖlke and Rico Fisher. Eye tracking and its application in usability and media research.

[Mital et. al., 2008] Anil Mital (Author), Anoop Desai (Author), Anand Subramanian (Author), Aashi Mital. Product Development: A Structured Approach to Design and Manufacture. Butterworth-Heinemann; 1st edition, 2008.

[Murray, 2015] Understanding Human Behavior in Dynamic Situations http://www.asleyetracking.com/Site/ResourceCenter/FeaturedResearch/HumanBehavior/tabid/298/Default.aspx#VGS [Retrieved, 25.05.2015]

[Myers, 1990] David Myers, Computer game genres. *Play & Culture*, 3, 1990, 286–301

[Newzoo, 2014] Top 100 Countries Represent 99.8% of $81.5Bn Global Games Market. http://www.newzoo.com/insights/top-100-countries-represent-99-6-81-5bn-global-games-market/ [Retrieved, 20.06.2015]

[Nielsen, 1993] Jakob Nielsen, Usability Engineering Paperback. Morgan Kaufmann, 1st edition, 1993.

[Nielsen, 1995] Jakob Nielsen, 10 Usability Heuristics for User Interface Design. http://www.nngroup.com/articles/ten-usability-heuristics/ [Retrieved, 30.03.2015]

[Nielson & Pernice, 2009] Jacob Nielson and Kara Pernice, *Eyetracking Web Usability*. New riders, first edition, 2009

[Nielsen, 2012] Thinking Aloud: The #1 Usability Tool http://www.nngroup.com/articles/thinking-aloud-the-1-usability-tool/ [Retrieved, 02.05.2015]

[Noldus] What's new in FaceReader 6? http://www.noldus.com/facereader/facereader-6-automatic-facial-expression-analysis-and-emotion-detection [Retrieved, 24.03.2015]

[Norman, 1988] Don Norman, *Psychology of Everyday Things*. Now, *The design of everyday things*. Basic Books, 1988.

[NY Times, 2003] Robert K. Merton, Versatile Sociologist and Father of the Focus Group, Dies at 92 http://www.nytimes.com/2003/02/24/nyregion/robert-k-merton-versatile-sociologist-and-father-of-the-focus-group-dies-at-92.html [Retrieved, 07.08.2015]

[Rubin and Chisnell, 2008] Jeff Rubin and Dana Chisnell, *Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests, Second Edition*. Wiley Publishing, Inc., second edition, 2008.

[Laitinen, 2005] Sauli Laitinen, Better games through usability evaluation and testing

http://www.gamasutra.com/view/feature/130745/better_games_through_usability_.php
[Retrieved, 22.05.2015]

[Shackel and Richardson, 2008] Brian Shackel, Simon. J. Richardson (editors), Human Factors for Informatics Usability. Cambridge University Press, first edition, 2008.

[SMI, 2015] Case Study Eye tracking: Games User Research. Key Lime Interactive.
http://www.smivision.com/fileadmin/user_upload/downloads/case_studies/cs_smi_games.pdf
[Retrieved, 01.07.2015]

[Spencer, 1985] Richard H. Spencer, *Computer Usability Testing and Evaluation*. Prentice Hall, 1985.

[Steam, 2015] Call of Duty: Modern Warfare 2.
http://store.steampowered.com/app/10180/ [Retrieved, 27.04.2015]

[SuperData, 2015] SuperData/Google event: Gamers are dead. Long live gaming.
https://www.superdataresearch.com/blog/gamers-are-dead/ [Retrieved, 20.06.2015]

[Surakka, Illi and Isokoski, 2003] Veikko Surakka, Marko Illi, and Poika Isokoski, Voluntary eye movements in human-computer interaction. In Jukka Hyönä, Ralph Radach, and Heiner Deubel, editors, The Mind's Eye: Cognitive and Applied Aspects of Eye Movement Research, pages 473-491. Elsevier/North Holland, 2003.

[Tian et. al., 2001] Ying Li-Tian, Takeo Kanade, Jeffrey F. Cohn, Recognizing Action Units for Facial Expression Analysis. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, **23**(2), 2001.

