TECHNISCHE UNIVERSITAT BERLIN

MASTER THESIS

Effects of Environment Noise and Interaction Intensity on User Experience and Presence in Virtual Reality

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Declaration of Authorship

I, Rahul Thangaraj, declare that this thesis titled, "Effects of Environment Noise and Interaction Intensity on User Experience and Presence in Virtual Reality" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a master degree at this University.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- I declare that I wrote this thesis myself with the help of no more than the mentioned literature and auxiliary means.

Signed:

Date: 12-03-2021

"This dissertation originated in the Quality and Usability Lab of TU Berlin. Firstly, I would like to thank Technische Universitat Berlin for allowing me to pursue my dream of an M.Sc degree in Computer Science.
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Finally, I must express my gratitude to my family and friends, for their continued support and encouragement, without it, all this would be still a dream."

Rahul Thangaraj

Abstract

With the rise in development of commercial head mounted devices in the last few years we have witnessed a great surge of its use in various fields of engineering. While the technology itself isn't new but with the release of affordable head mounted devices there has been a greater growth of its use in various fields under various environment space. From various research's its quite evident that the device is slowing moving towards the points of being socially acceptable but its still unclear whether the use of the head mounted devices under different environment space offer the same level of immersion and presence as in a closed space. While there are various elements that can impact ones level of immersion or presence in the virtual space but the concept of noises in the public environment is always overlooked.In real life, distractions (like noises or color illumination) are something that generally annoys or affects a humans mental or emotional state. These distractions normally annoy people when he/she is trying to concentrate on the task at hand. With a constant amount of distraction we loss interest at one point and will eventually make wrong decisions or quit the task.

The idea of the research is to leverage the virtual reality technology and audio rendering techniques to understand the potential effects of various environment noises in terms of presence, immersion and decision making. The results can help the application developers to be vigilant when creating applications that are to be used in noisy environments and help them make an educated decision of the various setups required when deploying their products to environments that are rigorous in noise. The individuals reactions to noise will be assessed by means of various cognitive tasks (mathematical and memory based functions) within the environment and the results for those will be recorded based on the subjective evaluation placed at the end of each test condition. The sound sources are acquired and recorded from various real life elements and are blended into the environment. These sound sources are basically audio clips that are proven to interact with a humans decision making ability by causing a sudden surge in various emotional states (such as annoyance and anger). Some of them are based on binaural recording which adds a 3D stereo sound sensation for the listener. They will be triggered at random instances while the user is involved in the virtual space. Different types of environmental noises are placed in the environments with each having a difference in the levels of interaction. The purpose of having some tasks within the environment is to understand how an individual performs the activities while being subjected to various kinds of environmental noises. Its a good way for us to measure how a user reacts and adjusts himself to events with some good level of complexity in highly distracting environments. This would help us understand what all design and environmental factors(till what level the distractions doesn't kick in) can impact or bring down the users immersive experience within a virtual space even though the device seems to be gaining a growth in social acceptability.

Kurzfassung

Mit dem Anstieg der Entwicklung von kommerziellen kopfgetragenen Geräten in den letzten Jahren haben wir einen großen Anstieg ihrer Verwendung in verschiedenen Bereichen der Technik erlebt. Die Technologie an sich ist zwar nicht neu, aber mit der Veröffentlichung von erschwinglichen kopfgetragenen Geräten gab es ein größeres Wachstum ihrer Verwendung in verschiedenen Bereichen unter verschiedenen Umgebungsbedingungen. Aus verschiedenen Untersuchungen geht hervor, dass sich das Gerät langsam in Richtung sozialer Akzeptanz bewegt, aber es ist immer noch unklar, ob die Verwendung von kopfgetragenen Geräten in verschiedenen Umgebungen das gleiche Maß an Immersion und Präsenz bietet wie in einem geschlossenen Raum. Es gibt zwar verschiedene Elemente, die sich auf den Grad der Immersion oder Präsenz im virtuellen Raum auswirken können, aber das Konzept der Geräusche in der öffentlichen Umgebung wird immer übersehen.im realen Leben sind Ablenkungen (wie Geräusche oder farbige Beleuchtung) etwas, das im Allgemeinen stört oder den mentalen oder emotionalen Zustand eines Menschen beeinflusst. Diese Ablenkungen stören normalerweise den Menschen, wenn er/sie versucht, sich auf die anstehende Aufgabe zu konzentrieren. Bei einer konstanten Menge an Ablenkung verlieren wir irgendwann das Interesse und treffen falsche Entscheidungen oder brechen die Aufgabe ab.

Die Idee der Forschung ist es, die Virtual-Reality-Technologie und Audio Rendering Techniken zu nutzen, um die potenziellen Auswirkungen verschiedener Umgebungsgeräusche in Bezug auf Präsenz, Immersion und Entscheidungsfindung zu verstehen. Die Ergebnisse können den Anwendungsentwicklern helfen, bei der Erstellung von Anwendungen, die in geräuschvollen Umgebungen eingesetzt werden sollen, wachsam zu sein und ihnen helfen, eine fundierte Entscheidung über die verschiedenen Setups zu treffen, die beim Einsatz ihrer Produkte in geräuschintensiven Umgebungen erforderlich sind. Die Reaktionen der Personen auf Lärm werden anhand verschiedener kognitiver Aufgaben (mathematische und gedächtnisbasierte Funktionen) innerhalb der Umgebung bewertet und die Ergebnisse dafür werden auf der Grundlage der subjektiven Bewertung am Ende jeder Testbedingung aufgezeichnet. Die Schallquellen werden aus verschiedenen Elementen des realen Lebens gewonnen und aufgenommen und in die Umgebung eingeblendet. Bei diesen Schallquellen handelt es sich im Wesentlichen um Audioclips, die nachweislich mit der menschlichen Entscheidungsfähigkeit interagieren, indem sie einen plötzlichen Anstieg verschiedener emotionaler Zustände (z. B. Ärger und Wut) verursachen. Einige von ihnen basieren auf binauralen Aufnahmen, die dem Zuhörer ein 3D-Stereoklanggefühl vermitteln. Sie werden an zufälligen Stellen ausgelöst, während sich der Benutzer im virtuellen Raum befindet. In den Umgebungen werden verschiedene Arten von Umgebungsgeräuschen platziert, die jeweils unterschiedliche Interaktionsebenen haben. Der Zweck einiger Aufgaben innerhalb der Umgebung ist es, zu verstehen, wie eine Person die Aktivitäten ausführt, während sie verschiedenen Arten von Umgebungsgeräuschen ausgesetzt ist. Es ist ein guter Weg für uns zu messen, wie ein Benutzer reagiert und sich auf Ereignisse mit einem guten Grad an Komplexität in hochgradig ablenkenden Umgebungen einstellt. Dies würde uns helfen, zu verstehen, welche Design- und Umgebungsfaktoren (bis zu welchem Grad die Ablenkung nicht einsetzt) die immersive Erfahrung des Benutzers in einem virtuellen Raum beeinflussen oder beeinträchtigen können, auch wenn das Gerät immer mehr an sozialer Akzeptanz gewinnt.

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List of Abbreviations

VR	**V**irtual **R**eality
VE	**V**irtual **E**nvironment
3D	**T**hree **D**imensional
NASA TLX	**N**asa **T**ask **L**oad Index
ATI	**A**ffinity for **T**echnology Interaction
SAM	**S**elf **A**ssessment **M**anikin
PANAS	**P**ositive and **N**egative Affect **S**chedule
SUS	**S**ystem **U**sability **S**cale

Introduction

Sounds, in general is a part and parcel of any immersive technology by offering a different level of dimensions to the content and visual experience. The substantial amount of experience and value sounds bring in such technologies are immense. The process of simulating sounds in the immersive technology space has seen various improvements over the years, by a constant change in adapting to various sound algorithms in such technologies. Although sounds offer a good level of immersiveness and presence to the user by providing an enriching story telling experience, there still are cases where sounds can be annoying and bring down the user experience. Although there have been various research so far on the impact of sounds in general on virtual reality, until now only a little research has been per-formed on how environmental noises/sounds can contribute to the enhancement of the sense of presence and immersion when positioned in a multi-modal virtual space environment. Many international studies have shown us that environmental noise can have a negative impact not just from an health perspective but in multiple different ways. With this research we combine the virtual reality technology and it's audio rendering techniques to understand and study further on how the environmental noises can affect a user not just from a presence/immersion perspective but also from a decision making perspective. Thereby allowing the developers and designers to come up with a more educated approach when developing experience for Virtual Reality. The participants will be exposed to a set of conditions each differing in the level/intensity and timing of noise activity. Furthermore, the individuals reactions to those conditions will be assessed by means of cognitive measures (classified by tasks within the virtual environment) and subjective evaluations, on noise and visual annoyance from a presence, task load and emotional perspective.

1.1 Background, Motivation

The research topic of this master thesis is to understand the effects of environmental noise and interaction intensity on user experience and presence in virtual reality. The most important and critical component that should always be kept in mind when developing applications for virtual reality environment or systems is User Experience. It is an easy task for to develop applications for virtual reality systems but the goal is to ensure that the strategies used by designers and developer should in no way compensate on the user experience. In order for us to employ an effective and efficient user experience for applications developed to be used in the virtual reality, it is highly required of us to study and conduct various empirical studies to explore factors that contribute to a heightened sense of presence, or immersion, for users. With the help of these studies we get an opportunity to understand each individuals perspective on the various parameters that can effective construct a good level of

experience in a virtual environment, that seems as real as possible. With the help of these results one can possibly make an educated guess on various design and development parameters that needs to be addressed before setting out in the process of creating a virtual reality application. But user experience is not something that is just influenced by the design and development parameters, in other words not just the visual and interaction aspects but also parameters such as audio and sound design makes an efficient contribution. This is because it is a well known fact that sound enhance the level of presence and immersion in the virtual reality space. It is always required to find the right balance between all these features to provide an efficient user experience[1]. The type of sounds that will be concentrated on in this research is mainly the various familiar environmental noises with different level of intensity that one can find and relate with a real world environment. With the use of such noises in the game play we get a better understanding on how these design aspects contribute to the level of immersion and presence and user experience in the virtual environment. Noises that are perceived as more pleasant or relaxing in a real world environment might not lead to a pleasant experience in the virtual space. Traditionally, noise perception assessment is based on subjective noise annoyance, that is, a self-report measure of displeasure or irritation caused by noise exposure (ISO/TS 15666, 2003)[2]. The assessment methods and techniques used to assess these noises in a standard laboratory setup is quite straightforward, where the participants of the research study will be subjected to a collection of pre-recorded environmental noises and post which their responses will be reported and recorder by the degree of perceived noise annoyance on any likert scale based questionnaire. In other cases the noise annoyance and it's consequences will often be collected through surveys organized in social media sites. Based on the information presented in [3] we can infer that from the data that were analyzed with respect to these surveys the relationship between noise annoyance and noise levels in terms of dose–response models have shown that the higher the noise level (e.g. sound pressure level) the higher the number of people who are prone to being highly annoyed. Although this is true to some extend, the research study does question the reliability of these study models in predicting noises in any environments as the study model used may be insufficient. As it might convey information on the variations in individual annoyance reactions to the same noise exposure level[4]. The study model, dose–response curve parameters[5] are used by planners and consultants to predict noise effects in future years and to plan noise abatement programs[6]. Further reports collected from[3] suggest that only about 10 to 15% of the variability in ratings can be explained by noise level so there needs to be an efficient way to analyse the effects of noises. But most of these research study[3,6,7,8] examines the role of environment noises or sound for specific use cases such as from an architectural or urban design perspective and also not from a system usability's point of view. The studies doesn't report on the impact of different noise levels and intensity on their research. Their techniques doesn't classify these noises based on any criteria and are randomly induced in the virtual reality space. While this is helpful in replicating a real world environment where noises of different types exist along with each other but we don't have a conclusive evidence on the type of noises that has a higher significance over the other. Also, these studies doesn't emphasize on the effects of replicating real world noises in the virtual reality space. Questions such as the impact of these noises from a presence or immersion perspective, on different interaction level intensity, cognitive performance within the virtual space and finally the effects on individuals emotional level.

In an attempt to overcome all these limitations, we devise and propose here a

method to assess the impact of different environmental noises and varying interaction intensity on user experience. Here the individuals interact with the environment, each of these environments are set with a different interaction level intensity and with different environmental noises are triggered at random intervals to study of effects on how these two characteristics impact on user's experience in the virtual space. As said before the experience in virtual space is characterized based on different interaction level and by performing some simple cognitive and other gamified tasks. In this research, an immersive virtual reality environment is created and presented to the user's who has the option to interact and engage within the virtual space. Although the graphics of virtual environments are still far from being fully natural, but with the immersive virtual technology we create an impression that the users are surrounded by the virtual environment and have the impression of being present inside the virtual world; as said before users have the option to interact in real time with the objects and elements in the virtual reality space. These two characteristics determine the sense of credibility of a virtual scenario, that is, the sensation that the virtual environment is quite convincing and that it can replicate or generate events and actions that a participant can directly relate with sensorimotor contingencies[9]. However, the main reason for the success of the interactions/simulations in the virtual reality space is mainly due to the fact that these simulated environments are efficient enough in provoking user responses and behaviors that are similar to those portrayed or experienced in the real environments [10,9]. It can be brought as an argument that a video recordings or streaming pictures of actual environments or photo-montages of future environmental scenarios could have been used rather simulating a 3D generated world. But some of the previous works have shown that simulating an experience that quite similar to real world interactions can be reliably used to assess tranquility of spaces[11]. All the other type of representations such as Video recordings and streaming of pictures have the advantage of reproducing a more high quality visual effect, but participants are in no way connected with simulated world as they don't have the opportunity to interact with it and feel being disconnected[12].

1.2 Research Objectives

As discussed earlier there have been a few focused studies on the effect of environment noises and interaction intensity in Virtual Reality earlier such as [2,6,7,8,13,14] and this provides a research gap that we can utilize as an advantage. By being able to answer the research questions and achieve the research objectives, we hope to contribute to the advancement of knowledge in the user experience of virtual reality and help guide the designers and developers in creating content that provides an enriching user experience.

1.2.1 General Objective

To identify the experiential factors that affect the user experience and presence in virtual reality. The main emphasis of the study is on the factors that affect the user experience in VR by figuring out the individual parameters such as different noise types and interaction intensity to make an educated guess in designing or creating content for virtual reality.

1.2.2 Specific Objectives

1. To identify the parameters that influence the task load when the user is immersed and executing a task within the virtual reality space.

2. To identify the influencing parameters that has an impact on the level of presence and immersion within the VR space.

3. To identify the factors that are responsible in generating the positive and negative emotional feeling when the user is involved in the VR space.

4. And finally determine the parameters that contribute or contravene to the usability of the virtual reality system.

1.2.3 Research Questions

The answers to questions that we are trying to figure out from this research study are:

i). How users respond to different type(varying intensity level) of noises when they are involved in the virtual reality space ?

ii). What are the design guidelines for VR systems to enhance user experience ?

iii). Do difference in the level of interaction emote a higher degree of user experience and presence ?

iv). And finally do the difference in audio elements and interaction intensity in any way contribute to the two main characteristics, User Experience and Presence in virtual reality ?

The goal here is to first understand and research the various design paradigms that could be used to enhance user experience in virtual reality. The more we learn about these principles and parameters the more it helps us in constructing content for virtual reality applications that can steers us in the path of creating an efficient, effective and engaging application.

1.3 Structure of this Report

In chapter 2 we will dive deeper into the development process and other efforts that were carried out in creating the application for virtual reality. Wherein we go in details by encompassing the various details involved in the pipeline of constructing and structuring the elements of game play. Also, there is a detailed elaboration on how the schematics and the designs were finalized, the development of the different conditions were chosen. In chapter 3 a quick look into the subjective questionnaires that are to be used for this research study is briefed about. In chapter 4, a deep analysis on the data acquired from the user study is explained and interpreted. Figures, tables and various other representation techniques are used to present the data recorded from these questionnaires. Chapter 5 presents the research significance, discussions, the lessons learned, and the possibility of future work. The references and the appendices are provided in the last sections of the thesis.

Related Works

2.1 Brief Information on Existing works

Sound is one of the most important and integral part of an immersive virtual reality environment, by contributing to level of immersion, presence, and user performance by a significant margin. The main aim of designers and developers of virtual reality environment when developing an immersive virtual environments is that to create experiences that convince the users as if it were very real. But often the integration of sound and other related factors are ignored and neglected[25]. One of the experimental study[26] managed to analyze the effect of spatial-sound versus no-sound display on presence experienced by the user on a virtual environment. The results pronounced from this research show that a medium to strong effect of spatial sound, leading to higher levels of presence experienced. The analysis of the results of the study gave a quick indication that integrating a spatial-sound in a 3D generated virtual scene leads to higher levels of presence experienced by the user, and the effect ranges from a medium to large degree.

Although the results from the study was quite significant in many they still had certain limitations: First, the test participants did not have any type of task to do the scene they were just observing the scene and the sounds are triggered at different intervals. And they strongly suggest that using a task specific application might lead to different results with respective to the sound. Secondly, the study conducted used a within-subject design [27], where the same person is subject to test all the conditions giving subjects direct possibility of comparison. They suggest that using a between-subject design may lead to a different and maybe a more realistic effect estimation. This gives us a wonderful opportunity to extend this study by ensuring the user's are given with an option to interact and play around in the virtual environment and assess the impact of environment noises/sound with respect to presence and immersion.

The findings suggested in another research work[28] reiterates a similar claim that the addition of audio to the visual display increases the sense of presence by a significant margin and agrees with the results of several other multi-modal sensory studies of virtual environments. They used a between-subject design with the important factor being the audio condition (none, low fidelity, and high fidelity). The results from the survey showed that the user of sounds enhanced the sense of presence (or "being there") and also supplemented the quality of the visual display.

2.2 Proposed Changes in our research study

The first bigger change that was proposed in our study is to provided the users with an opportunity to interact with objects in the virtual space. We firmly believe

that inducing some level of interaction to the users in the virtual space will emote a higher degree of presence and sense of being there than just making the users stand in the scene and offer no interaction. Replicating interactions that are quite similar to what you find in your day today can make it easier for the users to connect with the virtual space thereby adding a greater level of immersion and presence.

Most of these research works speak about how the use of audio can contribute to higher level of presence but they never dive deep into the negative effects of sounds and other elements in the sound such as noises. Any audio played at a different intensity will have varying responses from a test subject. So, we would like to bring in the environmental noises or sounds of different intensity and build the virtual space with these sound elements.

The tasks presented in the virtual reality space are quite diverse in our case with the users working on a cognitive task in some of the conditions and another game based, story-line involved tasks are presented. These story-lines and tasks are weaved in such a way that it is much similar to events an user can experience in their daily life.

Since the environment is modelled in great details it provides us with the opportunity to conduct many proven test survey after the execution of each tasks. We bring the NASA task load questionnaires, presence questionnaire, positive and negative affect schedule, system usability score and self assessment manikin.

2.3 How & Why the proposed project is different & better ?

The existing system uses a forest scene to represent their 3D environment which although is great with a much polished graphics and visual quality it doesn't relate to an environment that an user can connect with quite easily. So, we choose to use a simple urban landscape environment to construct our story-line and tasks surrounding the same. This way we have the option to present the users with tasks that are more relatable and commonly found in daily environment.

One of the drawback mentioned in the current study is the need to setup an environment that offers the participants an opportunity to interact with the elements in the virtual space. In our proposed system we offer the users with an opportunity to interact with the virtual space. The interactions range from a simple button press to opening a cupboard and so on. The environment and the task is further supplemented with the environment noises to better replicate a real world environment.

As explained before with the inclusion of different interaction levels we have a great scope in conducting many surveys. We have tasks with varied level of intensity in the virtual space hence we use the NASA task load to study and understand which of the conditions(with respect to sound and interaction) have higher task load in general. And all the other survey are conducted with respect to sound/noise types and interactions used. Whereas the current study calculates just the value of usability score and leaves out many other surveys.

Design and Development

The development process that was brought to completion of the research study was characterised by many decisions that were taken by me and supervisors regarding the design, implementation and structuring of the work. Many of these discussions resulted in the more mature and stable version of the product, from many changes and adaption that were made on the fly in order to balance the effectiveness and relevance within the time window that was given. In this chapter we will dive deeper into the development process by encompassing the various details involved in the pipeline of constructing and structuring the elements of game play. There is also an of elaboration on how the schematics and the final designs were finalized, the development of the different conditions were chosen, following a chronological order starting from the beginning of the project, is shown.

3.1 Preparation and Structuring of Game play

From the initial discussions carried out with the supervisor it was quite clear that each of the test conditions are fixated with some stern requirements but these requirements never restricted or held me back from having more room for creativity and expression. This in specific offered me the opportunity to construct a neat and simple story line that the users can relate or make sense of without a greater level of complication. But this on the other hand posed a greater challenge to me as some of the works involved in the setup and construction of the game play needed me to have a strong in-advance planning. Since there are various elements involved in the process of game development it is highly required of me to figure out the elements that are necessary or required for me to even setup or start the project. For this very important reason I started to list out and frame the various tasks (ranging from micro to macro) and grouped them based on the category they can be clubbed into. This resulted in the identification of the following major tasks that are to be done so as to successfully complete the design and development phase (an overview of the timeline of the research study is available in the last section):

1. Prepare a rough draft for the game-play and identify the underlying challenges to implement them in the Unity game engine.
2. Finalize the story-line and underlying game-play for the research conditions.
3. Identify and design the 3D assets that are supposed to supplement the design of game level. And find the necessary means to animate and fix other issues that comes as a part of some of the downloaded assets.
4. Find and fix (errors, if any) the sound sources that are supposed to be placed in the virtual space.

5. Complete the development process by programming the various 3D objects that are required to be interacted within the virtual space.

6. Finally, have the application deployed in the oculus virtual headset and have it tested to find any anomalies with the developed capabilities.

Over the next few sections I will elaborate on the various tasks that were comprised in the successful completion of the above identified tasks.

3.1.1 Compiling the initial draft and Underlying challenges

To put forth a captivating story line of any kind I had to first make myself clear of the stern requirements this research study imposes on me. Since the presence factor, decision making and immersiveness are some of the key elements that drive this research I want the story-line to have some kind of relevance that one would come across normally in their day to day life. Although the immersiveness can be driven based on the level of interaction within the virtual space I also wanted to ensure that the visual elements that are offered in the scene does add some weight to it. These crucial elements bolstered me to step up my game of creativity and expressiveness but also stay humble to the requirements of the research study.

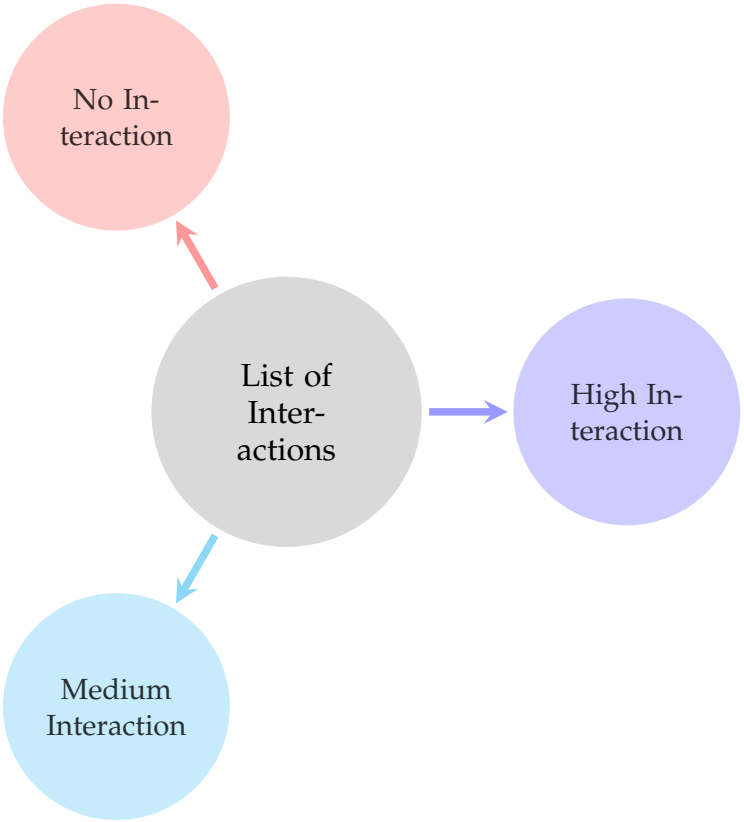


FIGURE 3.1: List of Interactions

Since interaction levels within the Virtual space is one of the primary areas we touch upon in this research, the story-line had to be weaved accordingly. To keep the story-line consistent across various interactions (shown in Figure 3.1) and also to not exert too much pressure on the users to adapt to the constant change of environment, I felt it is a sensible approach to reuse the scene and setup for all test conditions with minimal degree of change. Making it consistent not only suppress the pressure put

forth by the change in visual elements but also offers the element of comfortness as they don't have to toil hard to get to our research objective.

3.1.2 Finishing up the Story-line and Game-play

With having figured out the segments that constitute and make up the essential parts of the story-line I finalized the story-line and the underlying game-play. Since I wanted the stage to be set based on the scenario that one might easily come across in their day to day life I geared towards the designing of a scene with elements that represent an urban landscape. Although the scene does contain an urban landscape within the virtual space the player will be confined within a simple studio environment. The studio environment consists of various elements that offers multiple opportunities for the users to interact with them. The goal here is to present a space that reflects an environment the user is much comfortable, with that in mind I finalized on the possible interactions and activities:

1. "The player has to first accomplish some simple routine tasks such as moving around and picking up objects to get familiarized with the setup and scene. Since the controls are pretty much the same it should be much easier to get accustomed to and remember them. This would also give them the opportunity to understand what are the possible elements available in the scene and what are the various real world interactions presented in the game-play. The noises and other sound sources will be configured to render in a 3D space so that they act very similar to the way it acts in the real world environment."

2. "For a zero interaction scene there is not much to be carried out other than making the user present in the virtual space and trigger the audio sources at a random intervals. Since, there is not much interaction offered, many visual elements have been placed in the scene to give an impression that the noise or sounds might be generated from them. This is just to ensure that the user doesn't get distracted and are very much available in the virtual space.

3. "The medium interaction scene will be fit with many elements that offers the opportunity to interact with them in the virtual space. But the main goal in this interaction is to also identify and understand if the noises not only have an impact on presence and usability but also on the cognitive ability of the user. A simple mathematical game has to be played in this scene and the goal is to see if the user can concentrate and complete it successfully irrespective of any disturbances.

4. "The High interaction scene will be placed with actions that resembles many real life scenarios such as opening a cupboard or doors, switching on/off the buttons, picking up and grabbing objects. The story-line here is pretty simple, the user has to find two music discs that are missing from the music player and place them on the system and find a way to switch it on so that the characters in the virtual space can start with their dance session.

The reason to pick a scene, story-line and the underlying interactions of such kind is because this setup offers me a great amount of flexibility but also offers me with opportunity that can be stimulating from a creative point of view, giving me the possibility to create more meaningful representation.Also, this seemed to be the reasonable scenario which offered me an easy way to extend and inherit the other

requirement into the scene, environmental noises. The following are the list of noises that will be included in the game-play

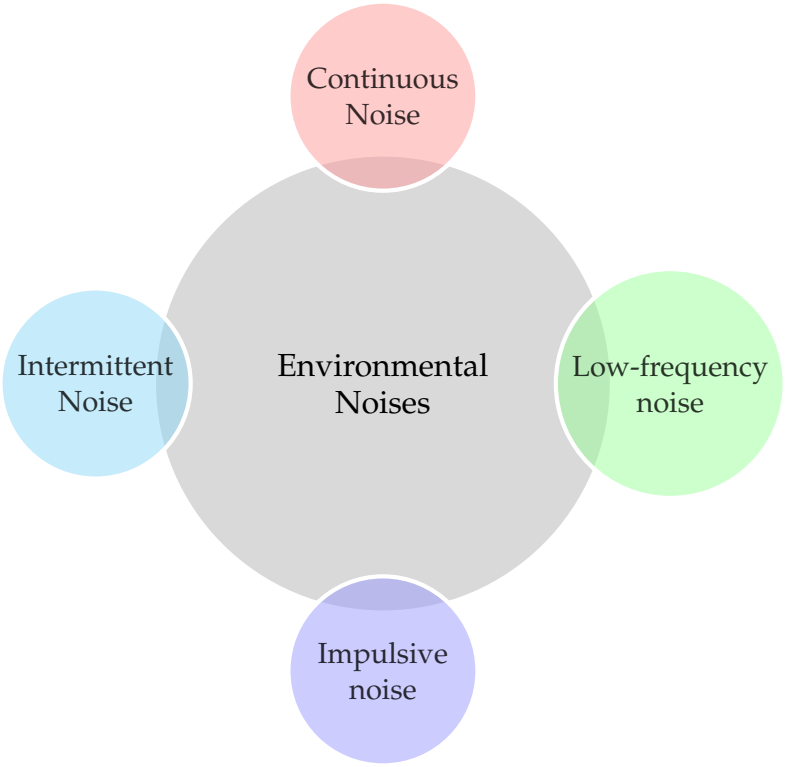


FIGURE 3.2: List of Noises

Here's a breakdown of the different types of noise that affect us all.

1. Continuous noise is exactly what it says on the tin: it's noise that is produced continuously, for example, by machinery that keeps running without interruption. This could come from factory equipment, engine noise, or heating and ventilation systems.

   You can measure continuous noise for just a few minutes with a sound level meter to get a sufficient representation of the noise level. If you want to analyse the noise further, you need to look for a sound level meter with octave band analysis. Octave bands allow you to break the noise down into its separate frequencies. This information will tell you exactly what frequency is causing the noise. You may even want to investigate the noise with 1:3 octave bands, which can provide even more detail about the frequency content of the noise you're measuring.

2. Intermittent noise is a noise level that increases and decreases rapidly. This might be caused by a train passing by, factory equipment that operates in cycles, or aircraft flying above your house.

   We measure intermittent noise in a similar way to continuous noise, with a sound level meter. However, you also need to know the duration of each occurrence and the time between each one. To gain a more reliable estimate of the noise level, you should measure over multiple occurrences to calculate an average. If you're using an integrating-averaging sound level meter, this will make the calculation for you and present this in terms of an LAeq.

3. Impulsive noise is most commonly associated with the construction and demolition industry. These sudden bursts of noise can startle you by their fast and surprising nature. Impulsive noises are commonly created by explosions or construction equipment, such as pile drivers, or your nextdoor neighbour doing some DIY on a Sunday morning.

   To measure impulsive noise, you will need a sound level meter or a personal noise dosimeter that can calculate Peak values.

   Don't forget that even in an environment that is usually quiet, a single very loud noise can cause hearing damage, which is why it's important to measure Peak levels alongside the average or Leq value. In most applications, Peak will be measured using the C-weighting, so you should make sure that your sound level meter provides this.

4. Low-frequency noise makes up part of the fabric of our daily soundscape. Whether it's the low background hum of a nearby power station or the roaring of large diesel engines, we're exposed to low-frequency noise constantly. It also happens to be the hardest type of noise to reduce at source, so it can easily spread for miles around.

   For low-frequency noise, you should be using a sound level meter with third octave band analysis, so you can analyse the low frequencies that make up the noise. You may also need to look at the C-weighted measurements and compare this to the A-weighted measurements, as this can show how much low-frequency noise is present.

3.2 Designing & Development Process

At the end of the previous process I had a visual prototype of the different scenes and the interactions that are to be presented in this research study. With the help of that prototype, this section will be presented with all the information that are needed to not just design the scenes but also the development of various interactions to be placed in the scene. I will start with the discussion on how the scenes and various other elements that contributed to the scenes in general were designed. Also, go in details on the various process involved in the scene designing and setup such as identifying the suitable 3D models, rigging the objects so that they can animated or simulated by using C# scripts, lighting the scenes, finding & fixing the audio sources and setting up the animation of the 3D characters. Then, I will do in detail on the development involving, mostly involves how the interactions and other respective elements are programmed and tested for production ready.

3.2.1 Game-Play Designing

- Zero Interaction :
  - **Main scene :** A typical setting for an urban home environment with a minimal list of objects but is fit with multiple characters that resemble the human form with some animations enabled so that they don't look like static objects.
  - **Interactions :** As the name suggests there are no meaningful interactions in this type of scenes. The user can turn and around gaze at various elements presented in the scene or try to find the various sound sources.

- Medium Interaction :
  - **Main scene :** A typical setting for an urban home environment with desks, screens, laptop, TV, music system, shelves, chairs and a game machine where the cognitive task is supposed to be carried out etc. Also, fit with multiple characters that resemble the human form with some animations such as sitting, standing and lying down on the sofa are enabled.
  - **Interactions :**
    * Interactions with the game machine such as pressing the button and manipulating the joystick control.
    * Move and navigate the character in the virtual space.
    * Interact with an Ipad in the game to quit to the previous screen.
- High Interaction :
  - **Main scene :** A typical setting for an urban recreation/aerobics studio environment with screens, music system, shelves, chairs, disco ball and a dance floor where the in game 3D characters will start with their dance routine once the task given to the user is completed successfully. The user can also join the game characters and dance along with them.
  - **Interactions :**
    * Interactions with cupboards and desks to find the music discs.
    * Picking up objects such as ID cards to open doors, music discs to be placed on the music system.And switching on the button to start the music system.

3.2.1.1 Game-play Environment

To build the exterior of the urban landscape environment a city 3D model was downloaded from the sketchfab website. Then the asset was configured and manipulated accordingly to create the view that is shown in the image below (Fig. 3.3). To construct the room environment itself, another asset was downloaded from the sketchfab website that included walls, ceiling, windows, lamps and window grills. Furthermore, I had to download other 3D models such as desks, Television, chairs & etc a normal urban room consists off. Then these models were placed and arranged accordingly to create a scene that looks like the image below (Fig. 3.4). The texture for some of those models had to be fixed so I had to use royalty-free images to create them with the help of a graphic program GIMP.

FIGURE 3.3: Urban Landscape Environment

Most of the exteriors in the Urban Landscape environment remains pretty much the same except for certain scenes. These changes are added as required to supplement the various audio sources included so as to promote the sense of believability. Since the character will remain within the room environment throughout the gameplay much effort is not put to fix the graphic elements outside of the room.

FIGURE 3.4: Sample Room Environment

The general structure of the room environment is constant across all test conditions but the placement of objects and inclusion/exclusion of 3D objects were determined based on the interaction conditions. That is, the complete room setup(including various objects) stays same for each interaction types such as zero interaction, medium interaction and high interaction. 24 Chapter 4. Implementation Figure 4.1: Office scene

3.2.1.2 Playable Character

The playable character inside Unity was implemented by using the Unity Integration package from Oculus Quest. At the time of the development the version of oculus package that was integrated into the game is version 17.0. From this package, the OVRPlayerController was used to control and navigate the user in the virtual space. The setup for oculus quest parameters is shown in the screenshot taken from Unity (Fig. 3.5)

FIGURE 3.5: Oculus Quest Parameters

Controls for both left hand controller and right hand controlled was included so that both the controllers can be used in the virtual space to interact with the elements. After adding a character camera constraint and setting the tracking of the player to floor level, the player was able to control this character inside the virtual environment.

FIGURE 3.6: Scene Exit Control

All of the scenes were packed into a single android apk file and then deployed into the oculus quest device. This is done to ensure that the user doesn't have to bear the burden of navigating through the oculus directory to find the respective conditions before starting to play. I had to develop an exit control that makes it easy for the user to go back to the condition list screen and pick the next condition to run. A detailed explanation of how this is accomplished is explained in the development process section. A screenshot of how this exit control looks like from unity is shown in Fig 3.6.

3.2.1.3 Scene Design & Setup : Zero Interaction

As far as the scene setup is concerned there is not much deviation from the setup that was explained earlier. The player controller is setup next to the window by default so that the starting location for the user across all conditions will be the same. There is not much going on this scene apart from the fact that a continuous noise is generated from an air conditioner duct placed in the scene.

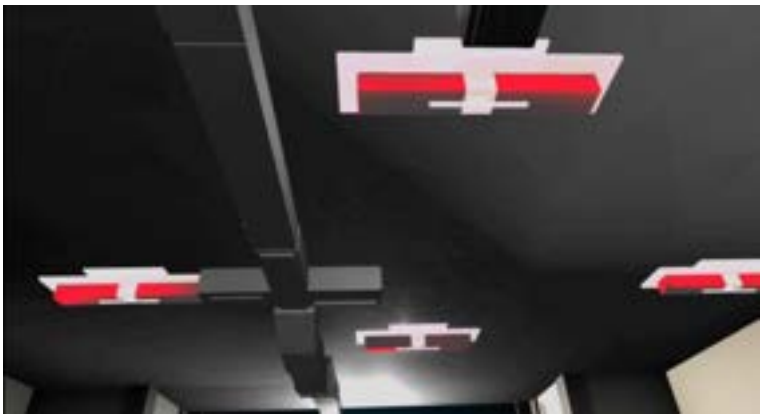
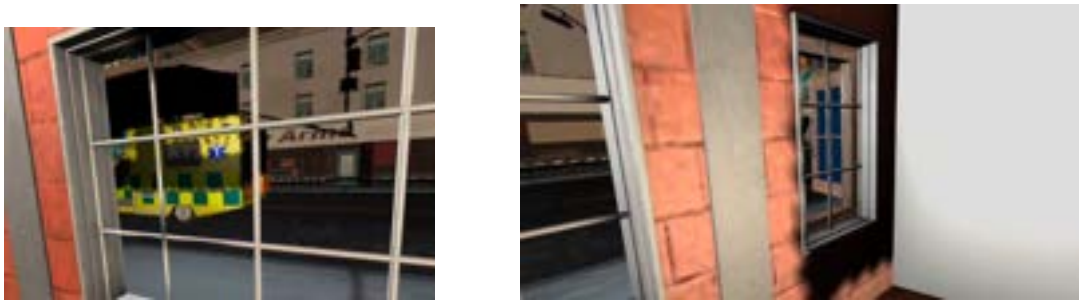


FIGURE 3.7: Air Conditioner Duct

A 3D object for an air conditioner duct was downloaded from sketchfab and replicated multiple times(also manipulated to some extent) using Autodesk Maya, so as to create a complex looking duct as shown in figure 3.7.

As the name suggests the noises in this interaction will be impulsive in it's intensity. To mimic and add some visual elements to supplement the noises that were chosen I had to add an ambulance 3D object in the game and a custom window so that they can be programmed and animated respectively via script which is explained in detail in the next section.



(A) Ambulance (B) Customizable Window

FIGURE 3.8: Impulsive Noise Visual Elements

For impulsive noise the audio elements that were placed in the scene for this condition is triggered at a different interval so as to evoke the feeling of surprise. The audio sources used in this condition are ambulance noise, a heavy thunder & lightening sound and the window close & open sound.

In intermittent noise condition the overall design structure of the scene is pretty similar to others but a railway bridge has been brought into the scene so that it could be made to possible to move the train objects over this bridge. This is a single track bridge that was downloaded from sketchfab and the trains are placed on the two opposite sides of the bridges. This way on of the train can be configured to pass or move along in one direction and make the other move along in the opposite direction. The audio source is placed next to the user apartment so when the train passes the audio is loud and clear to the user immersed in the virtual space.

Finally in the low frequency noise case, few additional props were included in the scene to construct the visual elements. A table fan object is brought into the scene with the fan blade separated from the rest of the mesh. To extract the blade from the mesh, I had to bring this object into blender and select the vertices that comprise the blade and detach it from the original mesh using an in built mesh separate function provided in blender. This is done so that a fan rotation functionality could be added to it. Also, the pivot point of the fan blade is placed at the center of the blade so that when it is made to rotate it rotate along this point. Some additional vehicle props were also included in the scene that can be configured accordingly to create a traffic environment on the streets.

3.2.1.4 Scene Design & Setup : Medium Interaction

The first condition that will be discussed in this section is the continuous noise case. Two audio source are to be placed here with one being generated from a Television and the other being generated from a radio. A simple 3D model of a TV is placed at one end of the room on a table. The scale of the TV is adjusted accordingly to make it look better in the virtual space. Few furniture's such as a coffee table and sofa are

placed in front of the TV. The sofa will be used to place the characters in the scene, each will be assigned with an animation clip as their default state. Necessary box colliders are put up in place to ensure that the player doesn't pass through those. The radio 3D object is placed very close to the game machine where the tasks are to be completed.

For the impulsive noise condition, firstly, an alarm clock is placed on the table next to the game machine. The alarm clock's oscillating pin element is detached from the rest of the mesh. This was detached from the main mesh by selecting the vertices of the pin and use the separate selection tool in Blender. This is done to induce an ringing effect from a script when an alarm ring sound is played. Next, a car is placed on one end of the streets this will move further in position, next to the player area based on certain rules that will be defined in the script. Finally, a coffee machine is placed on the right side of the game machine. Also, a 3D character model is made to stand next to it, this is done so as to induce an illusion that glass break effect that will run at one point in game is caused by this character. Two sets of glass models (one of which is already broken) are placed next to the coffee machine, with the broken one being hidden at the start of the game and enabled at certain point.

For the intermittent noise condition, not much was required to setup the scene. An helicopter and aeroplane models are placed at two different ends of the game world. The helicopter wing is detached from the main mesh so that it can be given a rotation animation from the script. These objects will be made to move in space from the script and rules for movement will be defined there.

Finally, in the low frequency noise condition, only one audio source will be used and it is a recorded clip of people in a group conversing with each other. To supplement the audio source, three 3D character models are seated on top of the sofa in the centre of the house. They are all assigned with an animation clip that constitute a sitting and talking effect.

3.2.1.5 Scene Design & Setup : High Interaction

First, we will look into the scene design of continuous noise case. The main task to be completed in the high interaction will be the same, finding audio discs and turn on the music system once found. Most of the objects placed in the scene for medium interaction cases are removed. Three 3D character models are placed in the scene, they will be configured to start dancing once the main task is completed by the player. Since, this story-line leads to a dancing animation of the characters when the task is successful, a dance floor has been placed at the centre of the scene. With each cubes on floor is set with a point light. Also, a disco ball is placed in the scene and made to look like it is hanging down from the ventilation unit. A cupboard with many drawers is placed next to the dancing area, with one of the discs being hidden inside the drawers. The music system is placed at one end of the room on a table and an electrical line connecting the music system to a switch is drawn under the table. Also, the next discs is placed in the room adjacent to the dancing area on another cupboard.

The main design of other conditions in high interaction is pretty much the same except for few things. In impulsive noise, free access to the room adjacent to the main room is blocked with a door. To open the door user has to find a key card and deactivate the lock. The scene is also placed with a card reader than can recognize the card when placed. The cupboard in the adjacent room used for continuous noise is replaced with another cupboard and the disc is hidden inside one of the drawers. For intermittent noise and low frequency noise case the scene setup is pretty much

the same with the former has a vacuum cleaner placed on the floor for the sound source illustration but the latter doesn't include any design changes from others.

3.2.2 Interaction & Game-Play Development

In this section I will take you through the development activities that were carried out to get the interactions and other elements in the game work seamlessly. I'll also explain how the UI areas were setup and constructed. The programming language that was used to construct all the interactions and elements supporting the game-play is c#. And the IDE that was used to construct and test the logic of the script is Visual Studio 2019 Community Edition.

3.2.2.1 Development of UI Elements

When the game is first initiated in the oculus quest environment it loads to a start screen(in Fig 3.9(A)) that consists of two elements. The element that is named as introduction will play a pre-recorded audio that explains the research objective and purpose in detail. Selecting the start screen loads the condition list screen as shown in Fig 3.9(B), which has been assigned a number from 1 to 12. The user is supposed to pick the conditions in a random order, which will be given to them by me from a list I had prepared. The objects you see in the figure 3.9 below are just a simple cube objects that are assigned with a collider component. The purpose of the collider is to track the ray that is sent from a specific point in the right hand controller. This ray tracks the user action, checks which object has been selected by the user, determined based on the current position of the circle pointer as seen in the fig 3.9. The circle pointer or the blue ring is hidden by default and is supposed to move along in space based on the user hand position. When the ray from the hand controller hits a valid object then the ring appears, this is to provide the user with a visual guidance on where the selection marker is currently positioned.

(A) Start Screen (B) Condition Screen

FIGURE 3.9: UI Elements

When the start option is selected it moves to the next screen which comprises the lists of all conditions but given with a specific number. When any one of the condition is first selected it loads the concerned screen. The loading of the scene is made asynchronous so that there is a smooth transition between the loading of new scenes. If it wasn't set to be asynchronous then there wouldn't a gap between exiting the current scene and loading the new scene. To avoid this lag between scene transition I had to make it asynchronous.

3.2.2.2 Interaction Development per conditions

In the coming section I'll explain in details on how the various objects were programmed to complete and support the actions involved in the game-play. I will go through the various development process per each interactions in detail. This detailed explanation is not just about the development specifics of the main tasks to be completed but also contains the development specifics of all the elements that support the execution of each interactions.

3.2.2.3 Development of Zero Interaction Case

For case, Zero Interaction Continuous Noise, there wasn't any programming involved. To configure the audio source to get played continuously, an audio source component was first tagged to one of the game object and the placement of the audio source was moved next to air conditioning duct and the spatial blend(Volume Rolloff: Linear Rolloff) was to 3D. By setting the spatial blend to 3D I had much control on optimizing the minimum and maximum distance the noise can be heard in the virtual space.

FIGURE 3.10: Audio Source Parameters

The audio was also set to play on awake and was looped so that it is ensured to play without any pause. The maximum distance a noise could be heard was not

set by following any specific rules but by just some trial and error. The audio source parameters that was set for this case can be seen in Fig 3.10. Although this is a screen grab of on the of the audio parameters but almost all the audio source are configured with the same parameters.

For case, Zero Interaction Impulsive Noise, as the name suggests the noises will be a bit higher in intensity and will be played at a random interval. In this case the ambulance noise was configured to be played first. In order to trigger the siren sound source the ambulance has to reach a specific destination. The ambulance was configured to move towards a specific location in the 3D space by constantly updating the transform position of the ambulance every frame. Also, a custom speed variable was included to this transform position calculation to ensure that the movement to the destination is at a constant rate. An onTriggerEnter function was configured to check if any object is passing through a specific collider object placed in the scene. When the ambulance hits this specific location the sire audio source is enabled and movement of the ambulance is stopped for a file. After a while the ambulance begins to move towards its final destination. When the ambulance reaches it's final destination the rain audio source is enabled. Also, at this point a timer was configured to calculate & check if the time from playing the rain audio source has crossed 15 seconds. When the timer crosses the 15 second mark the lighting noise is enabled and lighting visual effect is also triggered in the game-play. After a period of time a window close and open noise is also triggered in the impulsive noise condition. This audio source was recorded by me using my mobile phone by opening and closing the window door in my flat. This audio source is also supplement with a window movement activity in the scene, a key-frame animation was created in unity to get this achieved. This animation basically affects the rotation of the object in y-orientation every 48 frames which is 2 seconds. A screen grab of this animation parameters from unity can be seen in Fig 3.11.

FIGURE 3.11: Window Animation Parameters

In the next section I'll be discussing about the zero interaction intermittent noise case, here the noises are configured to occur at an intermittent rate. The sounds of passing trains are played intermittently to replicate this effect in the virtual space. When the scene is initiated a train 3D object placed at one end of the 3D space moves towards a destination point. When this object passes through a specific collider area one of the train audio is played. On exiting the collider area the audio is configured to stop playing. Once the first train reaches its destined location another train starts placed at the opposite side starts moving to its destination location. Similarly, when this train pass through the collider area another train audio is played and on exiting the area the audio stopped. This action keeps repeating until the scene is running thereby creating an intermittent noise effect.

The last condition I'll be discussing in this section is Zero Interaction Low Frequency Noise. There are three different noises placed in this condition. The first low

frequency noise was placed next to the table fan, also a visual representation of fan rotation is added in the script to supplement the activity. This is achieved by setting a new rotational value in the Z-axis for the fan blades on every frame. In Unity this can be achieved using setting the transform local rotation value by calling the Quaternion Euler function. To achieve the low frequency effect the maximum fall off distance of the audio source was to set to a very low value so that even if the audio is played it won't be that audible. The fall off distance was configured accordingly for the others audio source used in this condition to achieve this effect and was calculated by trial and error.

(A) Fan Rotation

(B) Traffic Setup

FIGURE 3.12: Sound Source in Low Frequency Noise Condition

After a period of time, some of the vehicle objects as seen in Fig 3.12 have been programmed to move towards a certain location that is of a closer proximity to the user location. Once all the vehicle objects move towards the destined location, a traffic noise is set to play. The movement of objects is achieved using the move towards function provided by the unity vector3 object.

3.2.2.4 Development of Medium Interaction Case

This section will be split into two, the first section will contain information on how the main task is developed and the latter will contain information how the supporting scene elements were developed. The main task in this interaction is a simple cognitive game. In this game, there will be a total of 20 coins listed on the screen and the user is provided with the option to pick either one or two coins during his/her turn. The one who manages to pick the last coin will be the winner of the task. The research idea here is to understand and identify if the noises that are triggered during the game-play in any way affects or interferes with the users cognitive ability. The second section will be about all the noises and how the visual elements that supplement them are developed or brought into the game-play.

3.2.2.4.1 Development details of the Cognitive task

To start the mini game within the scene, the user has to first press the start button on the game machine with the right hand controller in the virtual space. After pressing the start button a series of text appears on the game machine screen, detailing on the rules and regulation of the task to be performed and how it could be performed. Once the rules are all displayed then the game starts and user is supposed to start the game by picking one or two coins. To pick a coin the user has to move his right hand controller towards a joystick and grab the same that is in the center of the game machine. Once the controller is grabbed and the user presses the A button on the right oculus controller, the joystick controller is rotated in the z axis by a positive value of 30 degrees. If the user pressed the B button on the right

oculus controller, the joystick controller is rotated in the z axis by a negative value of 30 degree causing the object to rotate towards the opposite direction. Pressing A button picks two coins and pressing the B button picks one coin. The oculus quest controller information can be seen in fig 3.13.

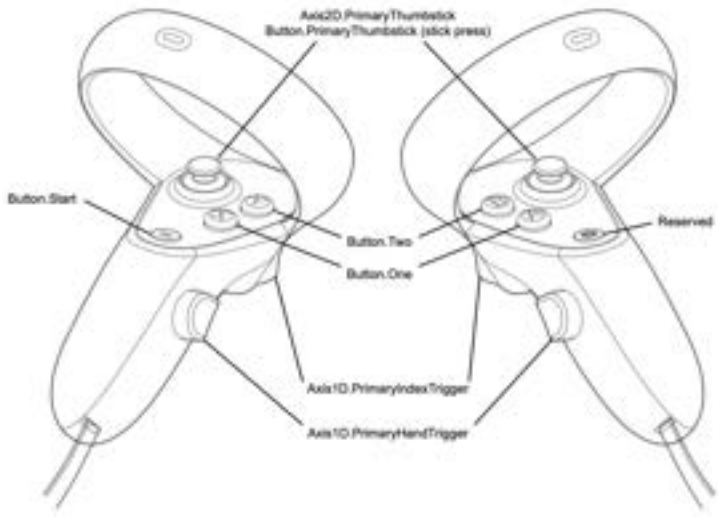


FIGURE 3.13: Oculus Quest Controller Setup

The joystick at the center of the game machine as seen in Fig 3.14 is rigged in blender. A bone has been setup so that it could be called during run-time to set rotation value. To make an object grabbable in the virtual space an oculus developed script component named OVRGrabbable has to be attached to the concerned object. In addition to it a box collider and rigidbody component needs to be attached so as to make it grabbable. Once the user turn is complete, that is when the coin is picked up then the control is given to the computer which picks a coins. The rule in which the computer picks up the coins are pretty random and doesn't follow a specific set of algorithm. Finally when the last coin is picked the game ends and display a text message on the game machine screen on who managed to pick up the victory.

FIGURE 3.14: Simple Cognitive Task

3.2.2.4.2 Development details of other supporting elements

For medium interaction continuous noise two sound sources are placed. One being the continuous from the video that is played on the TV screen in the game and the other being a recorded news played from the radio.

FIGURE 3.15: Video Player Parameters

To have a video played inside of the scene there needs to be some setup that needs to be completed in unity. The first task is to attach a video player component to the game object on which you want the video to be played. Then you have to determine the render mode, which is nothing but the type of object on which the played images from the video will be drawn. In my case I set this value with Render Texture. Render textures are textures to which something can be rendered to. They can be used to implement image based rendering effects, dynamic shadows, projectors, reflections or surveillance cameras. To get this setup, just create a new render texture and assign the render texture to the target texture field in the video player settings. Since, we also need the audio in the video to be heard we have to assign an audio source component to the audio source field in the video player. This link the video's audio to an audio source component that can receive the track's audio samples for processing. The video player setup for this condition can be seen from fig 3.15. The other audio source used in this scene is a pre-recorded news clip which has been configured to play on awake so when the game loads it just start's playing till the end.

In medium interaction impulsive noise, three sets of impulsive noise has been put into the scene with each being triggered at a different point during the execution of the main task. The first audio trigger is set when the total amount of coins that have been picked so far in the game is greater than 4 but less than 6. Then the analog clock alarm sound is started. When the alarm sound is triggered then a function that controls the alarm bell striker movement is also triggered. This manipulates the

rotational value of the striker in the z orientation every frame and make it look like it has been animated. When the current coin count is greater than a value of 8 then the alarm trigger is stopped and a car object positioned on the street starts moving to a specific point marked in the scene. When the coin count value gets between 12 and 14 the car horn audio is triggered. When the coin count value gets between 16 and 18 the character which is standing next to the game machine is made to move.

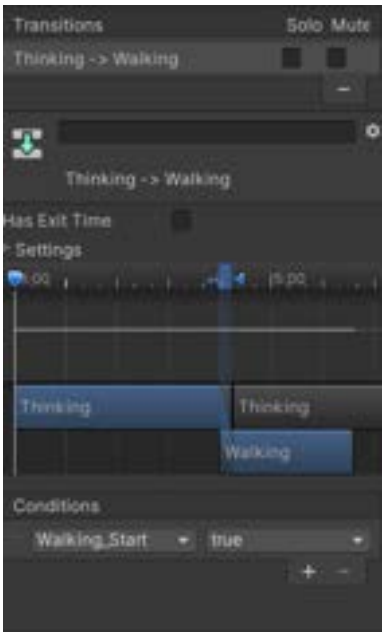


FIGURE 3.16: Animation Transition Parameters

This is achieved by enabling the animator component on the character that has a walking animation assigned to it. Since the audio that is played at this point of time in the game is a glass breaking noise a broken glass 3D object is made to fall next to the coffee stand. The walking animation was download from the mixamo site and is enabled once the conditions are met by setting the animator components set bool value of the animation to true. When the game loads a standing animation of the character is played but when the bool value is set to true then animation states makes a transition from the standing to walking animation. The conditions to make this transition happen is configured in the animator window of the Unity screen.

(A) Before Touch (B) After Touch

FIGURE 3.17: Game Exit Control

Once the task is completed, the user is required to quit and go back to the home screen of the game where all the conditions are listed. To get the exit control appear

you have to press the primary index trigger button on the left or right hand controller. When pressed a scaling animation is played which sets the scale of the object with a value that makes it visible to the user. On pressing the same button again the reverse of the animation is played which scales down the object to a value of 0.1 units. The exit control objects has a text display which asks the user to touch on a specific place on the object. When the touch is successful the menu screen is loaded. When the location to be touched is not touched yet the text will be displayed in red color but when the touch is successful the color of the text will turn to green. The illustration of text color change can be visualized from fig 3.16.

The next condition we'll look into is the medium interaction Intermittent Noise. The sound source used by me to represent this condition is the noise of a flying helicopter and aeroplane. They are triggered one after the other intermittently. The two game objects are placed in the 3D space and are programmed to move or translate to specific destination from the script. The helicopter object is programmed to start when the main task in the game is triggered by the user whereas the aeroplane object is not allowed to move or translate till the total coin collected so far is either 10 or 11. Both the game objects are set with a tag name, this is done to find which game object is passing through a specific collider placed in the scene. Based on the tag assigned to the game object a specific sound source is played. Also another on trigger exit function is also placed so that when these game objects move beyond this collider then the audio has to stop playing.