[Tian et. al., 2003] Ying-Li Tian, Takeo Kanade, Jeffreyy F. Cohn. Chaspter 11: Facial Expression Analysis

[Taylor, 2013] Frederick Winslow Taylor, *The Principles of Scientific Management*. CreateSpace, Independent Publishing Platform, 2013.

[Torre and Cohn, 2011] Fernando De la Torre, Jeffrey F. Cohn.
Visual Analysis of Humans, Chapter 19: Facial Expression Analysis, pp 377-409. Springer, 2011.

[Vicente, 2004] Kim Vicente, *The Human Factor: Revolutionizing the Way People Live with Technology*. Routledge, 2004.

[Wharton et. al., 1994] Cathleen Wharton, John Rieman, Clayton Lewis & Peter Polson. *The Cognitive Walkthrough: A practitioner's guide*. In Jacob Nielsen and Robert L. Mack (Editors), *Usability inspections methods*. Wiley, 1994.

[Wikia, 2015] Game Modes.
http://callofduty.wikia.com/wiki/Game_Modes [Retrieved, 10.07.2015]

[Zirinsky, 1986] Mark Zirinsky, Usability testing of computer documentation. In: Proc. of the 5th SIGDOC annual international conference on Systems documentation, 61-65

[Tobii, 2015] User experience with eye tracking for Guerrilla Games': Killzone 3
http://www.tobii.com/Global/Analysis/Marketing/CustomerCases/Tobii_CustomerCase_Valsplat_GuerrillaGames.pdf?epslanguage=en [Retrieved, 23.03.2015]

Appendix A:
BACKGROUND QUESTIONNAIRE

Background Information

Age: ______________

Gender: [ ] Male [ ] Female

Occupation:
[ ] Entrepreneur
[ ] Employer
[ ] Student
[ ] Retired
[ ] Unemployed or on leave

Education:
[ ] Comprehensive or elementary school
[ ] High school
[ ] College / University degree
[ ] Else:
____

Computer and Internet Use

How do you evaluate your computer skills?
[ ] Excellent, I understand how computers function
[ ] Good, I use computers often and fluently
[ ] I can use basic functions such as email
[ ] I am a novice in computer use
[ ] I don’t use computers at all

What kind of video game user are you?
[ ] Expert
[ ] Advanced
[ ] Average
[ ] Novice

What kind of games do you play?
[ ] Action
[ ] Adventure
[ ] Role playing
[ ] Shooter
[ ] Simulation
[ ] Strategy
[ ] Sports
[ ] I don’t play games

Which platform do you use the most often to play video games?
[ ] Desktop/Laptop
[ ] Console
[ ] Mobile/Tablet
[ ] Internet
[ ] N/A

Use of the Call of Duty: Modern Warfare 2

Have you ever played the Call of Duty: Modern Warfare 2 before this test?
[ ] Yes
[ ] No
[ ] I'm not sure

If you have played this game before, when you played it last?
[ ] Less than week ago
[ ] Less than month ago
[ ] Less than 6 months ago
[ ] More than 6 months ago

What kind of experience do you usually look for while playing an action game?

____

____

____

____

____

Appendix B:

CONSENT TO RECORD A USABILITY TEST

You have been invited to participate in a usability testing for a video game, Call of Duty: Modern Warfare 2. By participating in the usability test you will help me to understand the user behaviour while playing a video game.

You will be asked to perform different tasks during the game. In addition, i will ask you to fill in questionnaires and i will interview you about your experience of playing this game. The test will be recorded.

During the test, we will record the computer screen and its events, a video image of your face, and audio. The materials recorded during the test will be used to evaluate the user behavior. The recordings will be destroyed after the data analysis.

The results of the test will be reported anonymously.

Participation in this test is voluntary. You can also, stop participating in the usability test at any point.

Duration

The experiment will take about an hour to complete. It includes the introduction to the experiment, filling the background information, consent form, playing a video game and followed by a short interview and questionnaire.

Declaration

By signing this consent form, I agree to participate in the experiment and understand that there is no monetary compensation for my participation. I also understand that my participation is voluntary and I reserve the right to cancel my participation any time without facing any consequences.

Date and place: ________________________________

Name & Signature: ________________________________

Contact Information

If you have any questions, concerns or complaints about this experiment, its procedures, risks or benefits, you can contact the responsible person; Faisal Iqbal (Faisal.Iqbal@uta.fi).