Finally, the last condition we will look in this section is the medium interaction low frequency Noise. Not much effort was required to setup this scene. The sound source used in this condition is just an audio recording of a conversation by a medium sized group. The audio source was placed next to the sofa object in the scene where all the characters are seated, The characters have been setup with a sitting animation, downloaded from mixamo and configured in unity. The maximum fall off radius is adjusted accordingly in the sound source to achieve a low frequency effect when the user is immersed in the virtual space.

3.2.2.5 Development of High Interaction Case

Just like the previous section even this section will be split into two, the first section will contain information on how the main task is constructed and the latter will possess information on how the supporting elements in the scene were developed. The main task that is to be completed by the user in this scenario involves the following story line. You are in the recreation or dancing area of your apartment with your friends but there is no music to play to get started with your dance routine. Your task is to search through the entire apartment to see if you can find any audio discs and place them on the music system and switch it on. The research idea here is to understand and investigate if the noises that are triggered during the game-play in any way affects or annoys the user experience whilst immersed in the virtual space. The second section will be about all the noises and other visual elements that are placed to supplement these sound elements are developed and brought into the game-play.

3.2.2.5.1 Development details of the main task

Since the main task to be completed in this condition will not be explained to the user beforehand. I placed a small trigger in the scene that will execute an audio recording when the user gets to it. This trigger is placed next to the dance instructor found in the front part of the dance floor. This is supposed to act as a guide to the

user on what is the current task that needs to be completed. When a task is completed the user can go back to the instructor and she will list out another task as needed. When all the tasks are completed the dancers and the instructor will begin dancing, more details on this is explained in the next section. Once the task is clear the user will search through the things in the scene to find the audio discs.

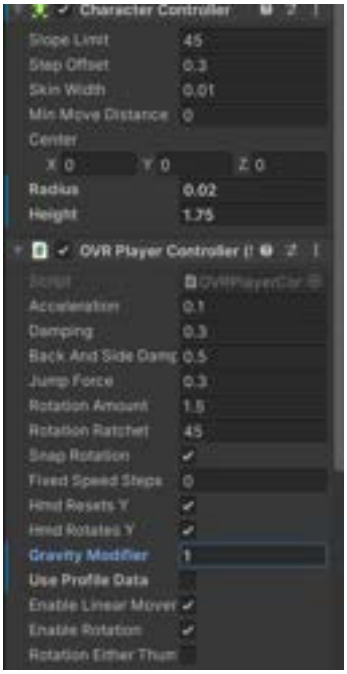
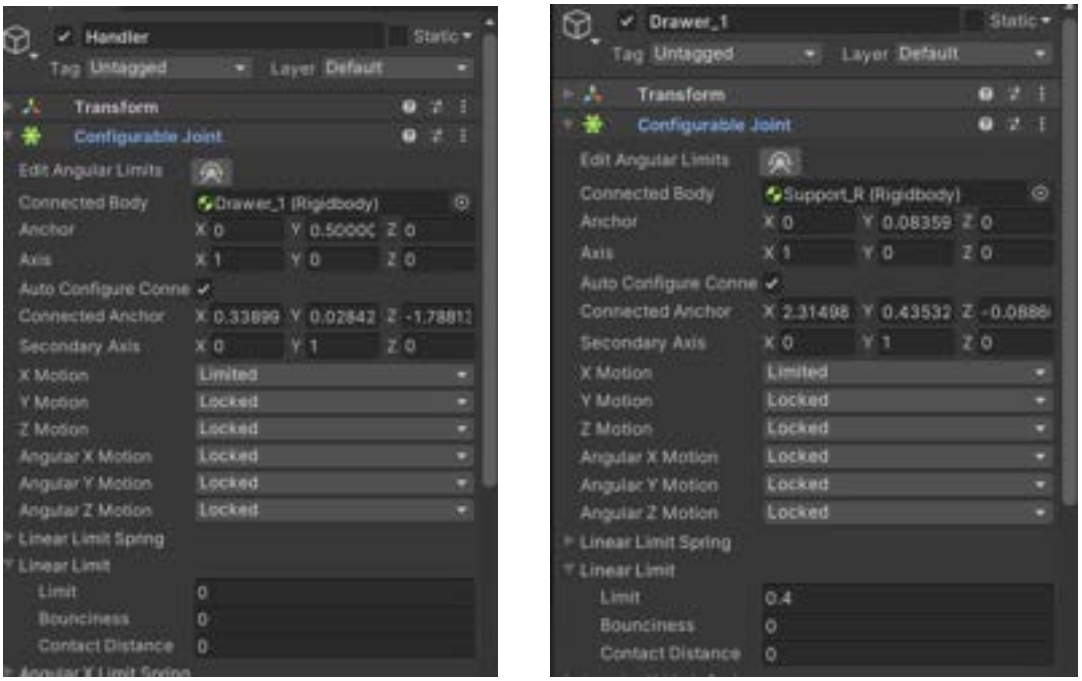


FIGURE 3.18: Enable Controller Movement

As explained before there is no character movement action enabled in the zero interaction case. But for both medium and high interaction this has to be enabled. This was achieved by setting the gravity modifier on the OVR player controller component with a value of 1 (any thing else other than 0). As per the script the character movement is calculated based on this value, so setting this to zero will zero out the move value thereby restricting the character movement from the controller.

To find the audio discs the user has to be search through the cup boards. In order for the player to interact with the handle of the cup board. The object has been attached with a script written by me that extends the oculus OVR grabbable script component. The handle is also assigned with a configurable joint with only the motion in X direction is enabled and all the other linear and angular motions are disabled. The handle is a part of a drawer, since the movement of handle should impact the movement of the drawer, it is assigned as the connected body in handle's configurable joint.The joint configuration for both the handle and drawer can be seen from fig 3.19. This setup of connecting each other influence the transform position based on the object that is grabbed and moved in space by the user. The drawer join is assigned with a linear limit 0.4, this restrict the drawer to move only 0.4 units in the X direction. Also, to ensure that the handle object cannot be dragged to a longer distance by the user a simple logic has been devised in the update method of the grab script. When the distance of the hand goes beyond 0.4 units from the handle position the grabbed object is force released.



(A) Handle Joint (B) Drawer Joint Setup

FIGURE 3.19: Configurable Joint Parameters

One of the two discs to be found is placed inside the main room of the scene. This is hidden inside the cup boards, also the user can come across other things in the cupboards that could be helpful for finding the another disc. Once both the discs are found the user needs to place the discs on top of the music system. A collider is placed on top of the music system that can recognize the discs when the object is dropped on top of it. Once both the discs are dropped on top of the music system the user needs to find what else needs to be done to complete the mission. The user has to go to the dance instructor again and get the next mission details. The user has to find a switch in the room that can help switch on the music system. That is again fit with a collider to check if the hand is being moved into it.

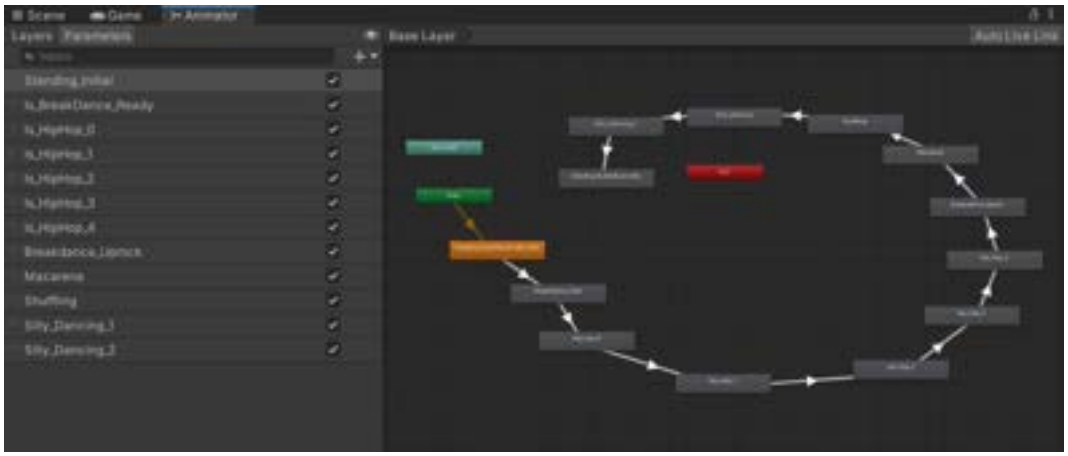


FIGURE 3.20: Character Animation Parameters

When the switch is pressed in the scene then the dance animation is enabled. And the dance floor lights are lit and the disco ball is rotated in the y axis by a

degree of 30 multiplied by the delta time every frame. The light intensity of both the dance floor and disco ball lights are based on the sound intensity. The disco ball is also configured to change it's color after every .8 seconds.

As far the dance animation is concerned, a series of dance routines were downloaded from the mixamo website. Then they are orderly configured in the animator section of unity. A set of few boolean values have been configured and they are set as true by default. The rules and these configuration can be seen from fig 3.20. When the music system is turned on the animation controller on all the characters are enabled. When enabled it by default runs the first animation clip connected to the entry block (green box object). A timer value of 19 seconds has been configured in the animation manager script which controls how long a dance routine is played. When the timer expires the clips boolean parameters value has been set to false. When the parameters is set to false then the animation controls transitions to the next connected animation clip in the path seen from fig 3.20.

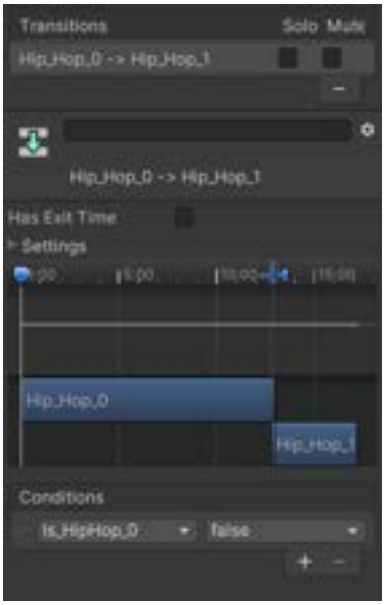


FIGURE 3.21: Animation Transition Condition

Fig 3.21 shows an example of one such animation transition condition. As you can see from the figure this condition is a transition from Hip_Hop_0 routine to Hip_Hop_1 routine. For the transition control to move to routine 1 a condition has been defined, which states for the transition to occur only when the routine 0 parameter has a value of false. This value change to false from true is controlled by the animation manager script, which sets the value of a parameter to false after 19 seconds.

3.2.2.5.2 Development details of other supporting elements

For high interaction continuous noise not much effort was required to setup the supporting elements of the scene. There's just a single audio source placed in the scene which keeps playing till the main task given for the user is complete. A simple condition has been placed in the script to see if the button that turns on the music system has been pressed. If yes, then the audio source that controls the continuous noise is set to stop playing. In high interaction impulsive noise, two audio sources have been set to play sometime during the game-play. The first audio source that

is triggered will be a fire alarm coming from one of the building blocks next to the place where the user is positioned. A particle effect was created with the Unity Particle system to achieve the fire and spark effect from the nearby building when the audio source is triggered. The lifetime variables has been set with a value of 10, when the value reaches to zero the corresponding particle will expire. The final render of this fire effect can bee seen from fig 3.22.

FIGURE 3.22: Visual Effect Final Render

Features such as base particle properties, emission, shape, color over lifetime, size over lifetime, texture sheet animation and renderer were setup accordingly to accomplish this effect. The details of the effects can be seen from fig 3.23 The maximum particle has been setup with a value of 1000 so as to give a thick fire emission effect. Three more additional particle effects has been placed along with the main fire effect, with each of them adding additional overlay and other fire specific effects such as spark and so on. The basic setup required to achieve the main particle effect is explained as follows. The start size of the particle is given with a value of 2.5 and make them last for a duration of 5 seconds. Also, each particle is assigned with a randomized start rotation value so that the particle doesn't look like being emitted towards a single direction. In the emission setup the rate over time has been set with a value of 10 this ensures that a total of 10 particle is emitted per second, higher the value more the computational challenge hence it is set with a small value. Emitter shape is set with a value of Cone, it defines the shape of the volume from which the particles are to be emitted. Also, the color over lifetime is made to change from red to yellow and then to orange and finally to black giving it a burnt touch at the last. And finally the size over lifetime is made to change from a size of 1 to 3 over the life time of the particle.

After the fire alarm trigger, the fire truck is triggered to move to the destination where the fire has been triggered. Once the truck reaches it's final destination the water particle effect is enabled. This is more of a water sprinkle effect that was achieved by starting the particle with a smaller size and make them grow over time for a duration of 10 seconds and then expire. The script that controls the water particle effect will stop the effect once the timer from start of the effect crosses a value of 20. This timer also turns off the fire particle effect and moves the truck object to a different position.

There is a subtle change in the scene from the continuous noise setup to rest of the scenes in the high interaction case. To access the other room in the house a special card needs to be acquired to first unlock the door. Each door has an animator

component with a simple animation clip assigned to them. The animation is a simple key frame based translate in position effect created in unity.

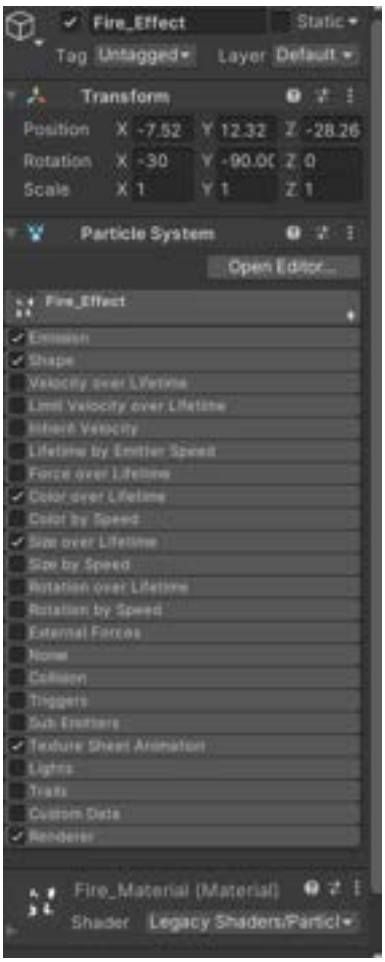


FIGURE 3.23: Visual Effect Setup

The script that controls the door opening disables the animator component by default making sure that the door is locked until the key card is found and placed on the card reader. When the key card is placed in front of the card reader an audio source with a clip of a key card open sound is played. Then the texture that is applied on the card reader is changed to a new texture displaying the unlocked text on it. The texture was fixed and updated accordingly in photopea before being brought into unity. The change in texture displaying the status of the door can be seen from fig 3.24.

The next case is the high interaction intermittent noise where a simple vacuum cleaner is placed in the scene which moves constantly between two pre-defined points. An audio source component with an audio clip of automatic vacuum cleaner is placed in it. The audio source is configured to play the audio clip for a certain period of time and then disable it for a certain period of time. This way we achieve an intermittent noise effect in the scene.

And lastly we have the high interaction low frequency noise case, where, a few sets of audio source component has been placed in the scene. Each of these audio source component are configured to play the same audio clip and is set to play on awake and loop continuously. To achieve the low frequency effect the maximum

distance of the audio volume is set to a minimal value. Also, the user has to be present next to one of these audio source to hear the noises.

(A) Door Closed (B) Door Open

FIGURE 3.24: Sliding Door Mechanism

3.2.3 Software's & Other Development Tool-kits Used

In the following section I will list out few information about the tool that were used to design and develop the game. These tool-kits were deployed on a windows 64bit operating system machine. Almost all of the tools listed below doesn't require one to purchase licenses except for Autodesk Maya. The Autodesk Maya version used in this project has an educational license that allows me use their product for non-commercial purposes.

3.2.3.1 Unity 3D Game Engine

The platform on which the game was created is called Unity [7]. Unity is one of the most widely used real-time 3D development platforms. Unity can be used to create games in both 2D and 3D. The engine offers a primary scripting API in C#, for both the Unity editor in the form of plugins and games themselves, as well as drag and drop functionality. Unity supports multiple external Virtual Reality and Augmented Reality plugins. It also has an internal asset store in which users can buy, sell and download 3D models and network plugins [12].

3.2.3.2 Blender

Blender [4] is a free and open-source 3D computer graphics software toolset used for creating animated films, visual effects, art, 3D printed models, motion graphics, interactive 3D applications, and computer games [10]. I used this software for modelling/rigging some simple objects in the scenes which I thought would be time consuming if designed using Maya.

3.2.3.3 Autodesk Maya

Autodesk Maya [5], commonly shortened to just Maya is a 3D computer graphics application that runs on Windows, macOS and Linux. It is commonly used to create assets for interactive 3D applications (including video games), animated films, TV series, and visual effects. In this research project, the application was used for modeling and fixing textures for the game-objects in the scenes. Since, most of the objects were downloaded from online sources such as sketchfab, in certain cases the UV's

were misplaced giving a weird looking texture. So, I had to rework the UV's using Autodesk Maya to fix those issues. [9].

3.2.3.4 Audacity

Audacity is software that enables the users to both records and edits audio clips free of cost. The interface of Audacity is simple and very user-friendly. It also offers cross-platform compatibility and supports multiple plugins and libraries for enhanced functionality. It can run smoothly on Windows, Apple macOS, and Linux operating systems. All these features have made Audacity one of the most popular audio editing software available today. It was used in this research project to fix and edit some of the audio clips that were downloaded from the internet and also the ones that were recorded using my personal mobile phone.

3.2.3.5 Freesound

Freesound is a collaborative repository of CC licensed audio samples, and non-profit organisation, with more than 400,000 sounds and effects, and 8 million registered users (as of March 2019). Sounds are uploaded to the website by its users, and cover a wide range of subjects, from field recordings to synthesised sounds. Audio content in the repository can be tagged and browsed by folksonomic means as well as standard text-based search. Audio content in the repository is also analysed using the open-source audio analysis tool Essentia, which powers the similarity search functionality of the site. Freesound was used in this research study to find and download all the environmental noises and other audio sources that were used in the game-play.

3.2.3.6 Mixamo

Its an online platform from where a collection of character animation was downloaded. We can browse a collection of high-quality 3D characters. From realistic to cartoon, fantasy to sci-fi, there's a character for every purpose. Each character comes fully textured and rigged so we can use immediately in our creative projects. We can download characters and animations in multiple formats, ready to use in motion graphics, video games, film, or illustration. Whether we just need one animation or a hundred, export optimizations will keep our projects light and efficient. Also to have the transition controlled just by changing the parameter of the boolean values in the script I had to ensure that the has exit time is set to false. Exit Time is a special transition that doesn't rely on a parameter. Instead, it relies on the normalized time of the state. It ensures to make the transition happen at a specific time specified in Exit Time.

3.2.3.7 PhotoPea

Photopea is a web-based raster graphics editor used for image editing, making illustrations, web design or converting between different image formats. It is compatible with multiple web browsers, including Opera, Edge, Chrome, and Firefox. The app is compatible with Photoshop's PSD as well as JPEG, PNG, DNG, GIF, SVG, PDF and other image file formats. While browser based, Photopea stores all files locally, and does not upload any files to a server.

User Test Methodology

The next phase after development is to test the game for that a user testing was carried out which took place from the first week of September 2020 till the mid of October 2020. The goal of the user testing was to have the participants play each one the 12 conditions and to answer questionnaires based on what they experienced during the game. To eliminate any possible bias during the experiment, the series of conditions were randomized, and each participant was arbitrarily assigned to a sequence.

The first thing asked from the participants was to sign the consent form (B.3), stating that they agree to participate in the study, that they understand that the participation is voluntary and that they agree that their data will be collected, stored and used for scientific research and publications. Following the consent form, participants had to fill out the following list of questionnaires.

4.1 Demographics

A demographic survey is a research instrument in the form of a questionnaire that gives you a specific type of audience insight. It varies widely but you can get information about the respondent's age, gender, behaviours, and more.

Most surveys aren't used to collect only demographic data. Rather, demographic survey questions are only part of a questionnaire. They can be an icebreaker and a great way to do cross-tabulation to get deeper insights into survey results.

In the end, it's important to ask questions that make sense for your audience. In this user study a the questionnaire starts with the general information of the user and proceeds further into research specific questions to give them an insight and also get an idea about the participant. To view complete list of questions asked in Demographics questionnaire then view section Appendix B.1.

4.2 ATI Scale

The 9-item affinity for technology interaction (ATI)[15] scale is designed to assess a person's tendency to actively engage in intensive technology interaction — or to avoid it. ATI can be seen as a core personal resource for users' successful coping with technology.

ATI is a key facet of user personality and therefore essential when assessing user characteristics in research on technology interaction. Use cases include the identification of sample biases in usability tests or adapting interfaces or technology-related training's to ATI values in the user group. To view complete list of questions asked in ATI Scale questionnaire then view section Appendix B.2.

4.3 NASA TLX Index

NASA-TLX[16,17] originally consisted of two parts: the total workload is divided into six subjective subscales that are represented on a single page, serving as one part of the questionnaire: for Mental Demand, Physical Demand, Temporal Demand, Performance, Effort and Frustration. There is a description for each of these subscales that the subject should read before rating. They are rated for These descriptions are as follows:

Mental Demand How much mental and perceptual activity was required? Was the task easy or demanding, simple or complex? Physical Demand How much physical activity was required? Was the task easy or demanding, slack or strenuous? Temporal Demand How much time pressure did you feel due to the pace at which the tasks or task elements occurred? Was the pace slow or rapid? Overall Performance How successful were you in performing the task? How satisfied were you with your performance? Effort How hard did you have to work (mentally and physically) to accomplish your level of performance? Frustration Level How irritated, stressed, and annoyed versus content, relaxed, and complacent did you feel during the task? To view complete list of questions asked in NASA TLX questionnaire then view section Appendix B.3.

4.4 Igroup Presence Questionnaire

The Igroup Presence Questionnaire (IPQ)[18] is a scale for measuring the sense of presence experienced in a virtual environment (VE). It has been constructed using a large pool of items and two survey waves with approximately 500 participants. It was originally constructed in German, but is now also available in English and Dutch. The item pool included both previously published items (translated into German) and new items. The IPQ, as we now publish and release it, also includes both types of items.

The current version of the IPQ has three subscales and one additional general item not belonging to a subcale. The three subscales emerged from principal component analyses and can be regarded as fairly independent factors. They are:

Spatial Presence - the sense of being physically present in the VE Involvement - measuring the attention devoted to the VE and the involvmenet experienced Experienced Realism - measuring the subjective experience of realism in the VE The additional general item assesses the general "sense of being there", and has high loadings on all three factors, with an especially strong loading on Spatial Presence.

The release of the questionnaire has the goal of making it available free of charge. Note that the English version of the questionnaire contains some items previously published by other authors. Those items are marked in the questionnaire.

Along with the items, we also provide data collected with the IPQ items. The data are supplemented by information on the participants and the technology used. You may realize that the publication of raw data is still a rather unusal step in the scientific community. The goal of this step is to provide you with a solid basis for understanding the data you collect with the IPQ. Furthermore, we strongly encourage all researchers who are collecting data with the IPQ to add those data to the database To view complete list of questions asked in Igroup Presence Questionnaire then view section Appendix B.4.

4.5 PANAS

The PANAS[19] measures both positive and negative emotions for clients from week-to-week as they engage in everyday life. (Magyar-Moe, 2009). Positive affect refers to the propensity to experience positive emotions and interact with others positively, even through the challenges of life. Negative affect, on the other hand, involves experiencing the world in a more negative way.

It can also be used as a tool for charting the immediate effects of therapy as well as any outcomes associated with positive psychological exercises, interventions or activities. The scale is sensitive to momentary changes in affect when clients are directed to complete the form based on their affect at the present moment.

Participants utilizing PANAS use a 5-point scale in which they determine if a concept applies. (Mulder, P., 2018). Very Slightly or Not at All, A Little, Moderately, Quite a Bit,Extremely. The final score is derived out of the sum of the ten items on both the positive and negative side. The PANAS is designed around 20 items of affect. The scale is comprised of several words that describe different emotions and feelings. To view complete list of questions asked in PANAS Questionnaire then view section Appendix B.5.

4.6 Self Assessment Manikin

The Self-Assessment Manikin (SAM)[20,21] scales developed by Bradley Lang in the 1980's are a pictorial rating system to obtain self-assessments of experienced emotions on the dimensions affective valence, dominance and arousal. A paper-pencil or computer based version can be used in an experimental procedure. Due to the non-verbal design it is usable regardless of the age, educational or cultural background of the probands. To measure "Joy of Use" SAM is suitable with restriction, because it measures only a global emotional status. It does not allow to infer the factors which caused joy.

The dimension valence describes the positive or negative feeling caused by a situation, an object or an event. E.g. anger and anxiety are supposed to have negative valence, joy is supposed to have positive valence.

The dimension arousal describes the perceived vigilance as a physiological and psychological condition of a person. The range reaches from excitation to doziness or boredom.

The dimension dominance describes how much a person feels in control of a situation. A small manikin means that the proband feels he/she has no power to handle the situation.

Please view Section B.6 in Appendix A to view complete list of questions asked in SAM questionnaire.

4.7 System Usability Scale

System Usability Scale(SUS)[22] was used to analyse the general experience of users with the system. According to a study SUS gives best results for small sample sizes. SUS is widely used in industry for analysing the user satisfaction with the system. The advantages of SUS are that it is quick and cheap. It is also good with large sample sizes, such that the calculation is fairly simple even with large sample size. SUS consists of 10 questions. Users can rate each question from a Likert scale ranged from 1 to 5. 1 stands for strongly agree and 5 stands for strongly disagree.

In order to calculate the final results, there is a specific technique. 1 needs to be subtracted from the user response of an odd question and for even question user response needs to be subtracted from 5. In this manner all the user responses would be converted from 0 to 4 range, where 0 is the most negative response. After this, for each user add up all the responses and multiply it by 2.5. It would convert the responses from a range of 0 to 100.

Scores above 80 means a good usability, 68 means an average usability and below 51 means the system needs an immediate usability improvement. Please view Section B.7 in Appendix A to view complete list of questions asked in SUS questionnaire.

4.8 Final Questionnaire

This questionnaire is asked at the end after all the conditions to be tested are completed. This is defined by me to acquire the general opinion from the user about the game and their experience. Also about their understanding of the goals of our research study. Please view Section B.8 in Appendix A to view complete list of questions asked in Final questionnaire.

Test Results and Analysis

In this chapter I will put-forth my analysis based on the findings and analysis derived from the survey that was conducted during the research study. A total of 25 people were involved in the user testing phase and their responses were collected by asking them to answer a wide range of objective questions. The responses gathered from the survey was analysed using the embedded tool from Google Docs, Microsoft Excel and IBM SPSS[23] software. This chapter focuses on presenting the gathered data in a meaningful way and evaluate the responses given for the questionnaires in a detailed manner.

This chapter at the outset provides the background to the participants by analysing their demographic details. This is followed by findings and analysis of data of each of the main questionnaires and finally concludes with the summary. Tables and diagrams have been used to facilitate a simplistic reader-friendly writing.

5.1 Demographic characteristics

In the section, I will provide a detailed analysis on the various demographic characteristics of the participants/users that participated in the user testing and survey. I will start with the age distribution of the participants and then will give an outline of the age distribution of the participants, followed by their profession. The second half of this section will contain information on some of the important questions that were asked along in the demography survey. These questions are in relevance to their exposure with the technology and tools that will be used in our tests. And some research specific questions that will provide some insights on the participants characteristics.

5.1.1 Age Distribution

The age group of all the participants of our survey is distributed between 23 and 35. (18 through to over 60) were represented. With a slightly larger numbers in the middle age bracket that is between 25 - 29. The age group of 29 accounts for 5, that is 20% of the total participants and the age group of 25, 26, 27 and 31 accounts for 3 each, that is 12% of the total participants. These age groups accounts for 70% of the total participants of the survey. The oldest age bracket was 35 which accounted for 1(4%) of the participants.

This data is collected at the start of the user testing, only once before the user beings the test in the Oculus Virtual Reality device. A graphical representation of the age distribution of our participants can be seen from Fig 5.1. The X-Axis contains the age details of each of the participants involved in the user testing and the Y axis represent the number of participants that fall under the same age group.

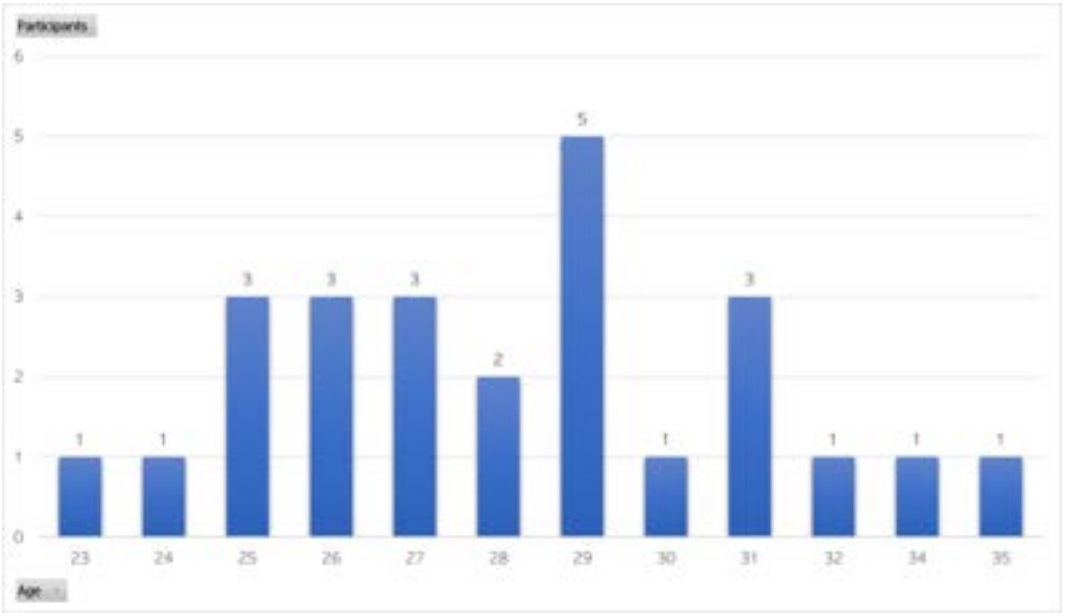


FIGURE 5.1: Age Distribution

5.1.2 Gender & Profession Distribution

Most participants that participated in the user testing are females, they hold the majority that accounts to a total of 14, which is 56% of the total participants. There were a total of 11 males that participated in our research study accounting to a total of 11, which is 44% of the total participants. A graphical representation of the gender distribution of our participants can be seen from Fig 5.2.

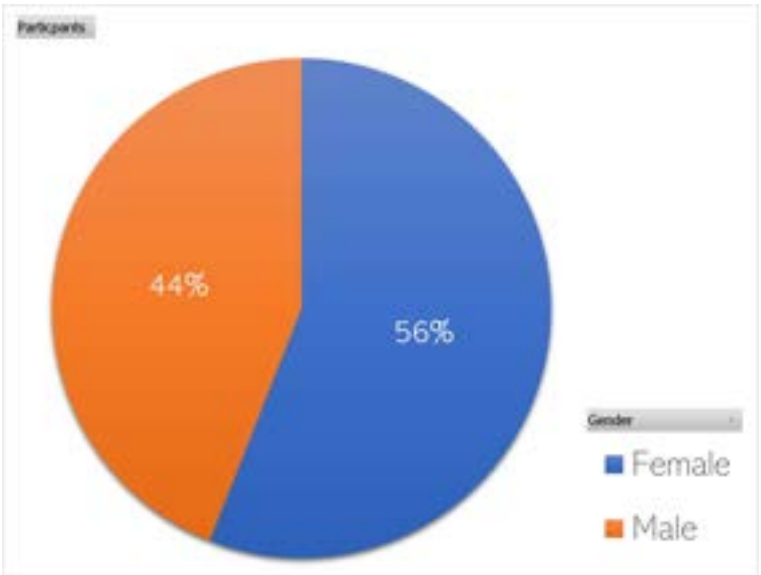


FIGURE 5.2: Gender Distribution

Majority of the participants that took part in our research study are students that are majoring in some technical subjects and software engineers. They account for a total of 68% of the total participants. Almost all of them are involved in some kind of technical responsibilities at their work or study environment. Hence, it was easier for to make them understand not only the objective of the research but also other

technical elements they should be aware of to complete the task. Most of them were also aware of the technical keywords that were used by me when going through the objective of the research study with them. A graphical representation of the profession distribution of our participants can be seen from Fig 5.3.

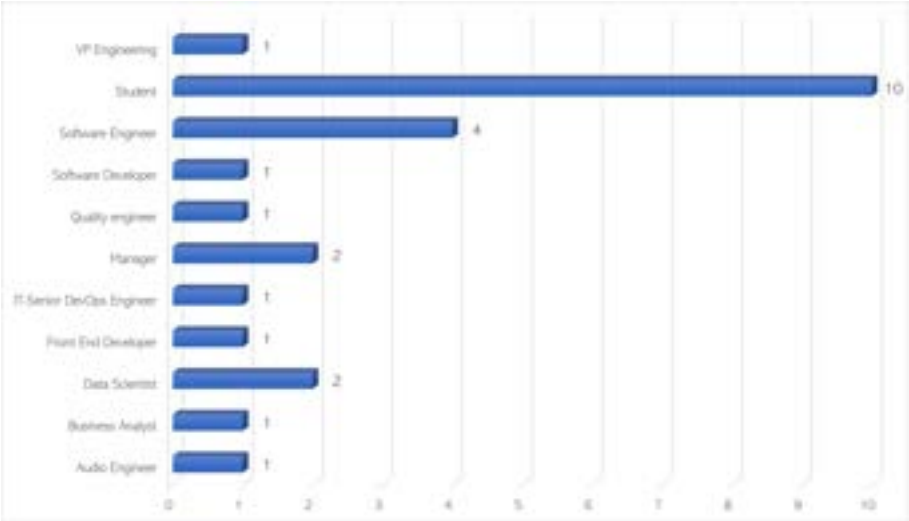


FIGURE 5.3: Profession Distribution

5.1.3 Technical Expertise & Research Specific Questions

Although, almost all the participants had good knowledge and expertise with technical subjects and contexts that were explained to them. Most of them never had any experience using a virtual reality device before but they have been longing to use them for a while, which I managed to understand from the discussion I had with them before the user test. The participants with no experience with any virtual reality device account for a total of 84% of the total participants. Only a meagre total of 16% of the total participants had experience using a virtual reality device before.

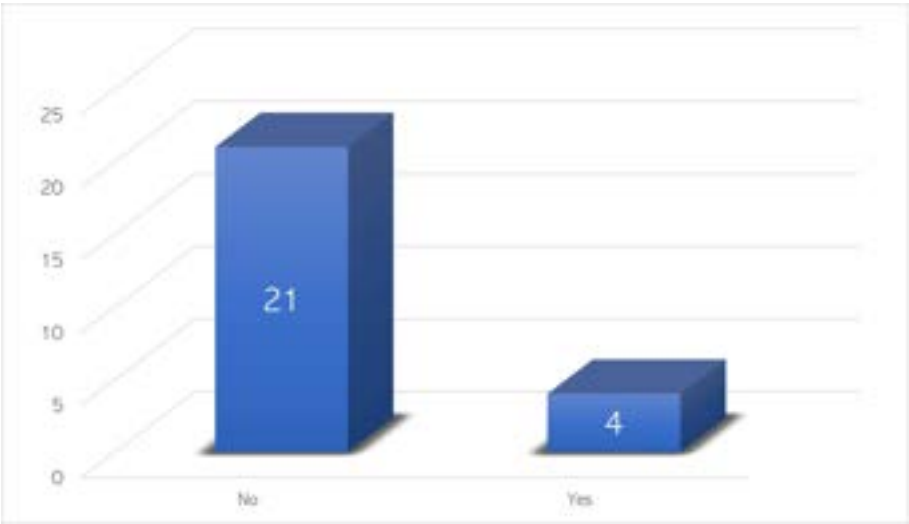


FIGURE 5.4: Experience with Virtual Reality

Of the 4 members that have previous working knowledge with virtual reality devices only 1 participant had experience using or working with Oculus Quest device

before.A graphical representation of this distribution of our test participants can be seen from Fig 5.4.

Few research specific questions were placed in the demographics questionnaire to understand how the user respond and react to such circumstances in their real life. The questions record how sensitive a participant is with respect to a noise and how sensitive is he with respect to noise. Based on this information that was collected from the questionnaire a Radar chart was created. A radar chart representation of the user sensitiveness towards environment noise seen from Fig 5.5.

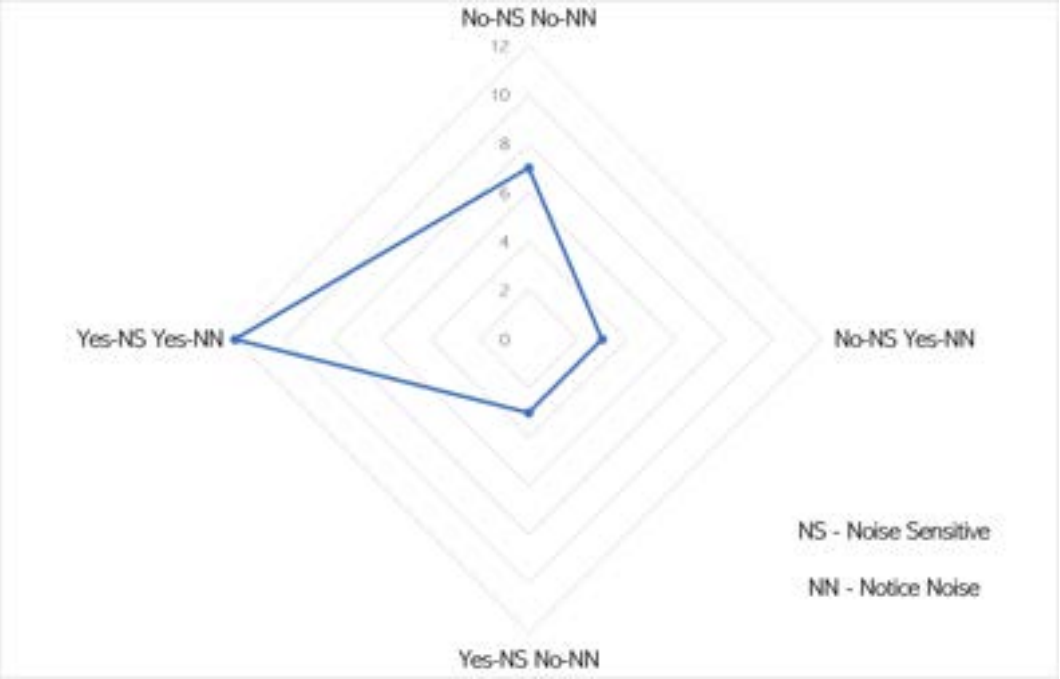


FIGURE 5.5: Sensitiveness Towards Environment Noise

It can be inferred from the chart that a major part of the participants notice and are also sensitive towards noise. A total of twelve members fall under this category who are very sensitive towards environmental noise in general and are also keen in noticing noises. Then there are a total of 3 members that are very noise sensitive in general but they don't notice noises that often at the work or other environments they are prone to visit. Then there are a total of 7 members that are noise sensitive and doesn't notice noises in general. Finally, a small share of people, 3 members who are not noise sensitive but notice noises in general.

5.2 Affinity towards technology

In this section I will go in details on the user responses for their affinity towards emerging technologies. The questions asked to a participant helps us understand if they would like to occupy themselves in greater detail with a technical system. Also, it helps us understand if they like to test functions of new technical systems and do they deal with such systems predominantly in their day to day life. The mean and standard deviation values for affinity to technology based on the responses that were provided by the user during the user testing phase can be seen from fig 5.6 and fig 5.7.

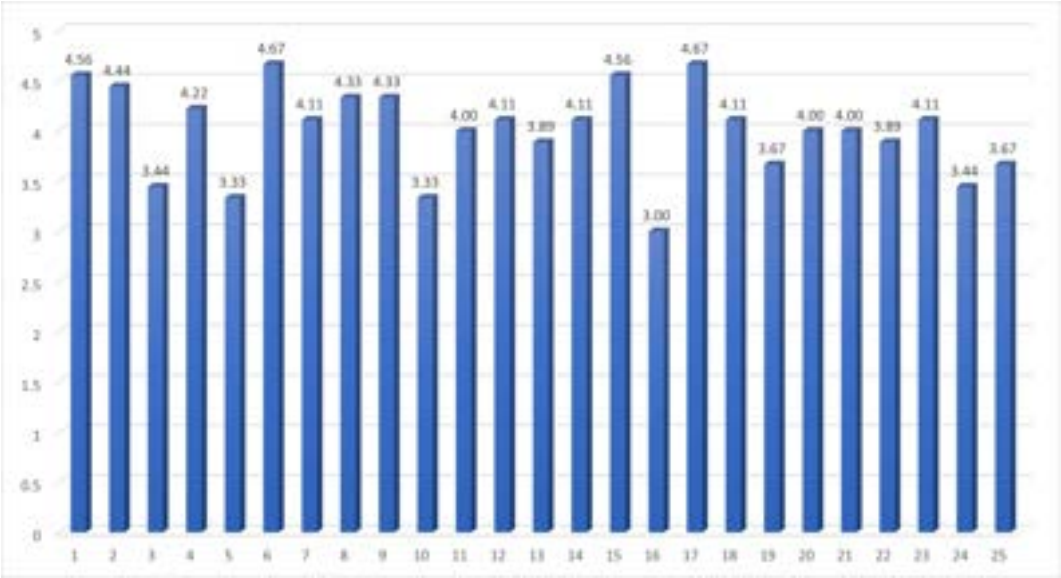


FIGURE 5.6: Mean ATI per user

With the calculation of standard deviation we can tell how the values provided for the questions by the user are spread out from the average value. A low value of standard deviation tells that most of the numbers are close to the average and a high value of standard deviation means that the values are more spread out. In our case although we do have some high values for standard deviation but most of the values are close to the mean score of ATI per user.

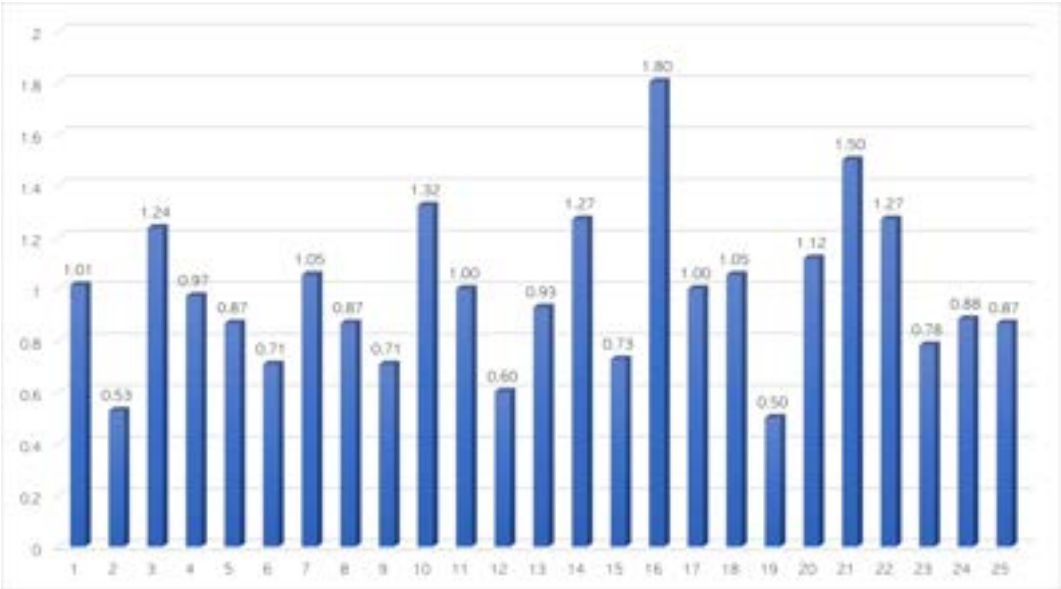


FIGURE 5.7: Standard Deviation in ATI score per user

After a quick analysis not a significant gender differences in ATI values were found from the samples, with men having a slightly higher ATI than the women participants:

Male : (N = 11, M = 4.02, SD = 0.95) Female: (N = 14, M = 3.98, SD = 1.004)

But it should also be taken into consideration that the total number of male participants and female participants weren't equal. There were 11 Male and 14 female participants that took part in the user testing phase.

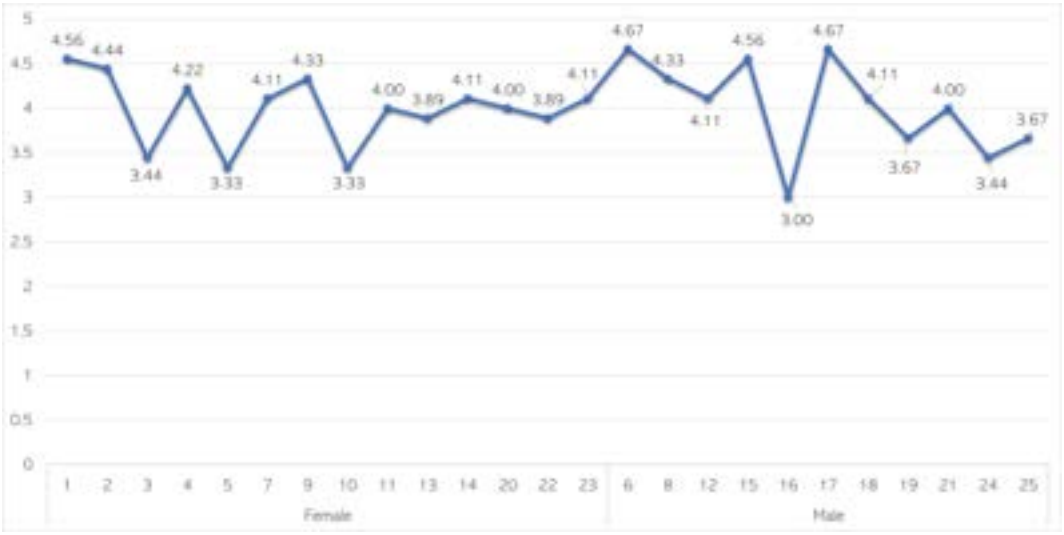


FIGURE 5.8: Mean ATI Distribution per Gender

The first responses we will analyze is about the user's that like to occupy themselves in greater details with the technical system. From Table 5.1 we can infer that most of the participants only agree to this to a slighter extent. With the other majority of people largely or completely agreeing to this statement.

Occupy with Technical Details	
Responses	Participants
Completely Agree	4
Largely Agree	9
Slightly Agree	10
Slightly Disagree	2

TABLE 5.1: User's that like to occupy with details of the system

Testing Functions of Technical System	
Responses	Participants
Completely Agree	7
Largely Agree	8
Largely Disagree	2
Slightly Agree	6
Slightly Disagree	2

TABLE 5.2: User's that like to test functions of new technical system

From table 5.2 we can infer a major share of the participants, 15 members, accounting to a total of 60% of the total participants are very much interested in testing out functions that are released in new technical systems. And the rest 40% of the participants doesn't share a similar opinion in this context.

Predominantly dealing with Technical System	
Responses	Participants
Completely Agree	5
Largely Agree	4
Largely Disagree	2
Slightly Agree	7
Slightly Disagree	5
Completely Disagree	2

TABLE 5.3: User's that predominantly deal with technical system on a daily basis

Table 5.3 gives us an idea about the proportion of people that predominantly deal with technical systems in their day to day life. The results are distributed across all possible responses with a major share of people slightly agreeing to it meaning they might have to deal with such systems some days but not always. Rest of the 18 participants are split equally between the group that agrees this to a fair share and doesn't agree much.

Intensively trying out new technical System	
Responses	Participants
Completely Agree	2
Largely Agree	7
Largely Disagree	2
Slightly Agree	7
Slightly Disagree	6
Completely Disagree	1

TABLE 5.4: User's that intensively try out new technical system

From table 5.4 we can infer that a major share of the participants, 13 members, accounting to a total of 52% of the total participants are somewhat biased in agreeing or disagreeing to this question. We can come to a conclusion that not many are

completely interested in trying out new technical systems when they are presented the opportunity. Although they don't disagree completely to it but they don't have a positive opinion about using them too.

Getting acquainted with new technical System	
Responses	Participants
Completely Agree	5
Largely Agree	9
Largely Disagree	1
Slightly Agree	8
Slightly Disagree	1
Completely Disagree	1

TABLE 5.5: User's that enjoy getting acquainted with new technical system

From Table 5.5 we can infer that a major share of the users enjoy spending time to become acquainted with a new technical system. 56% of the total participants fall under this category. Although, only two members disagree to it completely or largely but still the rest 8 members doesn't share a great positive opinion about getting acquainted with new system.

Not bothered about the how and why of technical System	
Responses	Participants
Completely Agree	1
Largely Agree	4
Largely Disagree	8
Slightly Agree	4
Slightly Disagree	8

TABLE 5.6: User's that want the system to work without knowing the details

A major share of the group disagree with the statement of this question. From table 5.6 we can infer that a fair share of participants are concerned about how a system works and why a system works in this fashion. This was quite clear to me when I was explaining the details of the research study at the start of the test as most of them were curious about how this system was setup and developed in general.

From Table 5.7 we can infer that the majority of the people try to understand how the system works. The trend between the results of this and the previous question is quite similar. Most of them are curious about knowing the how and why a system

works so that they can try to gain a better understanding on how it works. Although a significant number of participants have chosen to agree this argument on a slighter level but a wide opinion that we could interpret from the table is that most of them are completely in accordance with this statement.

Understand how the System works	
Responses	Participants
Completely Agree	1
Largely Agree	7
Largely Disagree	1
Slightly Agree	13
Slightly Disagree	3

TABLE 5.7: User's that try to understand how the system work in detail

From Table 5.8 we can infer that the trend in answers to this question follows the same pattern just like the last two questions. A major group of participants either disagree completely or largely and slight agree that it is not enough for them to know just the basic functionalities of system but also an in depth information is required. Giving us with enough evidence to conclude that most of the participants are quite concerned about knowing how the technical system presented before them works in detail. There were also a lot of questions posed to me at the introduction session about the technical system involved in our research to support the context of this result.

Concerns only on the basic functions	
Responses	Participants
Completely Agree	1
Largely Agree	6
Largely Disagree	5
Slightly Agree	8
Slightly Disagree	5

TABLE 5.8: User's concern is knowing just the basic functions of the system

And just like the last few questions the answers for this questions seem to follow the same trend. A major group of the participants completely agree with making full use of the capabilities of a technical system. By looking into the table we can understand that although a considerable amount of participants from the group of participants that agree to this statement in general, a fair share of people agree to

this argument only at a slight level. But the general idea we grasp from this table is most of them are in someways curious about the various technical capabilities a system can offer. And they are very much interested in making a full fledged use of those functionalities. The details of the responses can be seen from Table 5.9.

Make full use of the technical capabilities of the system	
Responses	Participants
Completely Agree	3
Largely Agree	9
Largely Disagree	2
Slightly Agree	9
Slightly Disagree	2

TABLE 5.9: User's concern is knowing just the basic functions of the system

5.3 System Usability Scale

System usability Scale is used to analyse overall usability of the software. The key for System Usability Scale is given in the Table 5.10. Complete results for score per each question our presented in detail in the Appendix C, Section C.1.3 and Section C.2.3. SUS score will be able to tell one about our usability performance in the aspects of effectiveness, efficiency, and overall ease of use. The average SUS score is 68. This simply means that a score of 68 will just put you at 50th percentile.

Interpreting System Usability Scale (SUS) Score		
SUS Score	Grade	Adjective Rating
> 80.3	A	Excellent
68 – 80.3	B	Good
68	C	Okay
51 – 68	D	Poor
< 51	F	Awful

TABLE 5.10: General guideline on the interpretation of SUS score

The final usability score that was calculated against all the data that was received from the user testing phase is 76.2, which falls under the grade B that is classified as good rating in the guidelines for SUS scores. The scores that have been identified for this research were charted into a graph that can see from Fig 5.9. From this individual breakup of the sus scores we can understand that most of the scores are

concentrated between a value of 70 - 90. The largest possible value we have received for the application is 97.5 that is very close to being perfect. But unfortunately some user found the system in general and other elements that comprise this system to be really complicated and was difficult to use by giving us a score of 35. To summarize, although a very few group of participants found the system to be challenging, we still do have a considerable amount of participants that thoroughly enjoyed the system and found it usable.

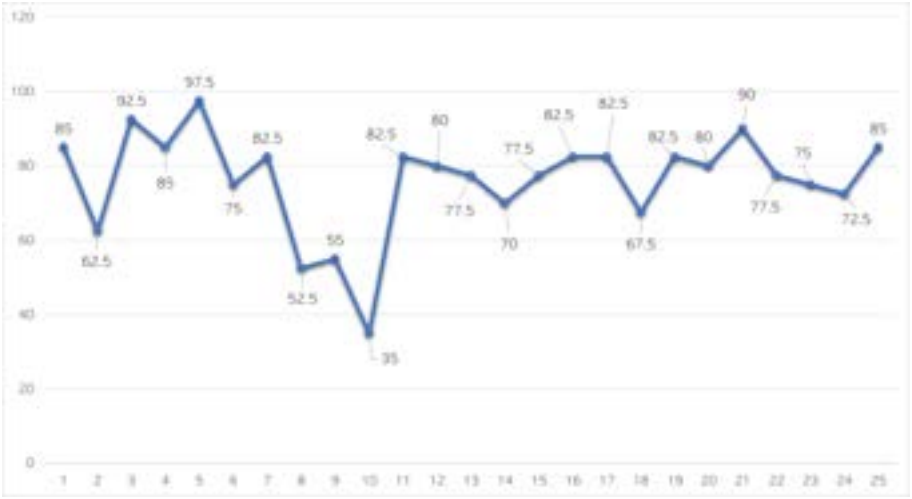


FIGURE 5.9: System Usability Score Individual Breakup

The individual breakup of data that we say in Fig 5.9 was segregated and assigned a property rating based on the guideline of SUS score, table 5.10 and the resultant chart can be seen in Fig 5.10. From fig 5.10 we can infer that a major share of participants have rated the system as excellent (12 members), followed by a rating of Good by 8 members. And finally 4 members have specified a rating of poor and 1 member has given a rating of awful for the system. Their opinion might have been influenced by various challenges they faced when using the virtual reality application. Also, they could have found the final system difficult and complicated to use in general.

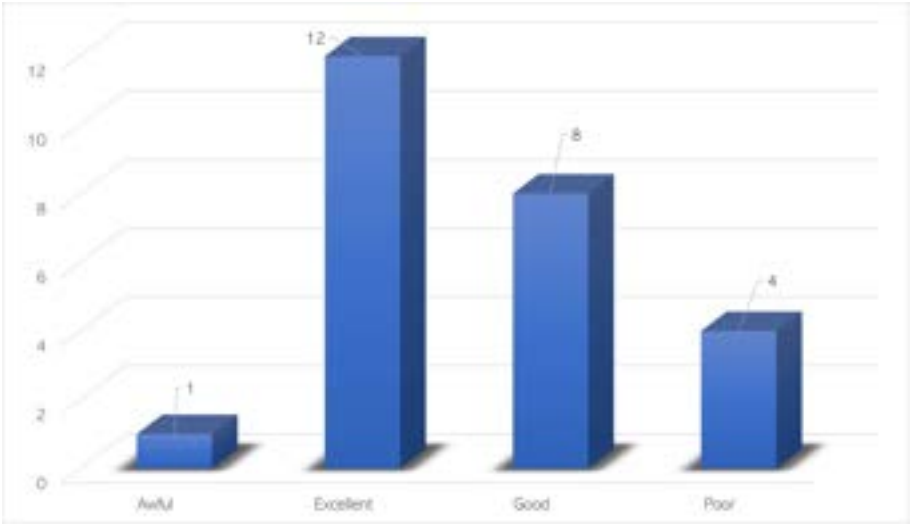


FIGURE 5.10: System Usability Score

Looking at the segregated SUS score of the user test, it is clear that a majority of the participants(80%) rate the product as Excellent (12 - 48%) and Good (8 - 32%). And Only 5% see it as poor and 4% see it as an awful experience. Taking a closer look at the Awful group, we can infer that this participant falls under the median age group (29) with no prior experience in virtual reality who works as a customer success manager. According to these findings, it could be a hypothesis that the lack of experience of the participant in using such systems could have made them given such poor rating.

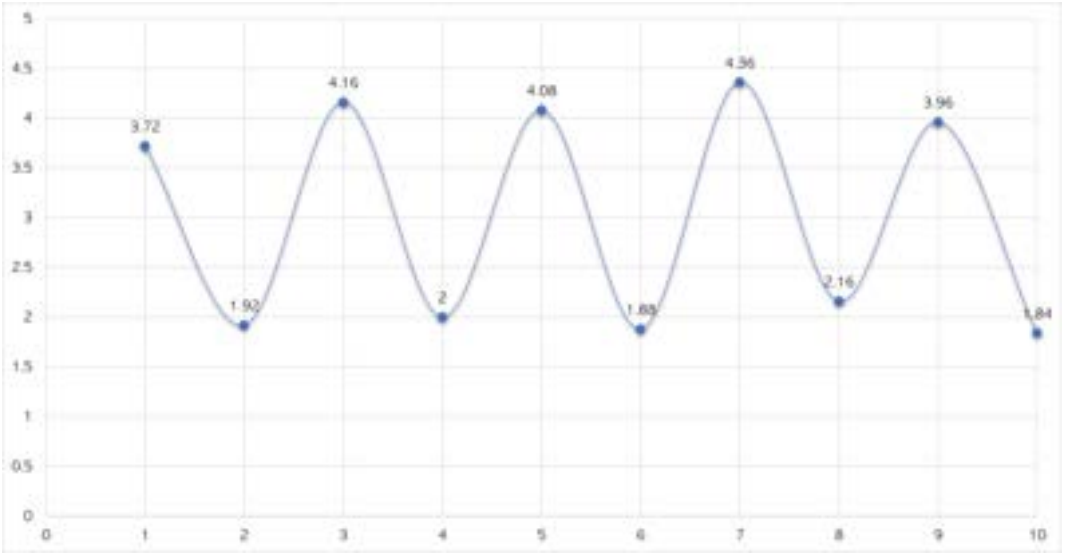


FIGURE 5.11: Mean Value Per SUS Question

From Fig 5.11 we can get a broad idea on what is the central value that have been received for each of the questions. The detailed evaluation of the individual questions showed us the following results for the 25 test participants: Most of the participants would love to use the system more frequently (M = 3.72, SD = 0.97). The participant group did not find the system to be unnecessarily complex (M = 1.92, SD = 0.70). Most of the participants found that the system was very easy to use (M = 4.16, SD = 0.89). There was no agreement on the question of requiring technical assistance in using the system (M = 2, SD = 1.15). A much higher standard deviation found in this answer might be due to the fact that two members completely agreed with needing an assistance to use the system while the rest doesn't need much assistance. The participants agreed that the individual components in the system were very well integrated (M = 4.08, SD = 0.86). Most of them though there were no inconsistency in using the system (M = 1.88, SD = 0.88). A higher mean value of (M = 4.36, SD = 0.81) was received for the argument that the participants think most people would be able to use and familiarize this system very quickly. Not many find the application and system in general to be very cumbersome to use (M = 2.16, SD = 1.17). The rise in standard deviation is again due to the fact that some people found the system to be cumbersome. Most people felt self-confident in using the system (M = 3.96, SD = 1.01), but optimisation through more assistance in the game is conceivable. Such as constant display of the controls during the game and not only at the beginning by the instructor would be conceivable. Nearly nobody felt the need to learn more things to use the system. (M = 1.84, SD = 0.94). The participant that has provided an awful rating seemed to have completely agreed

with needing detailed assistance to use the system and also found the system to be cumbersome.

FIGURE 5.12: System Usability Score based on Gender

From Fig 5.12 we get a clear understanding and breakup of the sus scores based on Gender. An awful rating for the system was provided by one person who is a female and it constitutes to 4% of the total rating. Of the total 12 members(48% of participants) that have rated the system to be excellent, 8 are female and 4 are male. Then, of the total 8 members(32% of participants) that have rated the system to be good, 3 are female and 5 are male. And finally, of the total 4 members(48% of participants) that have rated the system to be poor, 2 are female and 2 are male.

5.4 Nasa Task Load Index

In this section I'll dive deeper into the results recorded from the NASA Task Load Index survey. A 5 point likert scale was used to record the user responses with one being the least and 5 being high. The X-axis consist the participant numbers and the Y - axis is the sum of all the responses in the questionnaire for a test condition. As explained already 6 elements are tracked and analysed from this questionnaire. All responses input by the user is represented on a bar chart with each responses being stacked upon one another.

From Fig 5.13 we can see the aggregated result of the responses for the no interaction continuous noise. It's quite clear from the graph that a major share of people doesn't find the condition to be physically and temporally demanding. Although, a good share of people consider the task to be not mentally demanding we still do have some people that seem to find this interaction to be mentally demanding. The hypothesis, based on the information we have, could be due to the fact that the continuous noise is more mentally demanding for these users. And this could also be inferred from looking into their responses to a question asking about their sensitivity to environmental noise in general from the demographics questionnaire. Almost, all of the respondents that stated the task to be mentally demanding have a higher sensitivity to environmental noise. Also, most of them are successful in the task they were given and they hardly needed to put in a lot of effort to complete the task. Finally, about 44% of the total participants (11 members) were frustrated when working in this condition but the rest 56% (14 members) weren't.

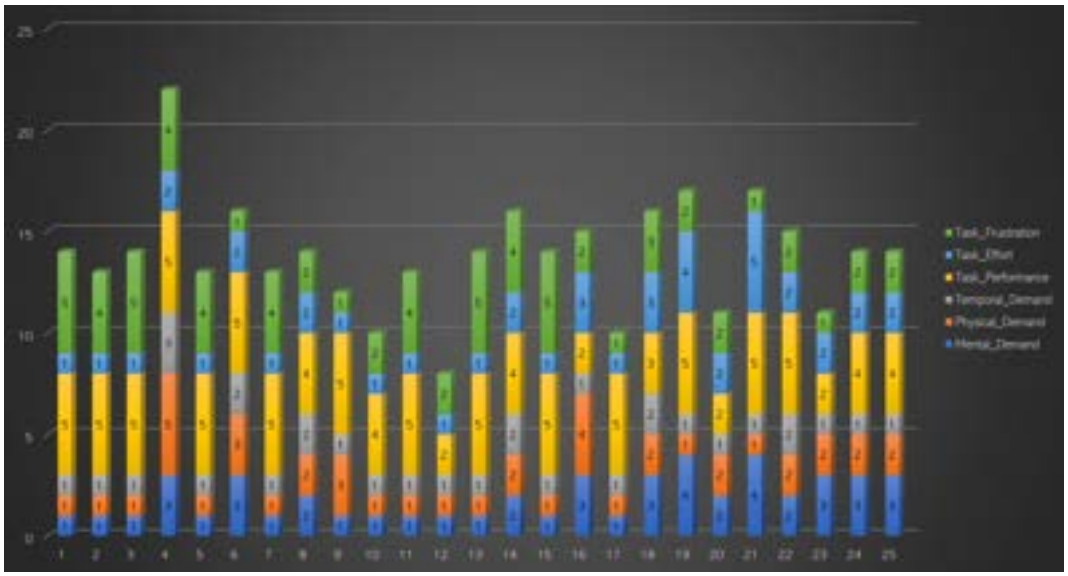


FIGURE 5.13: Aggregated Result : No Interaction Continuous Noise

From Fig 5.14 we can infer that most of them found this condition to be average or lesser on the task load level. With an exception of one participant that is very sensitive to environmental noise in general found this task with no interaction to be really daunting (M = 3.66, GM = 3.48).

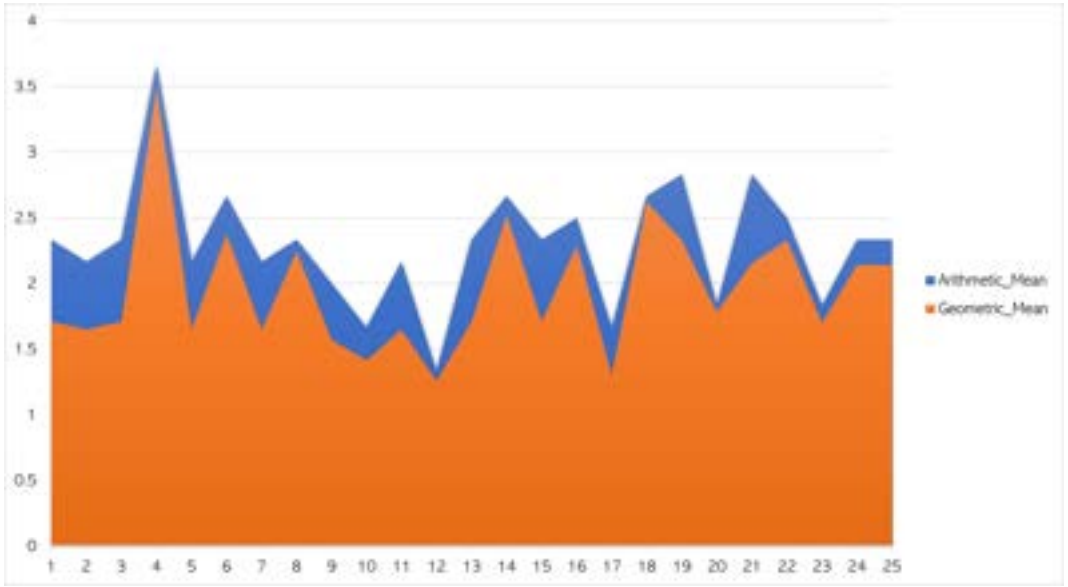


FIGURE 5.14: Arithmetic & Geometric Mean : No Interaction Continuous Noise

From Fig 5.15 we can see the aggregated result of the responses for the no interaction impulsive noise. About 80% of the total participants think this condition to be not mentally demanding but the rest 20% think they are mentally demanding. Almost all the participants find this condition to be very less in physical and temporal demand. Most of them were successful with their task and they hardly had to put in a lot of effort. But about 36% of the total participants were frustrated after completing this task and another 36% gave a neutral response to this argument and the rest 28% weren't frustrated after completing this task.

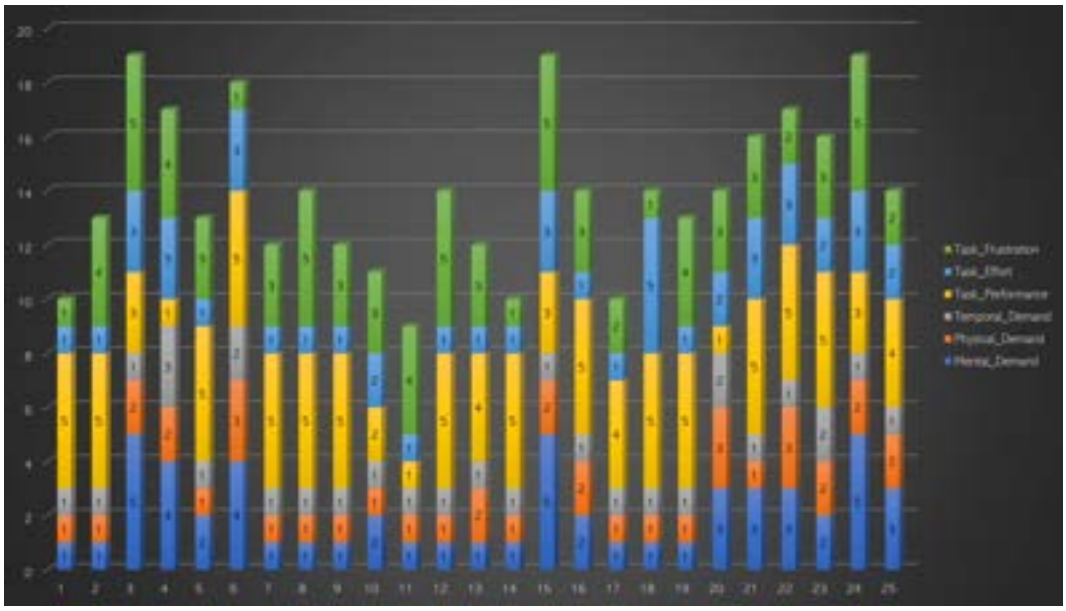


FIGURE 5.15: Aggregated Result : No Interaction Impulsive Noise

From Fig 5.16 we can infer that most of them found this condition to be average or lesser on the task load level but with an exception of few participants.

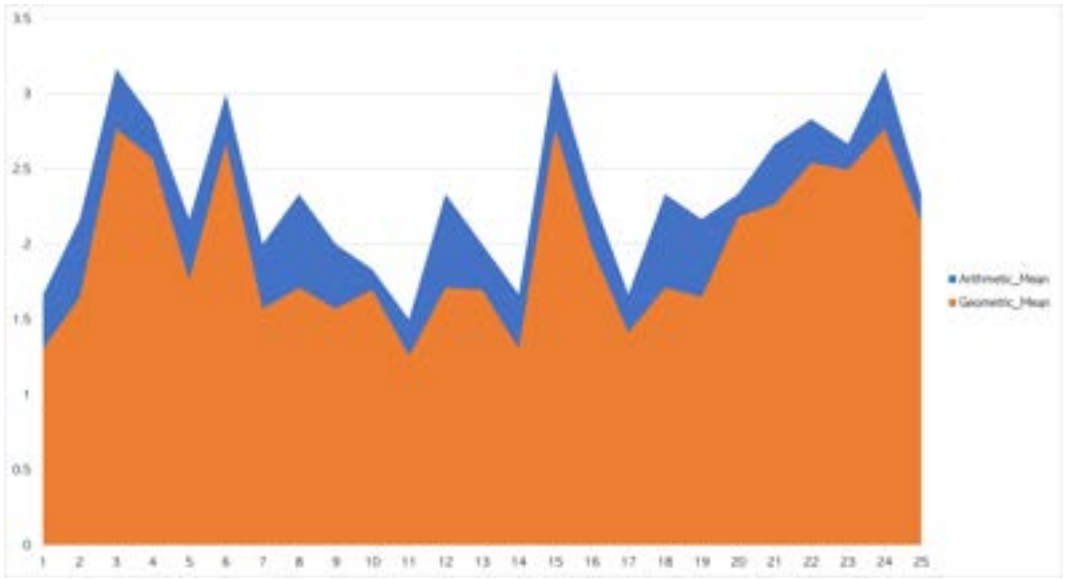


FIGURE 5.16: Arithmetic & Geometric Mean : No Interaction Impulsive Noise

From Fig 5.17 we can see the aggregated result of the responses for the no interaction intermittent noise. In this condition only 24%(6 members) of the total participants were frustrated when executing this condition, this is a much lesser value than what we had in the last two conditions, where the level of frustration was higher. And people that are sensitive to noise in general have mostly voted high in terms of mental demand for this condition again. The rest of the values are much similar in shape to what we had for the last two no interaction conditions.

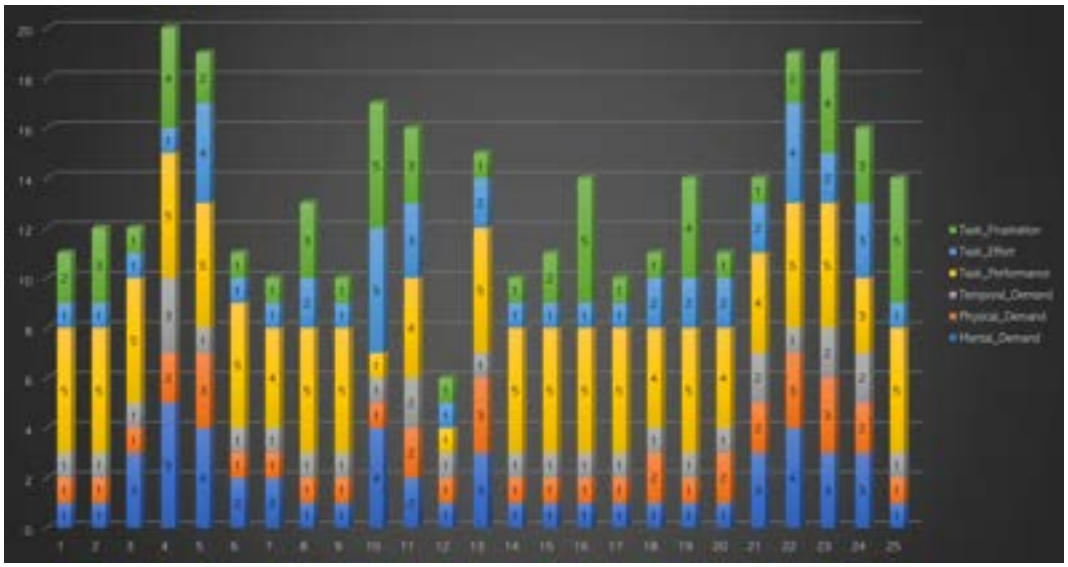


FIGURE 5.17: Aggregated Result : No Interaction Intermittent Noise

From Fig 5.18 we can infer that almost all of them found this condition to be average or lesser on the task load level with a maximum average around (M = 3.33).

FIGURE 5.18: Arithmetic & Geometric Mean : No Interaction Intermittent Noise

From Fig 5.17 we can see the aggregated result of the responses for the no interaction low frequency noise. The most important thing to notice in this case is, almost all participants (96% - 24 members) with an exception of 1 member (4%)found this case to be less frustrating. Although two members were neutral about this argument but we still get a clear impression that most of them had lesser levels of frustration. And that is much lesser than all the other cases in the no interaction scenario. The other responses for this case are much similar to what we had for the other 3 scenarios, discussed earlier.

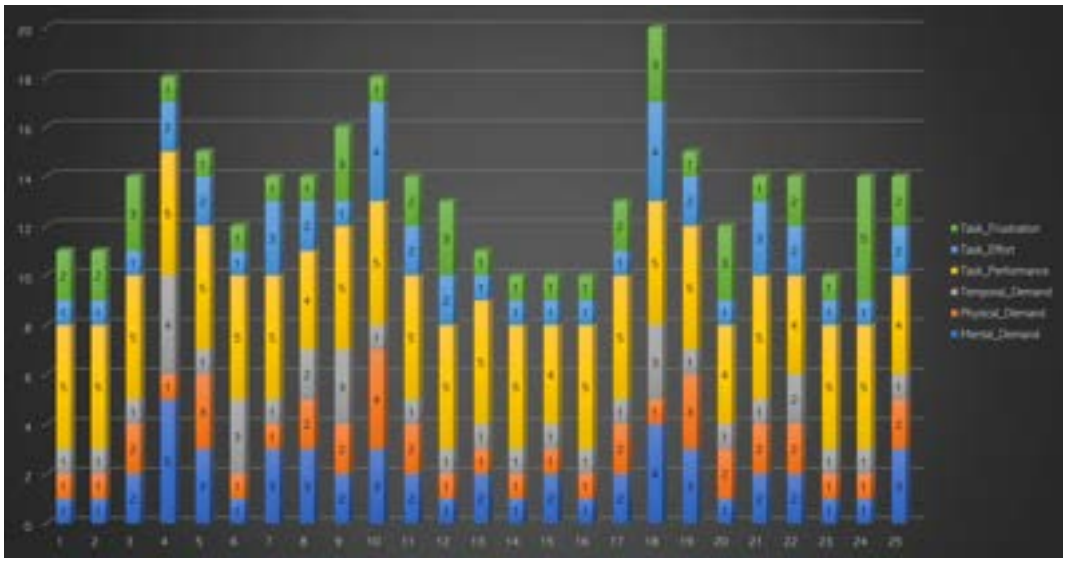


FIGURE 5.19: Aggregated Result : No Interaction Low Frequency Noise

From Fig 5.20 we can infer that almost all of them found this condition to be average or lesser on the task load level with a maximum average around (M = 3.33).

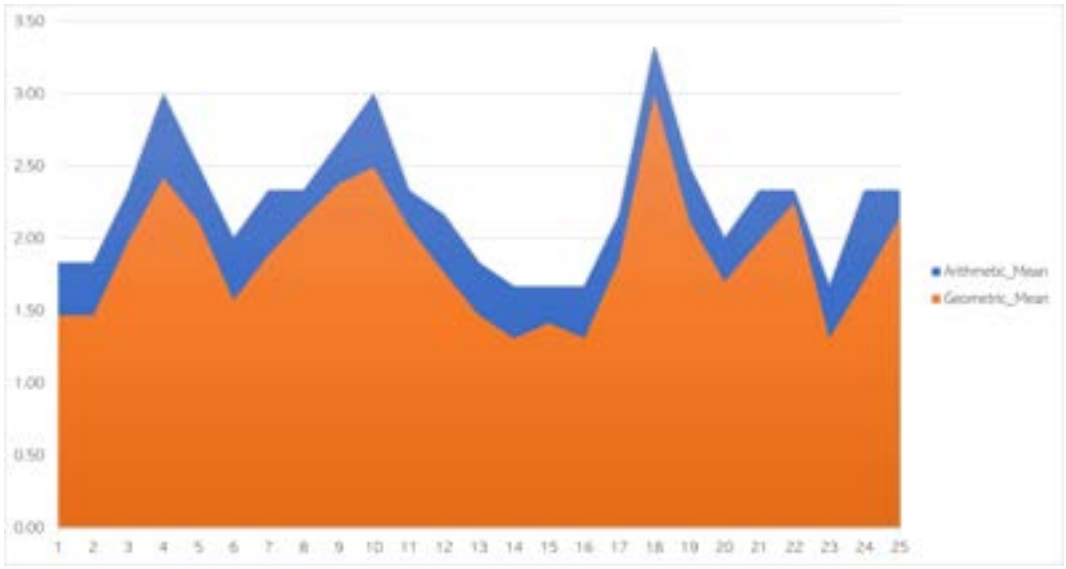


FIGURE 5.20: Arithmetic & Geometric Mean : No Interaction Low Frequency Noise

At the end of all the no interaction cases we can infer that most of the participants found the no interaction to be lesser on the task load level. Although there have been fluctuations in the level of task load we can still conclude that the major share of participants found the task to be less daunting. The most important thing that we have to notice is the level of frustration which seems to be much higher in continuous and impulsive noise but starting from the intermittent noise the frustration level seems to be dropping down which further drops down in the low frequency case. The average (arithmetic mean) task load index value for no interaction continuous noise (M = 2.31), impulsive noise is (M = 2.33), intermittent noise is (M = 2.23) and

low frequency noise is (M = 2.58). The average task load index for No Interactions cases stand at a value of (M = 2.28).

From Fig 5.21 we can see the aggregated result of the responses for the medium interaction continuous noise. The users were asked to complete a cognitive task in the medium interaction case and by looking into the mental demand section most of them found the task to be mentally challenging. A total of 14 members (56%) had a value between 3-5 for this question, signifying the need of mental demand in completing the task. Majority of the users were successful in the task with a few exception. And the level of frustration (with high frustration levels) stands very low with only 12% found the condition to be highly frustrating.

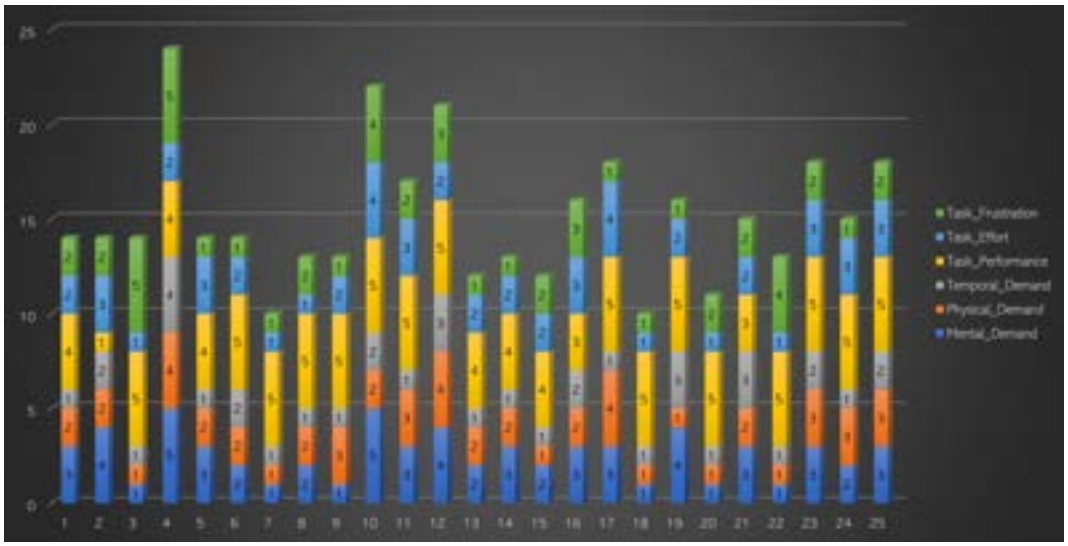


FIGURE 5.21: Aggregated Result : Medium Interaction Continuous Noise

FIGURE 5.22: Arithmetic & Geometric Mean : Medium Interaction Continuous Noise

From Fig 5.22 we can infer that almost all of them found this condition to be average or a bit higher on the task load level with a maximum average around (M = 4).

From Fig 5.23 we can see the aggregated result of the responses for the medium interaction impulsive noise. About 40%(10 members) of the total participants found the task to be mentally demanding which stands at a similar range to the previous case. The level of frustration in this case dips down further with just one member(4%) finding the case to be frustrating. The other areas have a similar response just like the previous cases.

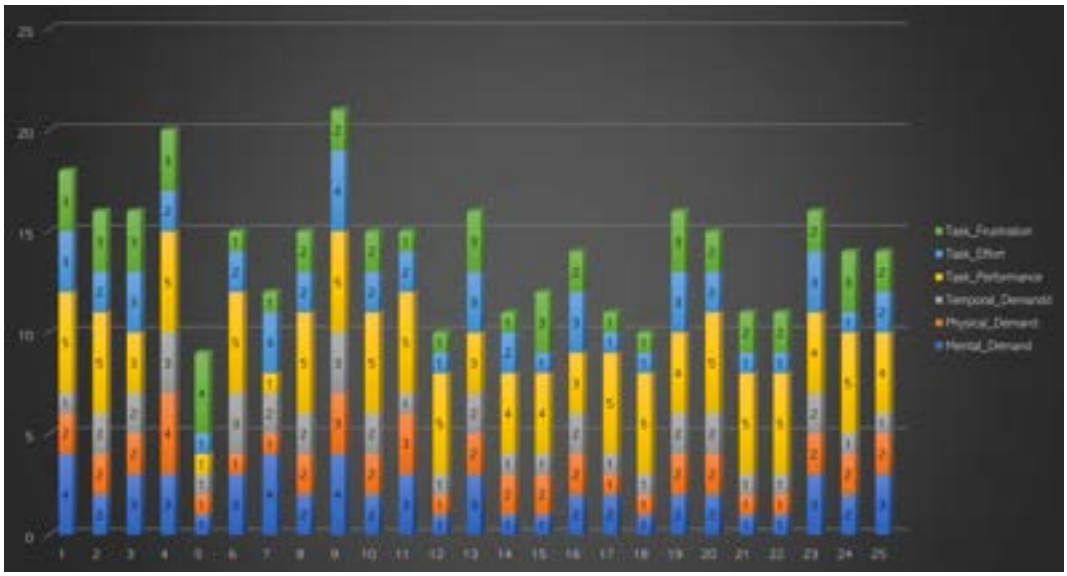


FIGURE 5.23: Aggregated Result : Medium Interaction Impulsive Noise

From Fig 5.24 we can infer that almost all of them found this condition to be average or a bit lesser on the task load level with a maximum average around (M = 3.5).

FIGURE 5.24: Arithmetic & Geometric Mean : Medium Interaction Impulsive Noise

From Fig 5.25 we can see the aggregated result of the responses for the medium interaction intermittent noise. Except for the mental demand section there doesn't seem to be much difference in the responses when compared with the earlier conditions. About 52%(13 members) of the total participants found the task to be mentally demanding which stands at a similar range to the previous cases. Although there are some changes in the values of other section they don't seem to have much significance.

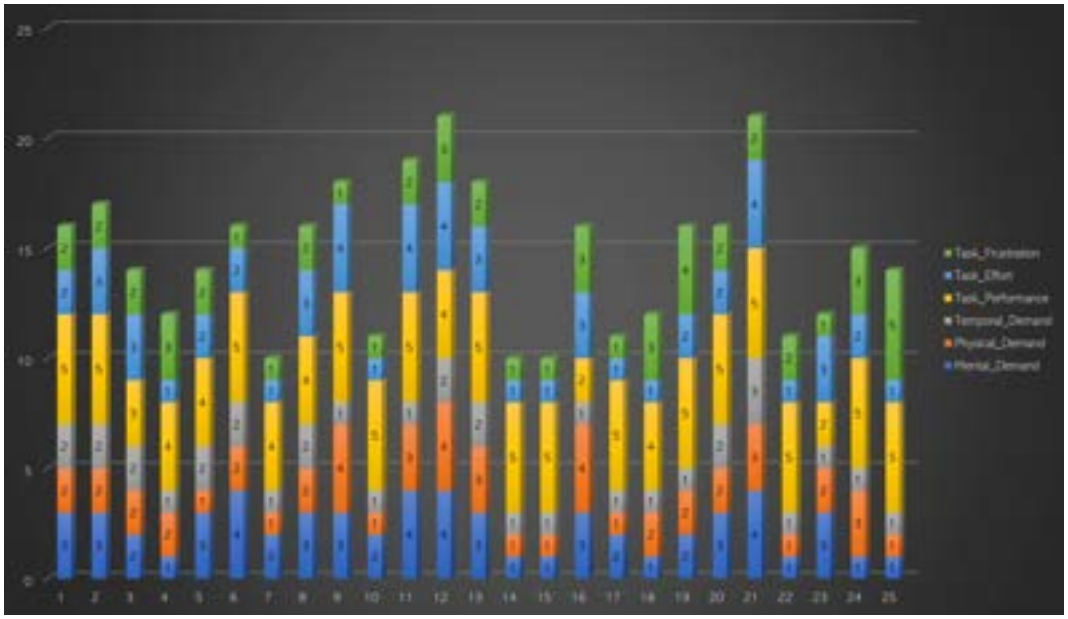


FIGURE 5.25: Aggregated Result : Medium Interaction Intermittent Noise

From Fig 5.26 we can infer that almost all of them found this condition to be average or a bit higher on the task load level with a maximum average around (M = 3.5).

FIGURE 5.26: Arithmetic & Geometric Mean : Medium Interaction Intermittent Noise

From Fig 5.27 we can see the aggregated result of the responses for the medium interaction low frequency noise. About 36%(9 members) of the total participants found the task to be mentally demanding which also stands at a similar range to the previous cases. Interestingly the level of frustration seems to have gone higher in this case, with 12 members (48%) rating with a score of 3-5 for this question.

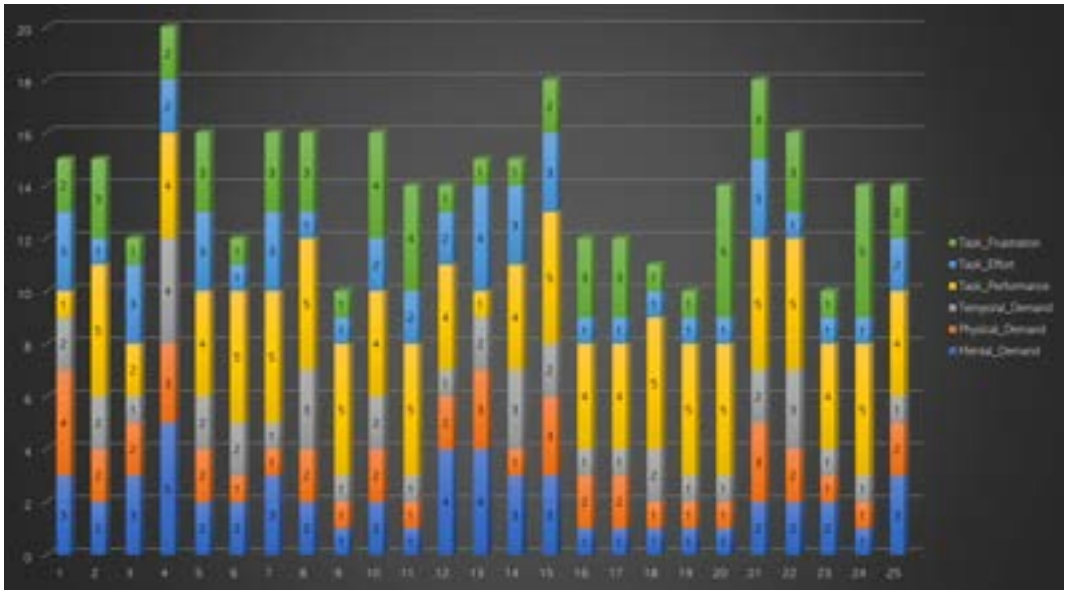


FIGURE 5.27: Aggregated Result : Medium Interaction Low Frequency Noise

FIGURE 5.28: Arithmetic & Geometric Mean : Medium Interaction Low Frequency Noise

From Fig 5.28 we can infer that almost all of them found this condition to be average or a bit lesser on the task load level with a maximum average around (M = 3.33).

The average (arithmetic mean) task load index value for medium interaction continuous noise (M = 2.51), impulsive noise is (M = 2.35), intermittent noise is (M =

2.44) and low frequency noise is (M = 2.37). The average task load index for medium Interactions cases stand at a value of (M = 2.41). The task load value has increased a value of .13 from the no interaction average task load. The part that had much significance and impact in the medium interaction case was the mental demand with the other areas seemingly lesser in significance. Although we have a significant rise in the mental demand it is a bit difficult to conclude on what noise type had higher significance. Since, the conditions are randomized the users might encounter a case at a different position than others so we can conclude the significance by just looking at the mean value. But we can conclude that the medium interaction had a significant rise in the mental demand which could have been due to the cognitive task + noises.

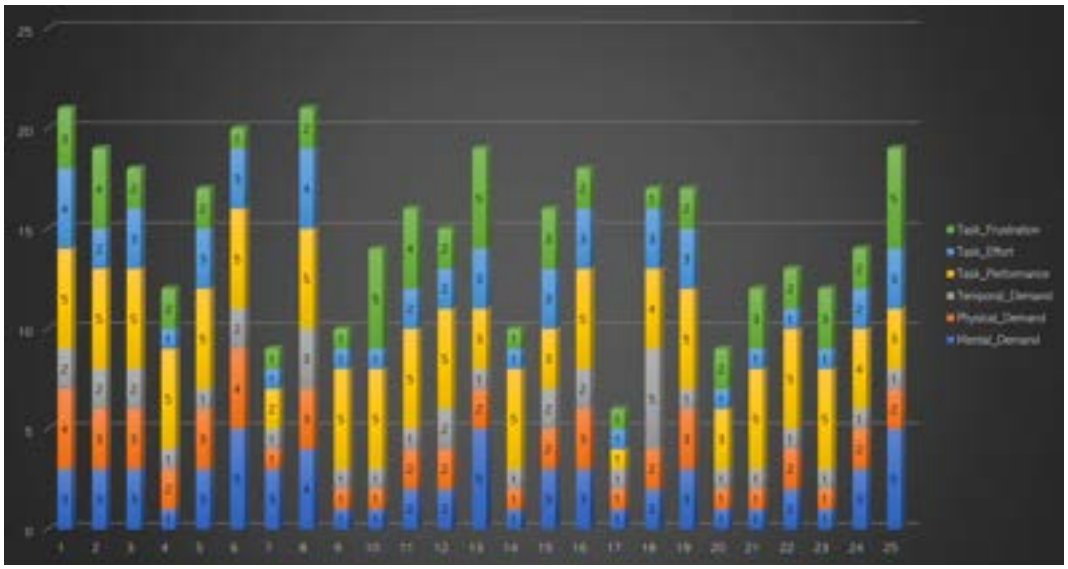


FIGURE 5.29: Aggregated Result : High Interaction Continuous Noise

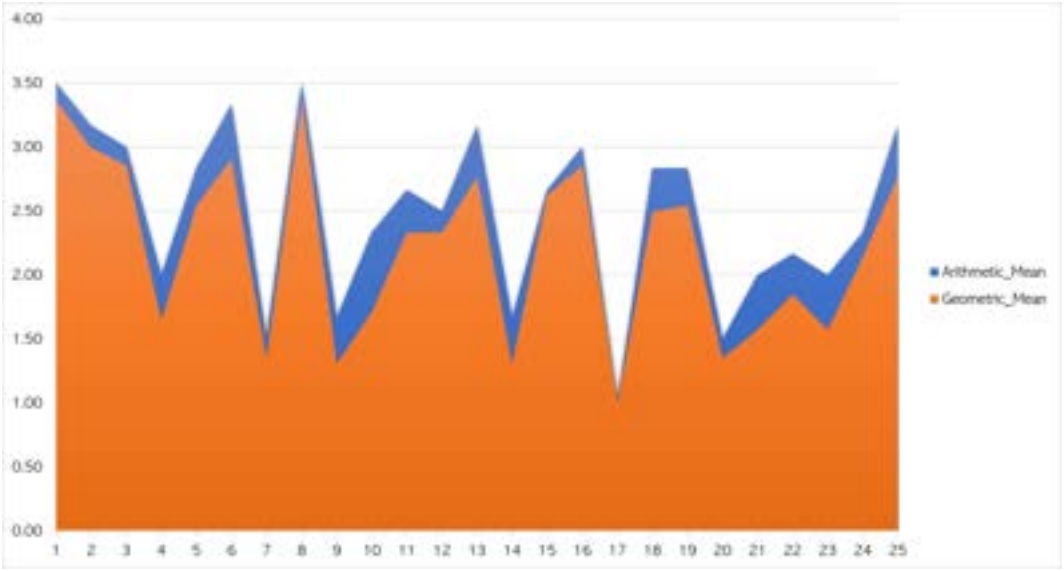


FIGURE 5.30: Arithmetic & Geometric Mean : High Interaction Continuous Noise

From Fig 5.29 we can see the aggregated result of the responses for the high interaction continuous noise. We can infer that the mental demand , physical demand and effort required to complete the task seemed to have some significance in this condition. About 52%(13 members) find the task to be mentally demanding, 32%(8 members) find the task to be physically demanding and 44%(11 members) find the task to be requiring some additional effort.

From Fig 5.30 we can infer that almost all of them found this condition to be average or a bit higher on the task load level with a maximum average around (M = 3.50).

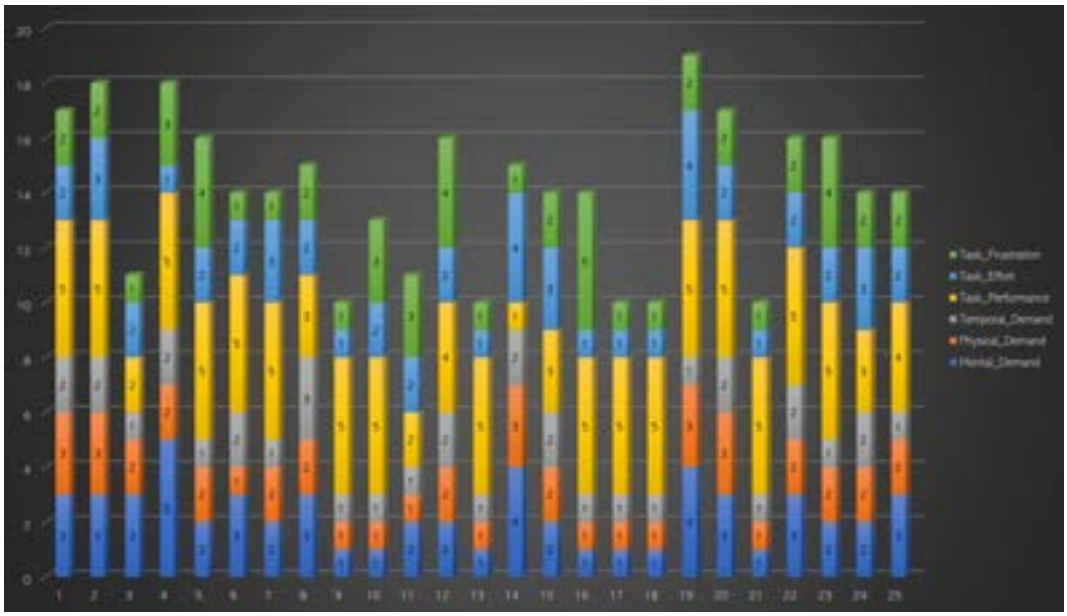


FIGURE 5.31: Aggregated Result : High Interaction Impulsive Noise

FIGURE 5.32: Arithmetic & Geometric Mean : High Interaction Impulsive Noise

From Fig 5.31 we can see the aggregated result of the responses for the high interaction impulsive noise. Almost all the other sections other than mental demand doesn't have a significant change in their values. About 44%(11 members) found the task to be mentally demanding by providing a rating value of 3-5.

From Fig 5.32 we can infer that almost all of them found this condition to be average or a bit lesser on the task load level with a maximum average around (M = 3.17).

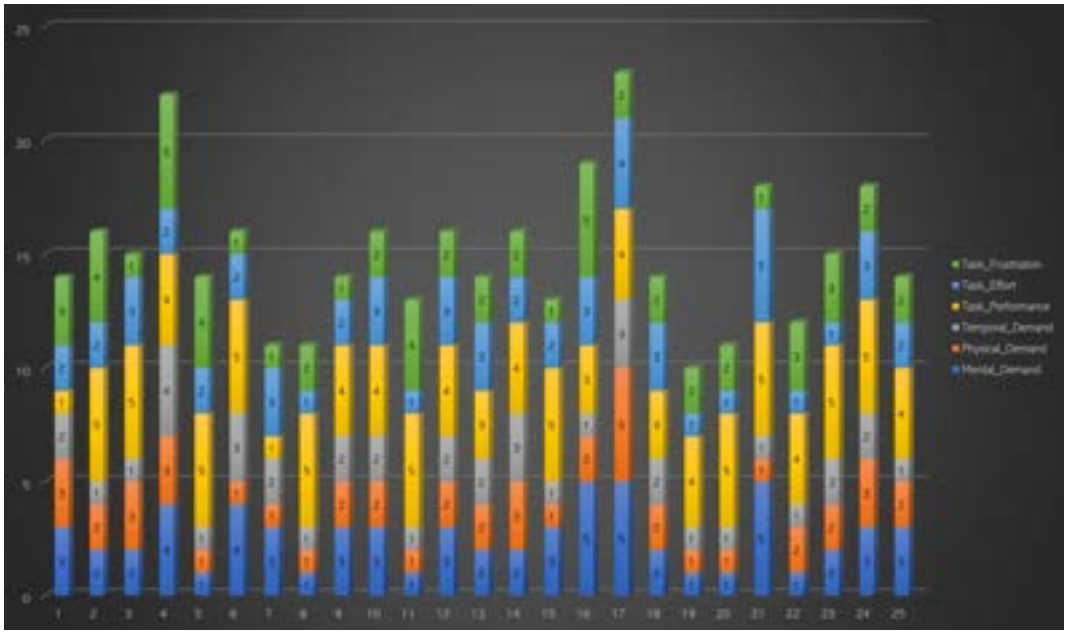


FIGURE 5.33: Aggregated Result : High Interaction Intermittent Noise

FIGURE 5.34: Arithmetic & Geometric Mean : High Interaction Intermittent Noise

From Fig 5.33 we can see the aggregated result of the responses for the high interaction intermittent noise. We can infer that the mental demand and effort required to

complete the task seemed to have some significance in this condition. About 52%(13 members) find the task to be mentally demanding and 40%(10 members) find the task to be requiring some additional effort.

From Fig 5.34 we can infer that almost all of them found this condition to be average or a bit higher on the task load level with a maximum average around (M = 3.83).

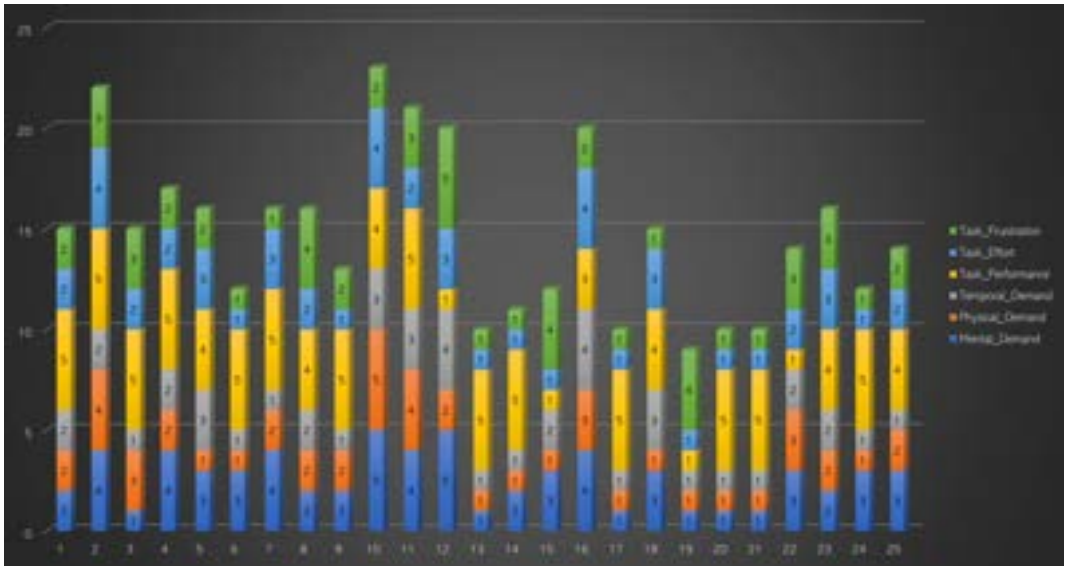


FIGURE 5.35: Aggregated Result : High Interaction Low Frequency Noise

FIGURE 5.36: Arithmetic & Geometric Mean : High Interaction Low Frequency Noise

From Fig 5.35 we can see the aggregated result of the responses for the high interaction low frequency noise. We can infer that the mental demand and effort required to complete the task seemed to have some significance in this condition. About 56%(14 members) find the task to be mentally demanding and 32%(8 members) find the task to be requiring some additional effort.

From Fig 5.36 we can infer that almost all of them found this condition to be average or a bit lesser on the task load level with a maximum average around (M = 3.66).

The average (arithmetic mean) task load index value for high interaction continuous noise (M = 2.49), impulsive noise is (M = 2.35), intermittent noise is (M = 2.5) and low frequency noise is (M = 2.46). The average task load index for No Interactions cases stand at a value of (M = 2.45). The final average is a bit higher than no interaction case but it seems to stay at a similar range in comparison with the medium interaction. The values of mental demand , physical demand and task effort seemed to have had some significance in this case which could be seen from the charts. The average value in the NASA task load questionnaire hasn't crossed a mean value of (M = 2.5) thereby indicating that the task load has been pretty average.

In the following section the results from my analysis using SPSS tool is presented. Firstly, the results of sphericity will be covered.

Mauchly's Test of Sphericity	
Measure	Significance
Physical Demand	.962
Temporal Demand	.181
Performance	.307
Frustration	.202

TABLE 5.11: Sphericity assumed Elements for NASA Task load Index with respect to Interactions

Mauchly's Test of Sphericity	
Measure	Significance
Mental Demand	.988
Physical Demand	.458
Temporal Demand	.137
Performance	.559
Effort	.573
Frustration	.375

TABLE 5.12: Sphericity assumed Elements for NASA Task load Index with respect to Environmental Noise

Mauchly's Test of Sphericity tests the null hypothesis, that the variances of the differences are equal. Thus, if Mauchly's Test of Sphericity is statistically significant ($p < .05$), we can reject the null hypothesis and accept the alternative hypothesis that the variances of the differences are not equal (i.e., sphericity has been violated).

Results from Mauchly's Test of Sphericity are shown in Table 5.11, 5.12 and 5.13 for the NASA task load.

Mauchly's Test of Sphericity	
Measure	Significance
Mental Demand	.718
Physical Demand	.396
Performance	.809
Effort	.171
Frustration	.423

TABLE 5.13: Sphericity assumed Elements for NASA Task load Index with respect to Environmental Noise and Interactions

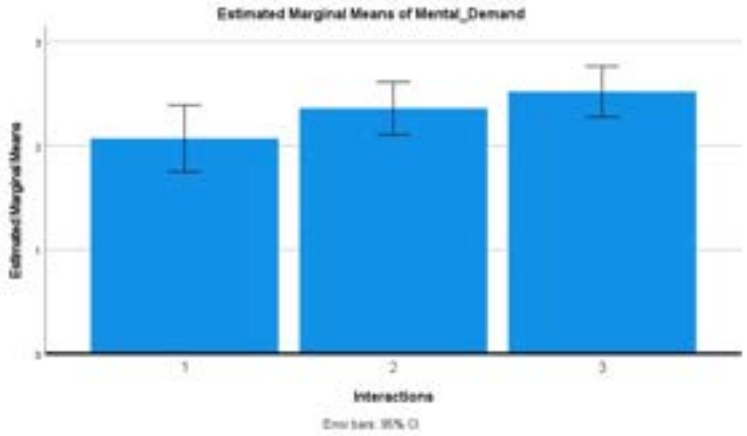


FIGURE 5.37: Marginal Means of Mental Demand per Interaction

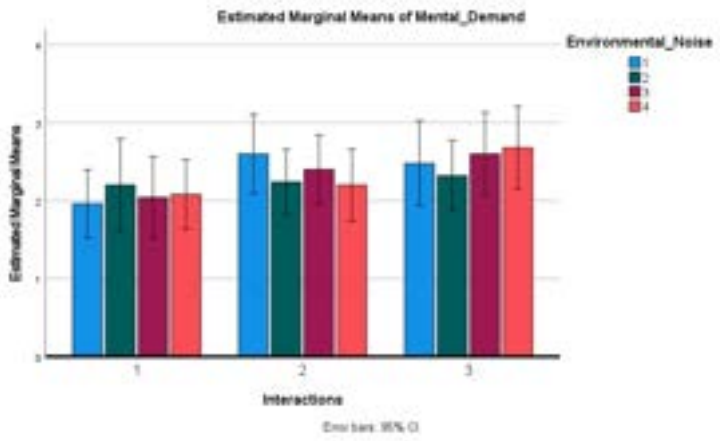


FIGURE 5.38: Marginal Means of Mental Demand per Interaction & Environmental Noises

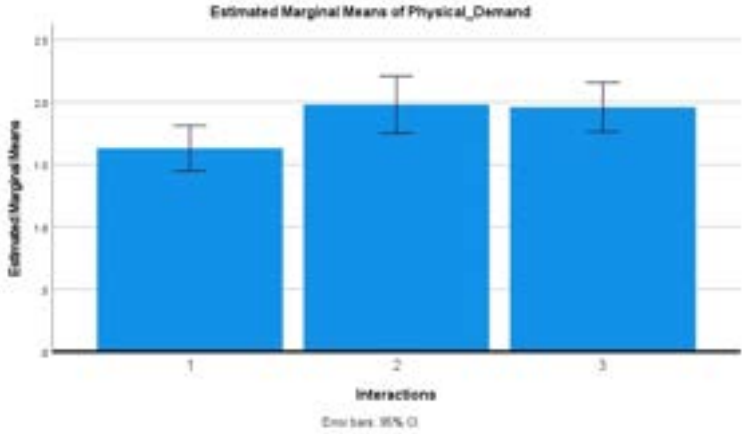


FIGURE 5.39: Marginal Means of Physical Demand per Interaction

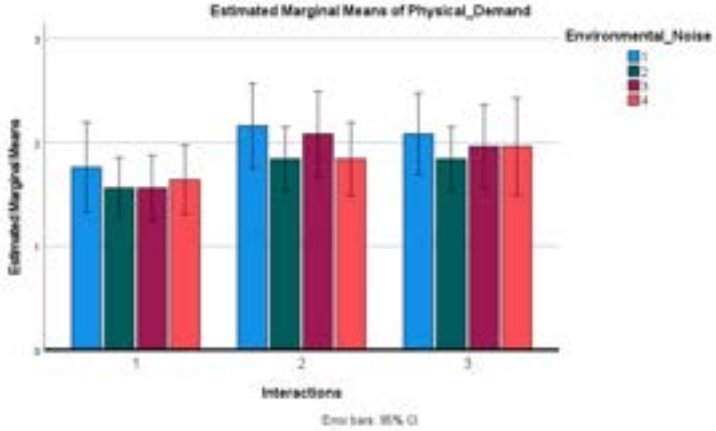


FIGURE 5.40: Marginal Means of Physical Demand per Interaction & Environmental Noises

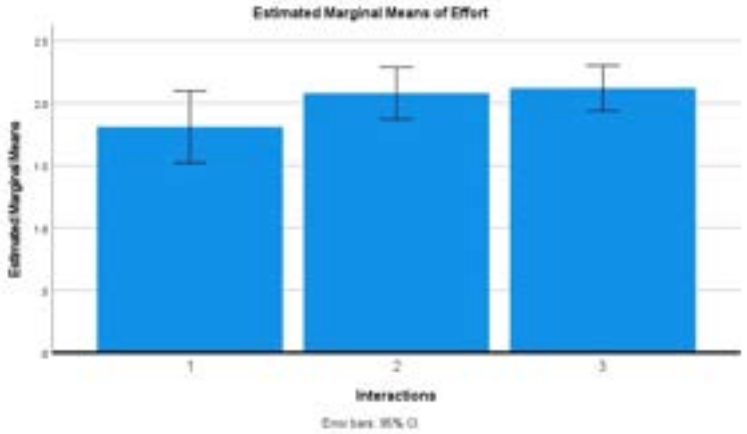


FIGURE 5.41: Marginal Means of Effort per Interaction

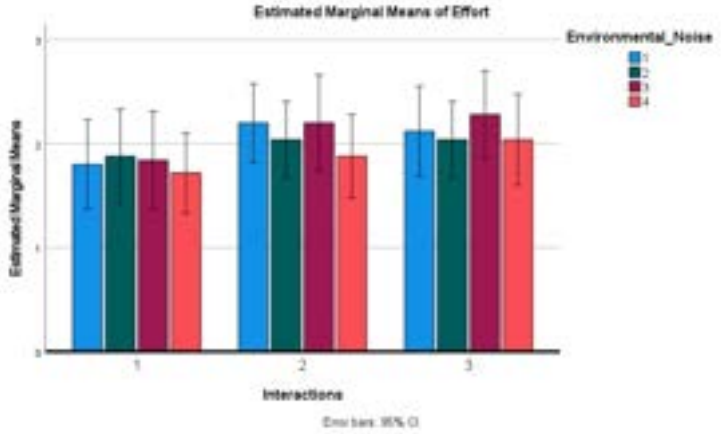


FIGURE 5.42: Marginal Means of Effort per Interaction & Environmental Noises

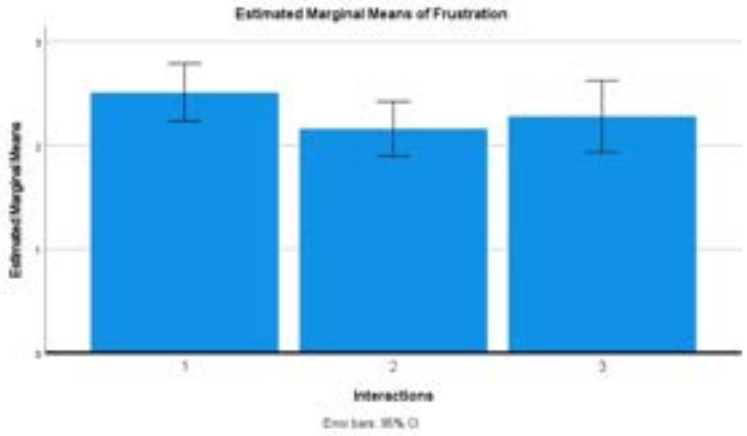


FIGURE 5.43: Marginal Means of Frustration per Interaction

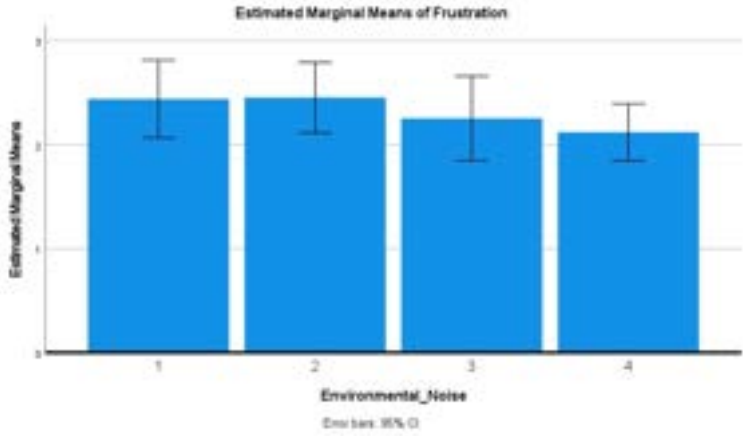


FIGURE 5.44: Marginal Means of Frustration per Environmental Noises

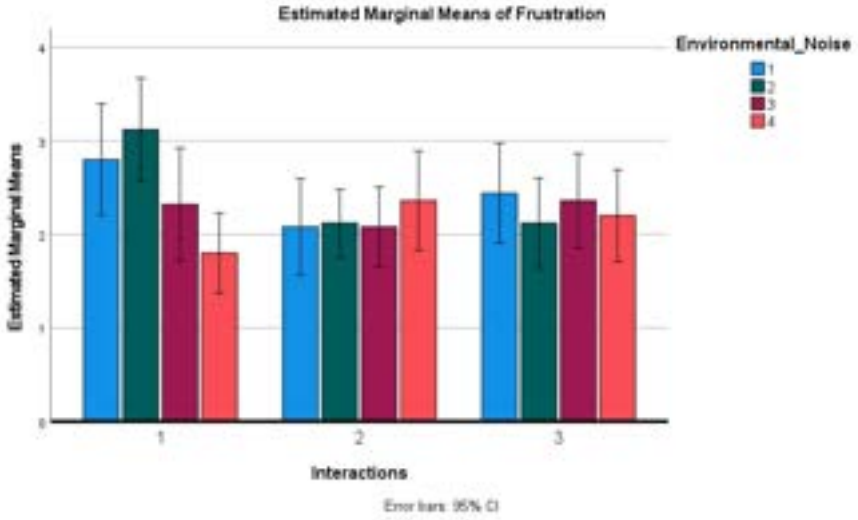


FIGURE 5.45: Marginal Means of Frustration per Interaction & Environmental Noises

From Fig 5.37 we can infer that the mental demand seemed to have raised as the interaction intensity grew higher. The conditions with no interaction (1) has a lesser mental demand in comparison with conditions with medium(2) and higher(3) interaction. This might be due to the fact that there is no task to be performed in no interaction and in medium interaction there is a need for mental demand as the participants were asked to perform a cognitive task. And finally, in high interaction the user will be part of story-line where you progress to next steps by completing a task which involves a good/some level of mental demand. The same hypothesis applies for physical demand, can be seen from Fig 5.39 and 5.40. There is a need for physical demand in the medium and high interaction since the users are offered with the opportunity to interact with objects in the scene that needs them to perform some level of physical activity in the real world. The level of effort, Fig 5.41, keeps getting higher as the level of interaction increases. In no interaction the users have to invest on zero percentage on effort but for the other interaction levels they are supposed to bring in some effort to complete the tasks.

From Fig 5.43 we can infer that the level of frustration is higher in the no interaction case, where the users have zero opportunity to interact with the virtual space and are supposed to stare at the scenes. This could have contributed to higher levels of frustration in no interaction. Interestingly, high interaction is next up in the level of frustration, this might have been induced by the environmental noises that were placed in the level. This could have caused the user to give an higher level of frustration value. Also, we can infer from Fig 5.44 that the continuous noise (1) and impulsive noise(2) scenes have induced a higher level of frustration for the participant. With the intermittent noise(3) and low frequency noise(4) inducing a lesser level of frustration.

5.5 Igroup Presence Questionnaire

In this section I'll dive deeper into the results that were acquired from the Igroup presence questionnaire and understand how the virtual reality application fared in terms of presence and immersiveness in virtual reality. Two charts, one about the average for Each IPQ items and the other for the average of sub-scales are plotted

to provide a detailed examination of the results. In chart1, the data examines the general presence, termed as G1 in the chart, the next 5 data measure the spatial presence (SP : 1-5), then the next four data is about one's Involvement (Inv : 1-4) and the last four data examines the experienced Realism (REAL : 1 - 4). The second graph provides us the average of these scores with respect to their individual sub-scales. A 5 point likert scale is used to record the results of the participants.

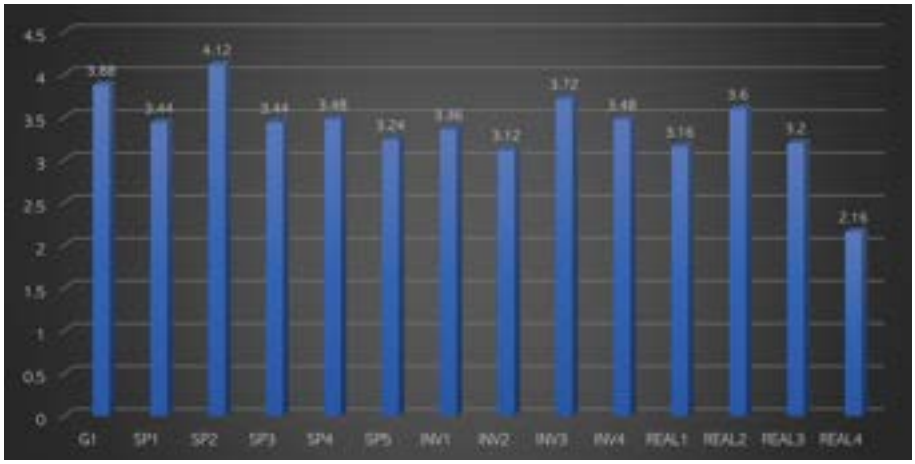


FIGURE 5.46: Average for Each IPQ Items: No Interaction Continuous Noise

From Fig 5.46 and 5.47 we can infer that the general presence experienced by the user is around (M = 3.88) suggesting us that the visual and other supporting elements induced a good amount of presence. The average spatial presence experienced by the users stand at a value of (M = 3.54). With the highest average value of (M = 4.12) from a question asking about user's agreement on if they felt like perceiving pictures(scale value : 1- fully agree and 5 - fully disagree). An average value of (M = 3.24) for SP5 (asking about the sense of being or felt present in the virtual space) indicates that some group of participants had a lesser sense of being present in the virtual space.

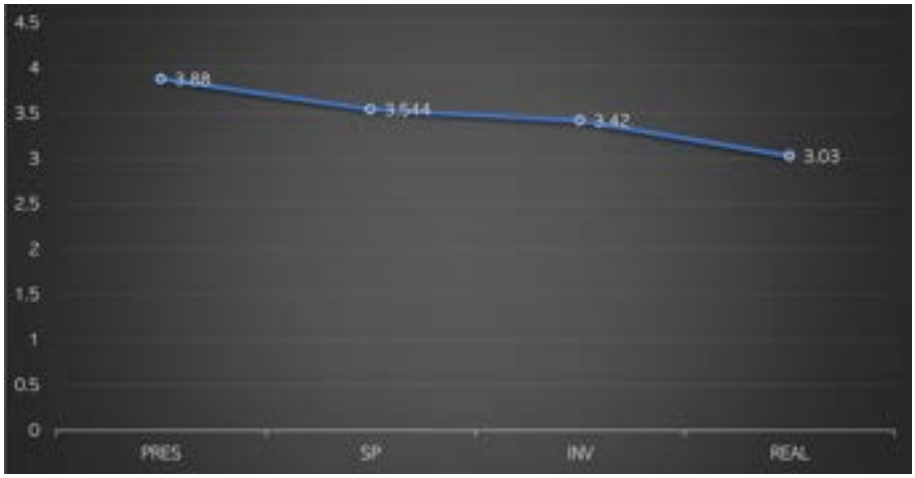


FIGURE 5.47: Average of the Subscales : No Interaction Continuous Noise

Although an average value of 3.42 was received for involvement (how involved they felt in the virtual space) but from the breakdown of the involvement values

we can understand that some group of people were still aware of the real world environment (INV2 : (M = 3.12)). And as far as realism is concerned an average of (M = 3.03) was received and many disagreed with the argument "The virtual world seemed more realistic than the real world", has an average of (M = 2.16) (REAL4).

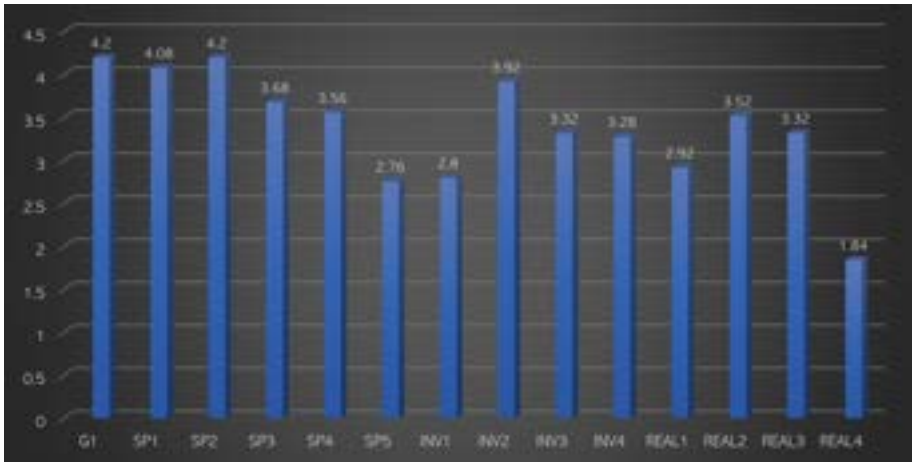


FIGURE 5.48: Average for Each IPQ Items: No Interaction Impulsive Noise

Most of the items and the final scores stand at a similar state just like the ratings of condition 1 (No Interaction Continuous Noise). Although the spatial presence has a good average score but the ratings for feeling presence in the virtual space has received a less significant score of (M = 2.76). The value received for awareness of the real world environment is (INV1 : (M = 2.8)) indicating that many users were well aware of the surroundings. And in terms of realism a strong disagreement (REAL4 : (M = 1.84)) was received for the question "The virtual world seemed more realistic than the real world". The values for involvement and realism is quite similar like other cases. And almost all the conditions in the no interaction case has received a lesser score, indicating a strong sense of disagreement from the participants on a specific question in the questionnaire which is "The virtual world seemed more realistic than the real world". The value for REAL4 is lesser than (M = 2.5) in the no interaction case.

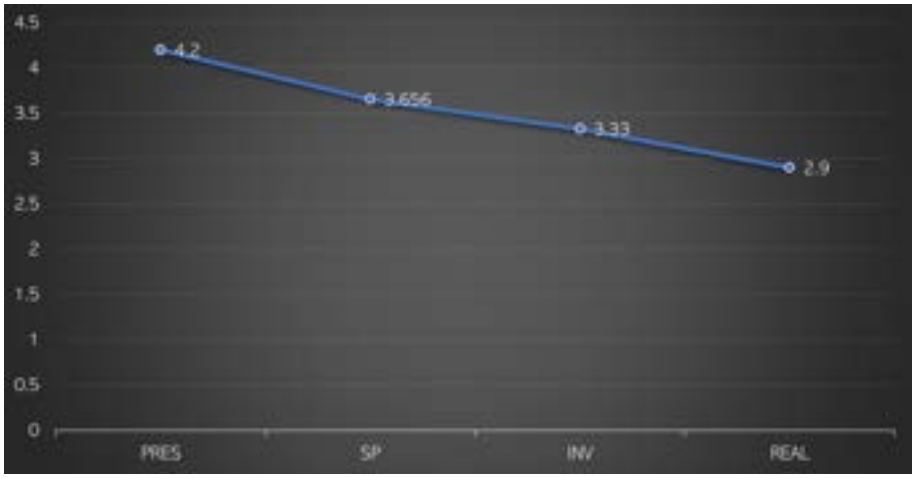


FIGURE 5.49: Average of the Subscales : No Interaction Impulsive Noise

The trend has been quite similar for the next two conditions Fig 5.5 and Fig 5.52, in the no interaction case. The value for general presence stays almost similar for all the no interaction case. The average value received for spatial presence is much higher in comparison with the last two conditions (No Interaction Continuous Noise and No Interaction Impulsive Noise). Thereby indicating us that the user's felt a greater level of presence in the Intermittent and Low Frequency Noise condition.

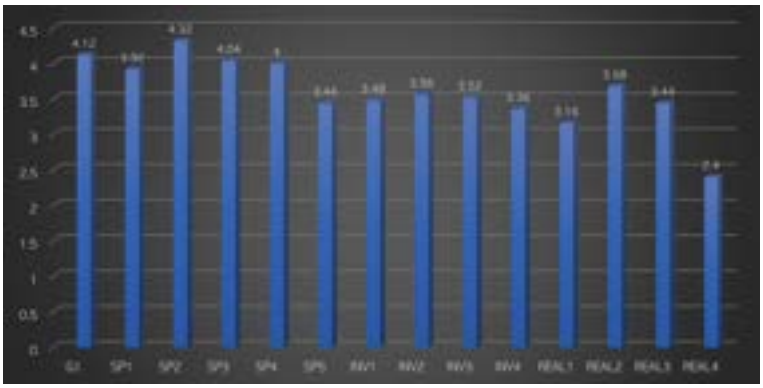


FIGURE 5.50: Average for Each IPQ Items: No Interaction Intermittent Noise

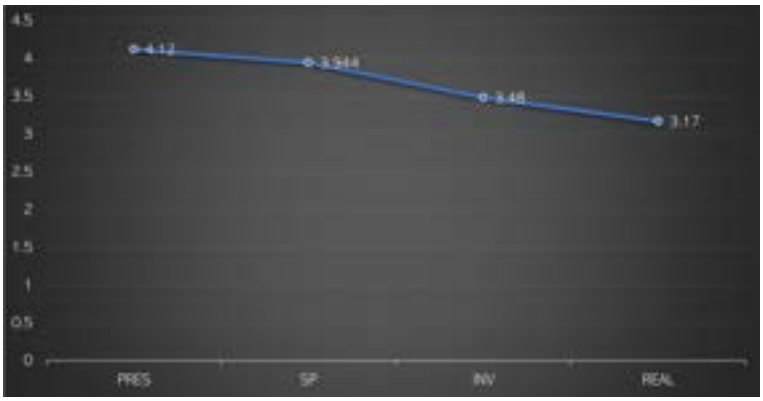


FIGURE 5.51: Average of the Subscales : No Interaction Intermittent Noise

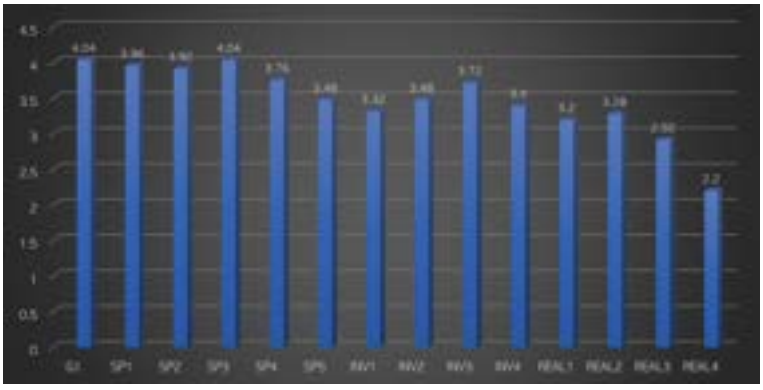


FIGURE 5.52: Average for Each IPQ Items: No Interaction Low Frequency Noise

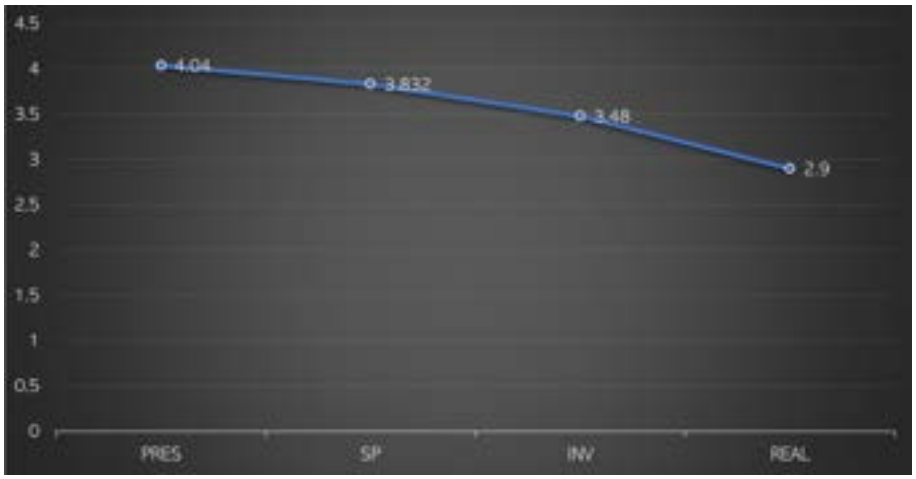


FIGURE 5.53: Average of the Subscales : No Interaction Low Frequency Noise

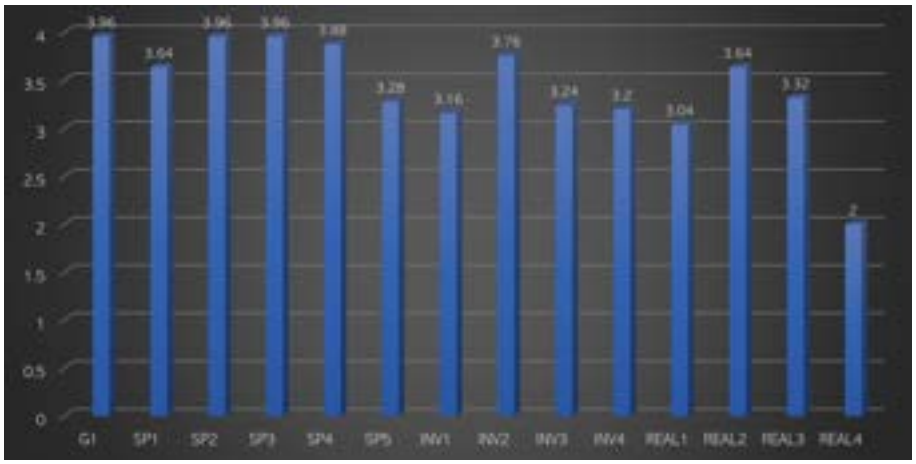


FIGURE 5.54: Average for Each IPQ Items: Medium Interaction Continuous Noise

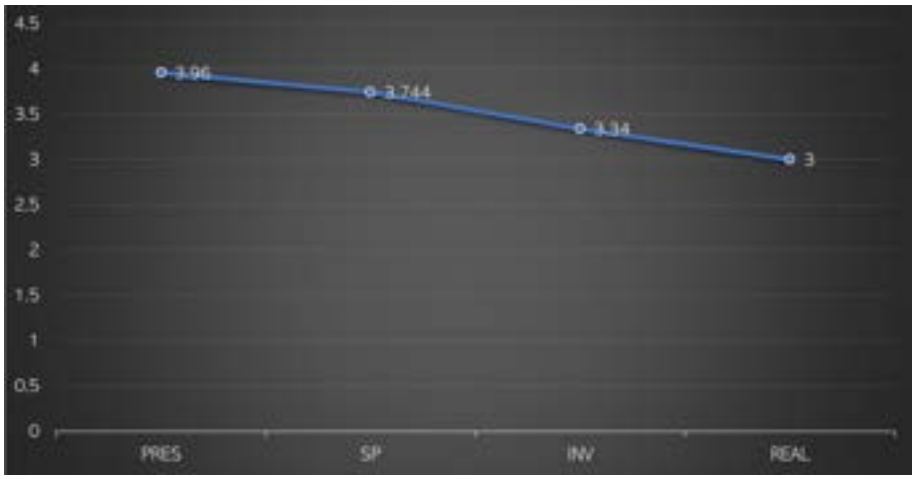


FIGURE 5.55: Average of the Subscales : Medium Interaction Continuous Noise

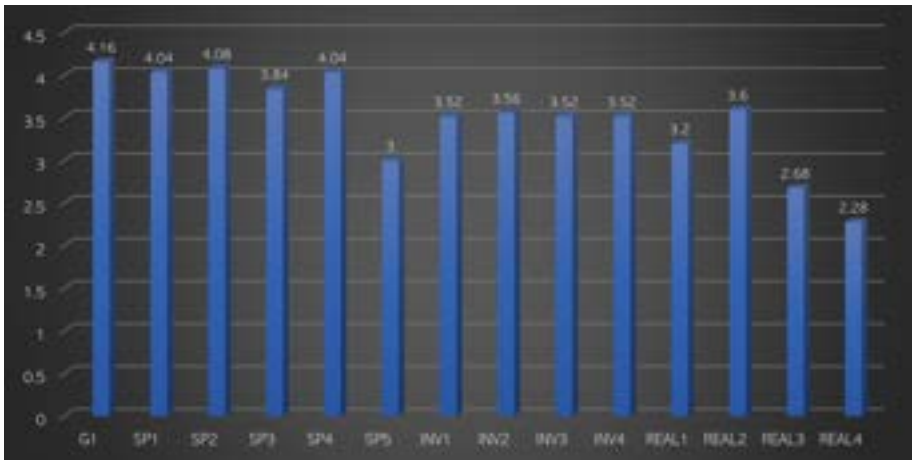


FIGURE 5.56: Average for Each IPQ Items: Medium Interaction Impulsive Noise

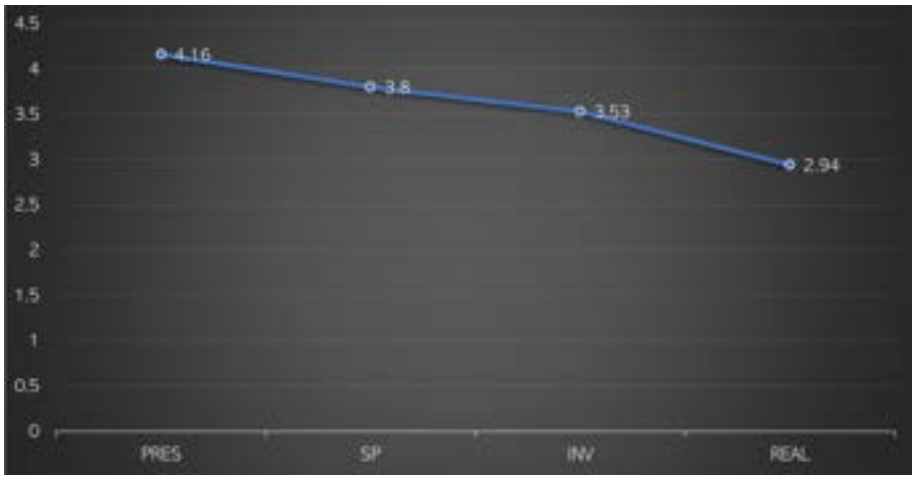


FIGURE 5.57: Average of the Subscales : Medium Interaction Impulsive Noise

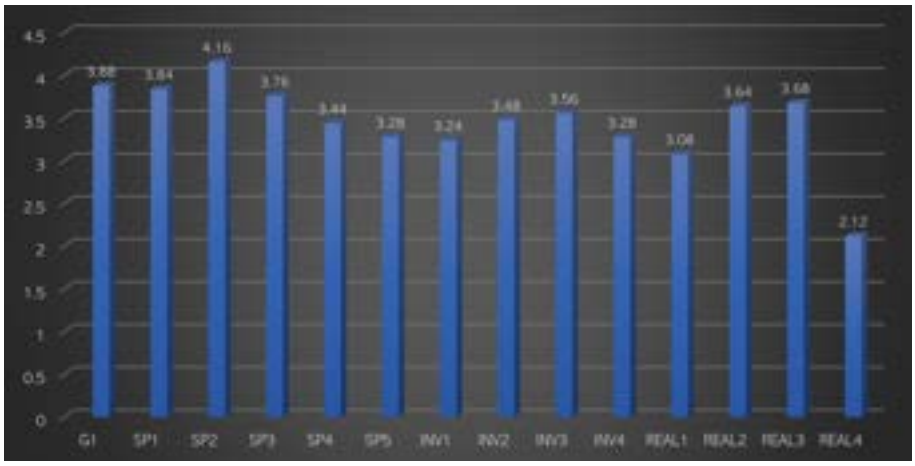


FIGURE 5.58: Average for Each IPQ Items: Medium Interaction Intermittent Noise

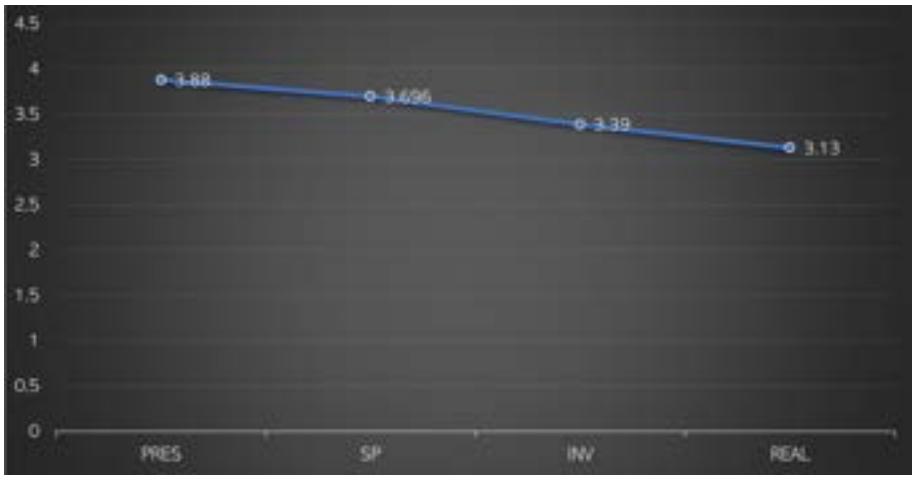


FIGURE 5.59: Average of the Subscales : Medium Interaction Intermittent Noise

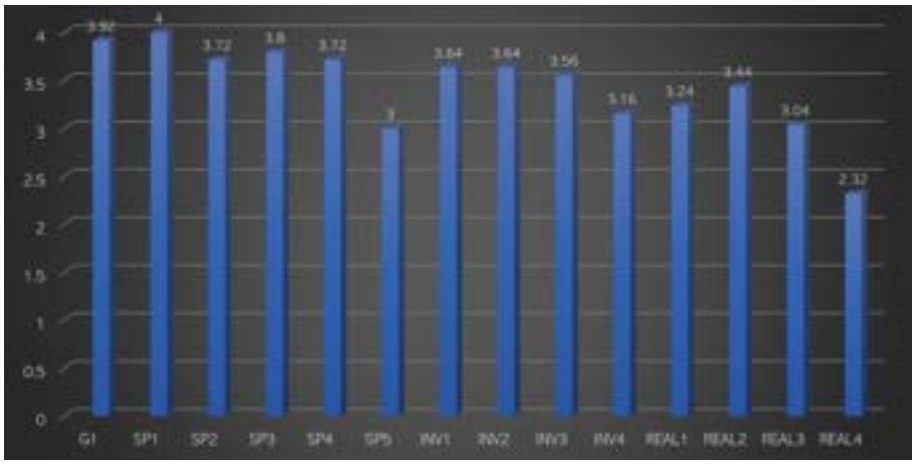


FIGURE 5.60: Average for Each IPQ Items: Medium Interaction Low Frequency Noise

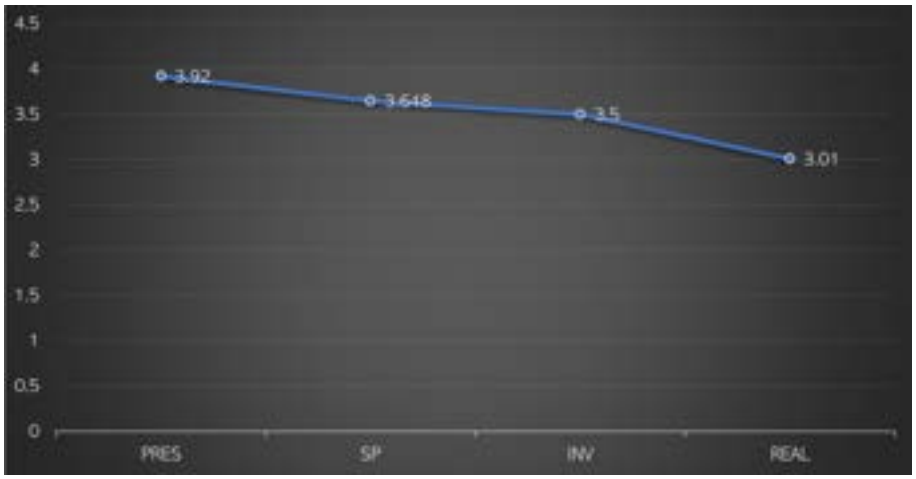


FIGURE 5.61: Average of the Subscales : Medium Interaction Low Frequency Noise

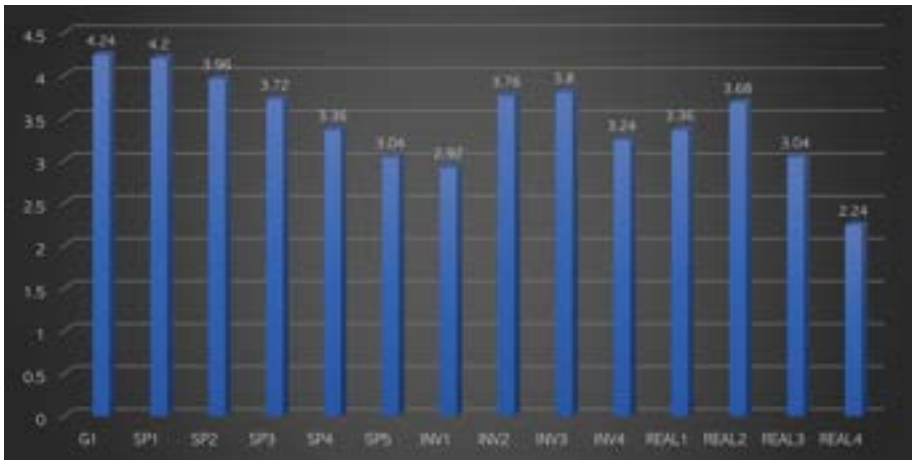


FIGURE 5.62: Average for Each IPQ Items: High Interaction Continuous Noise

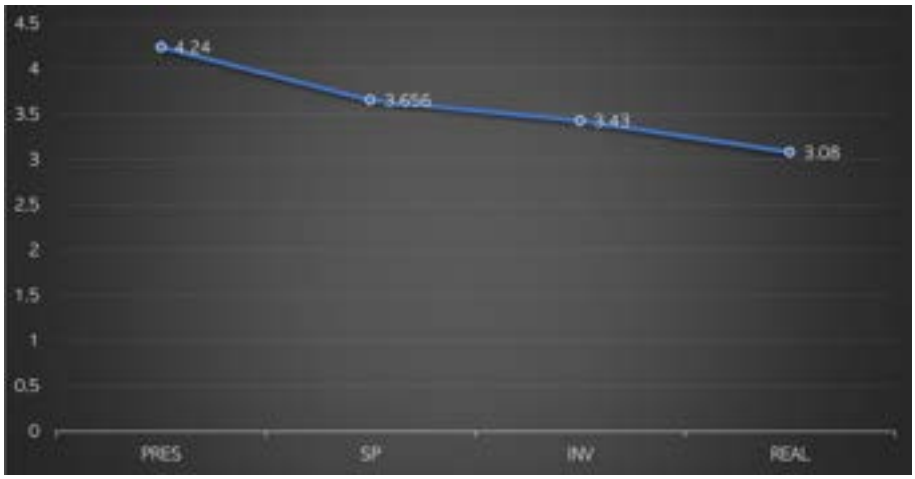


FIGURE 5.63: Average of the Subscales : High Interaction Continuous Noise

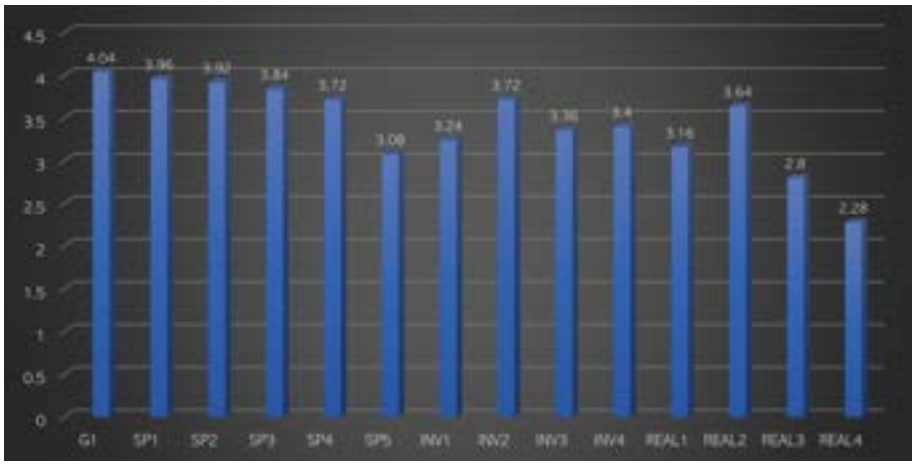


FIGURE 5.64: Average for Each IPQ Items: High Interaction Impulsive Noise

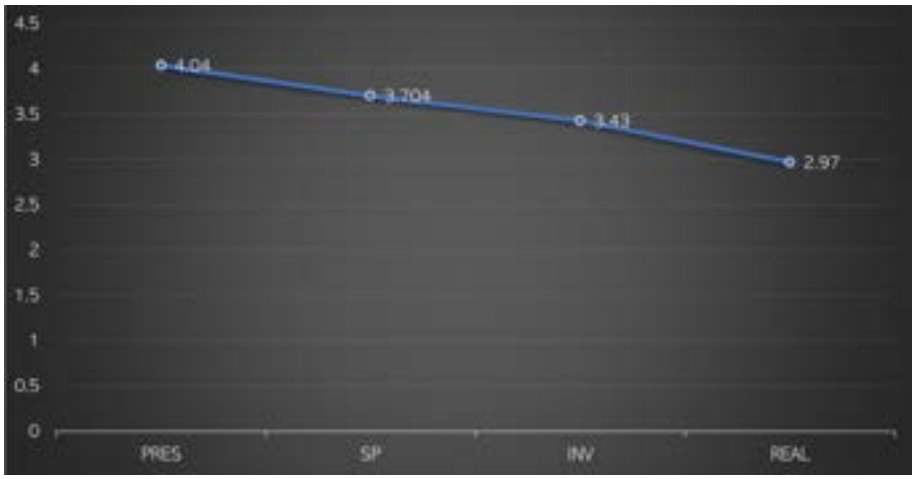


FIGURE 5.65: Average of the Subscales : High Interaction Impulsive Noise

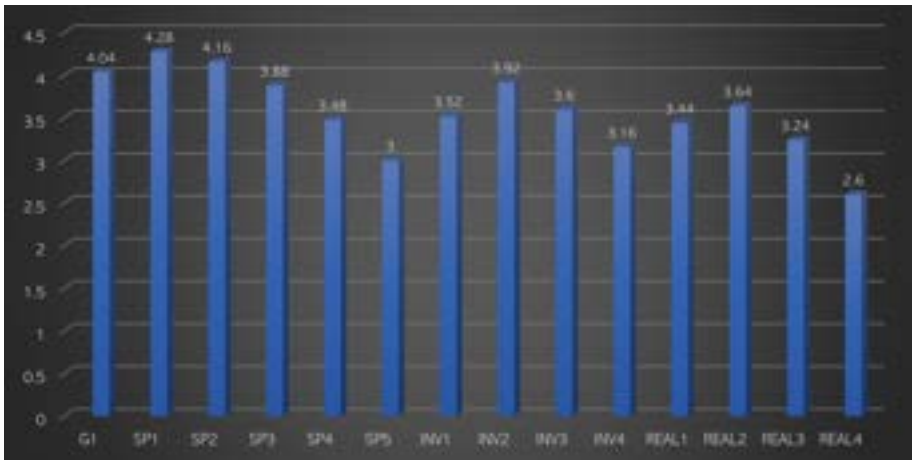


FIGURE 5.66: Average for Each IPQ Items: High Interaction Intermittent Noise

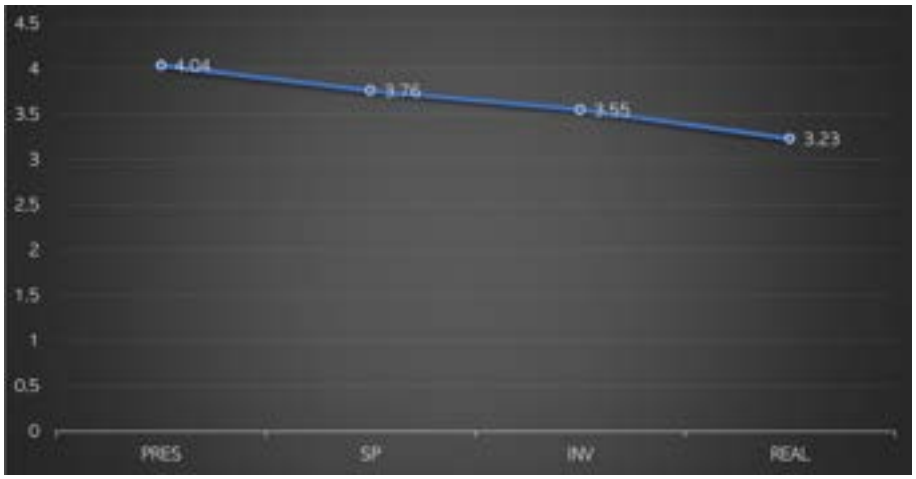


FIGURE 5.67: Average of the Subscales : High Interaction Intermittent Noise

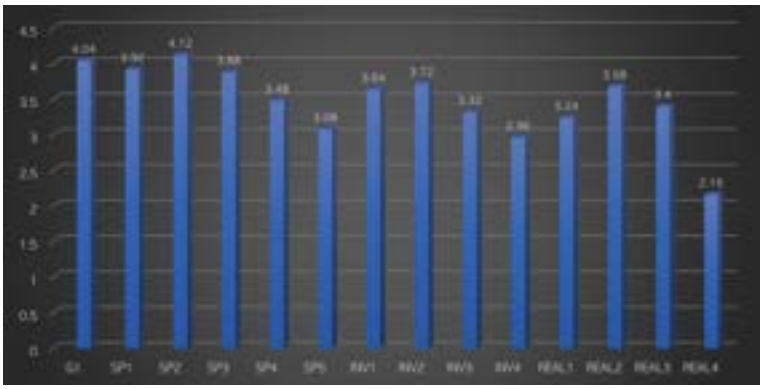


FIGURE 5.68: Average for Each IPQ Items: High Interaction Low Frequency Noise

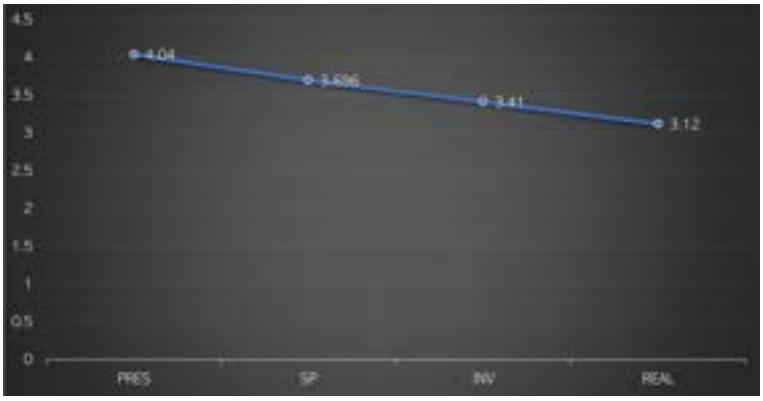


FIGURE 5.69: Average of the Subscales : High Interaction Low Frequency Noise

The values received for medium and interaction doesn't seem to change much from the values for no interaction cases. This can be seen from Fig 5.59 to 5.69 that are listed above. I'm not going into it in details as the images are self explanatory and are quite easy to understand. So, I'll go into the details of SPSS results.

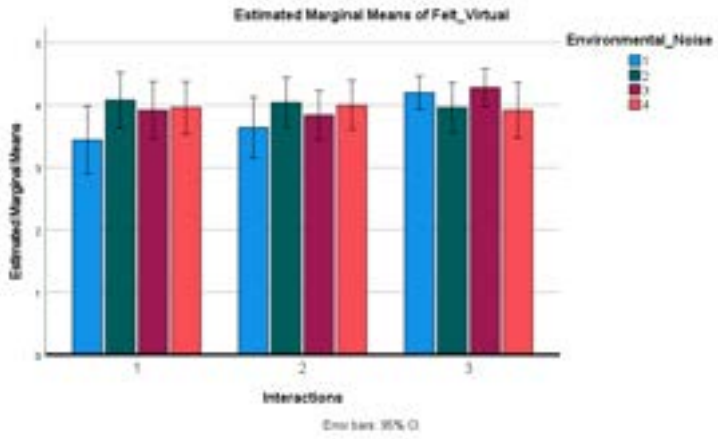


FIGURE 5.70: Marginal Means : Felt the Virtual World Surrounded me

Almost all of the participants confirm that the general level of presence in all the interactions were quite similar. This is evident from the average scores received for the general presence question, having an average of value greater than 4 or approximately 4 in most of the conditions. Although most of them gave a positive response to question SP1, "Somehow I felt that the virtual world surrounded me". But from our SPSS analysis Fig 5.70 we can infer that the value received for SP1 is comparatively higher in the high interaction case. The medium and no interaction case seem to have a similar state.

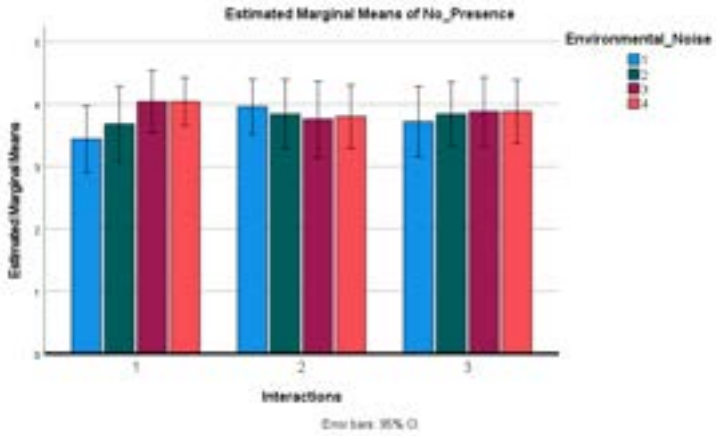


FIGURE 5.71: Marginal Means : Felt presence in Virtual Space

A strong sense of presence has been noticed in all the interactions, fig 5.71. Although there have been some variations with regards to the different environment noises but the overall opinion for presence in all the interactions are pretty good and they don't seemed to have been influenced by the interaction intensity.

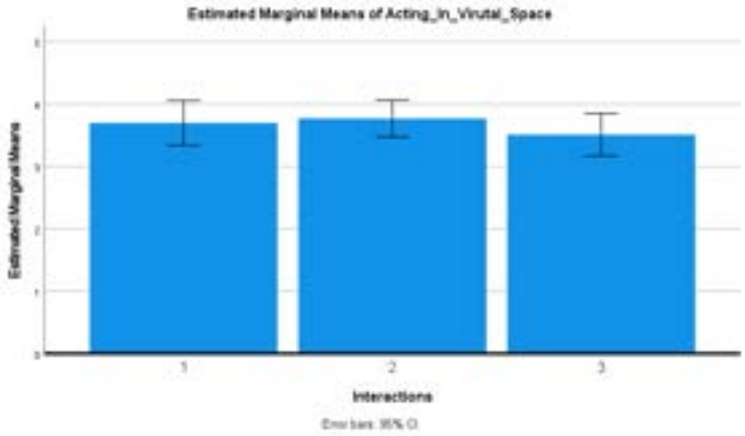


FIGURE 5.72: Marginal Means : Sense of Acting in VE

The average for SP4 is quite higher, indicating a good level of spatial presence and the users had a sense of acting in the virtual space, rather than operating something from outside. But from Fig 5.72 we can infer that the value seem to pretty much the same in no and medium interaction but for high interaction it seems to have gone down by a bit. Indicating that the extensive use of hand held controllers in the high interaction case might have caused the users to think that although they are operating in the virtual space, many actions are still triggered from the outside.

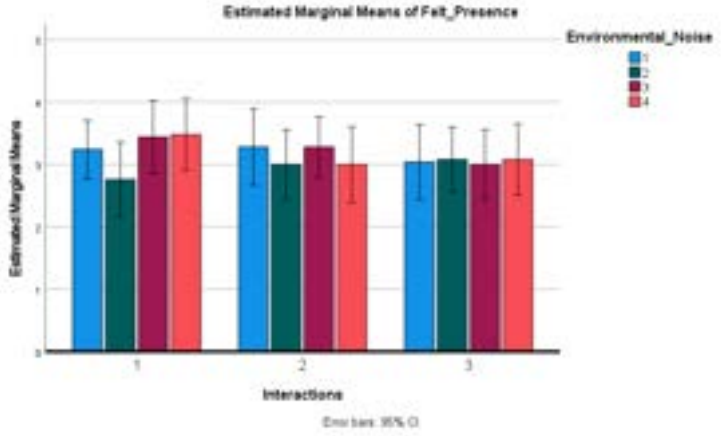


FIGURE 5.73: Marginal Means : Sense of being present in VE

From the value of presence, in Fig 5.73 we can infer that the no interaction (1) case have a good level of presence than the other two interactions. The level of presence seems to drop down a bit in the medium interaction (2) case and further down a bit in the high level of interaction (3). The hypothesis here could be with the use of hand held controllers to a good level of extent in the virtual space might have caused the users to concentrate in getting the controls for the game right rather than immersing in the virtual experience.

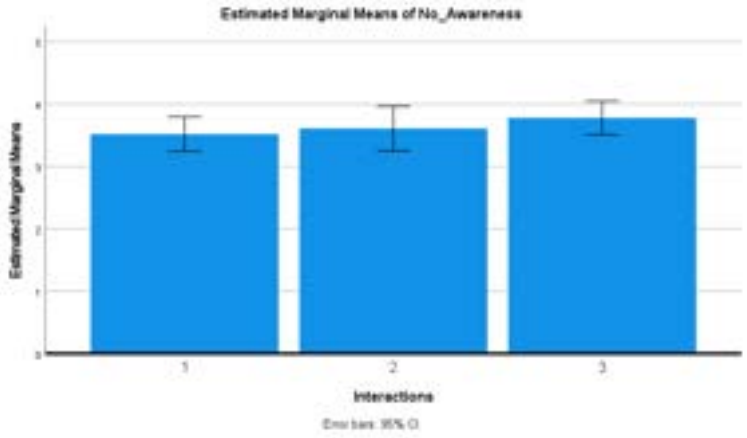


FIGURE 5.74: Marginal Means : Not aware of real environment

From Fig 5.74 with the increasing levels of interaction intensity the sense of being aware of the real world environment keeps dropping down. Although there isn't a significant difference in values we can still infer that there is some degree of change between interactions.

5.6 PANAS Questionnaire

The mean values of the positive and negative schedule of each conditions can be seen from Fig 5.75 to fig 5.86. Scores can range from 10-50 for both the Positive and Negative Affect with the lower scores representing lower levels of Positive/Negative Affect and higher scores representing higher levels of Positive/Negative Affect. The questionnaire can be seen from appendix

For the no interaction case, from Fig 5.75 till Fig 5.78 we can infer that the negative affect has a smaller values in all the four conditions with a very few exception. In impulsive noise case we have infer that the positive effect values are much lesser or much closer to the negative affect values with many users. Thereby giving a good indication that the positive effects are very less in this case.

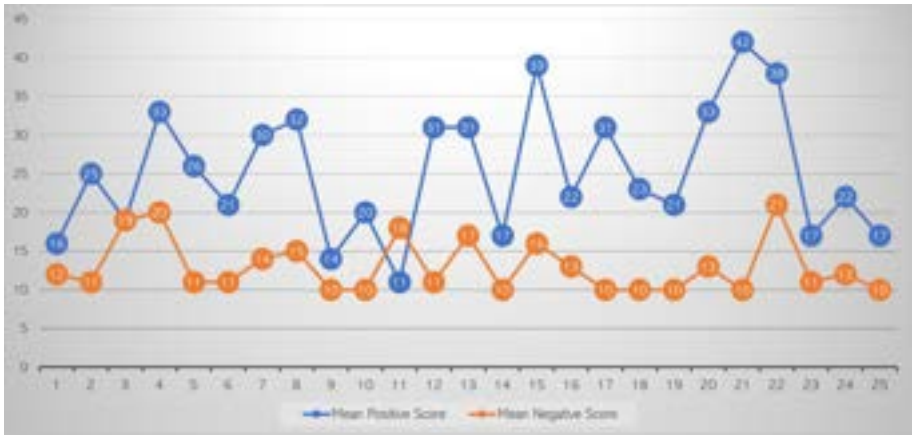


FIGURE 5.75: PANAS Score : No Interaction Continuous Noise

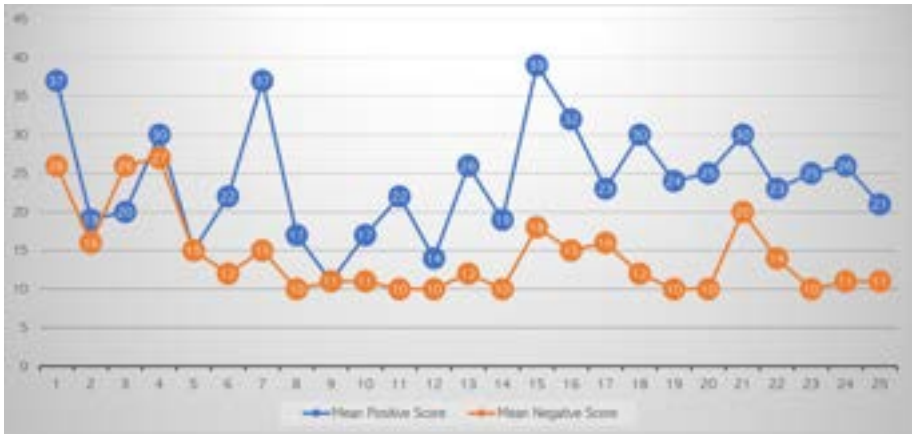


FIGURE 5.76: PANAS Score : No Interaction Impulsive Noise

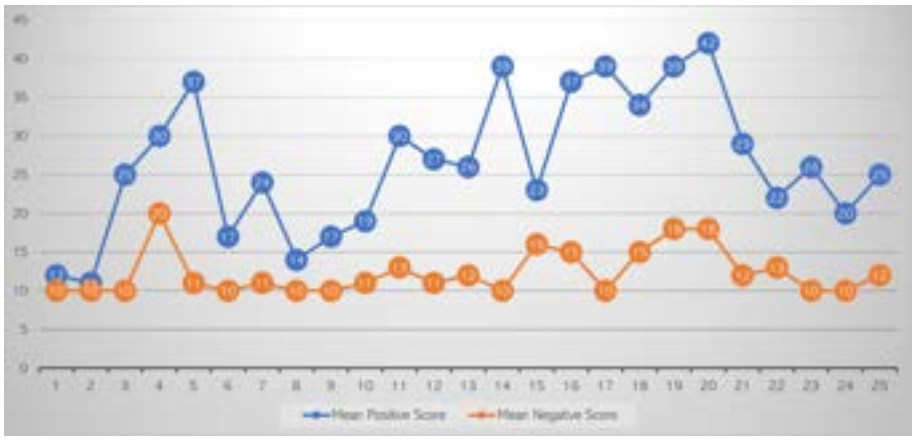


FIGURE 5.77: PANAS Score : No Interaction Intermittent Noise

The negative effect values in some users are much higher in the impulsive noise case too, the same can be inferred from fig 5.76. In other words the negative affect schedule is much lesser in almost all conditions except the impulsive noise case.

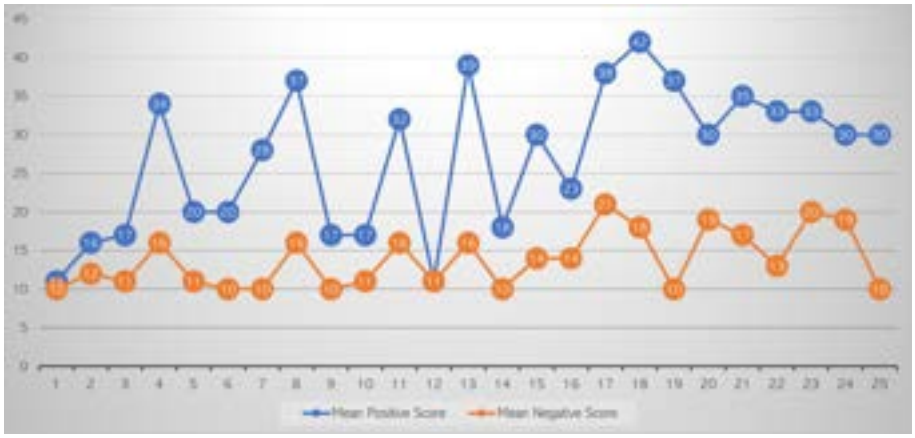


FIGURE 5.78: PANAS Score : No Interaction Low Frequency Noise

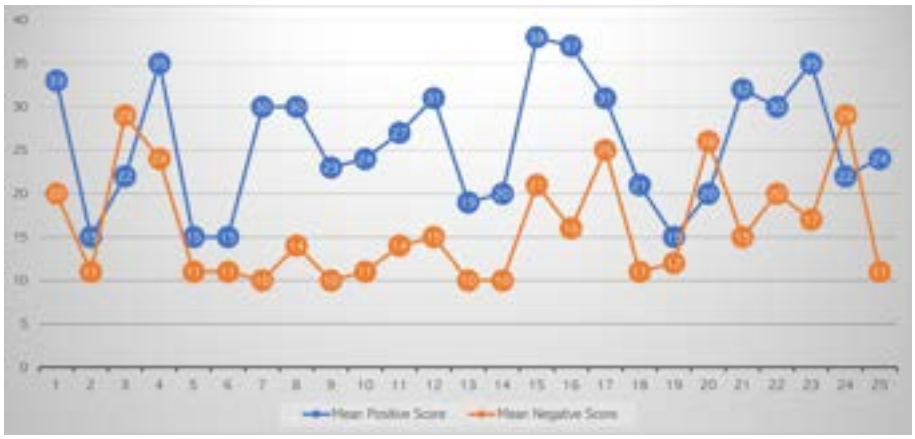


FIGURE 5.79: PANAS Score : Medium Interaction Continuous Noise

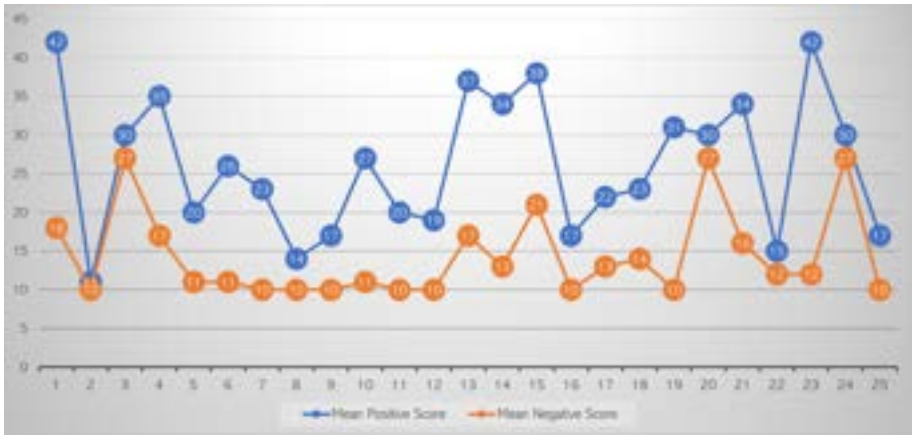


FIGURE 5.80: PANAS Score : Medium Interaction Impulsive Noise

From Fig 5.79 to 5.82 we have the results of medium interaction case. We can infer that a significant group of users have higher values for positive and negative effect

indicating that the added level of interaction in the virtual space could have given rise to different emotional responses. Apart from medium interaction continuous noise case no other cases in the medium interaction seem to have induced a greater value for negative affect schedule.

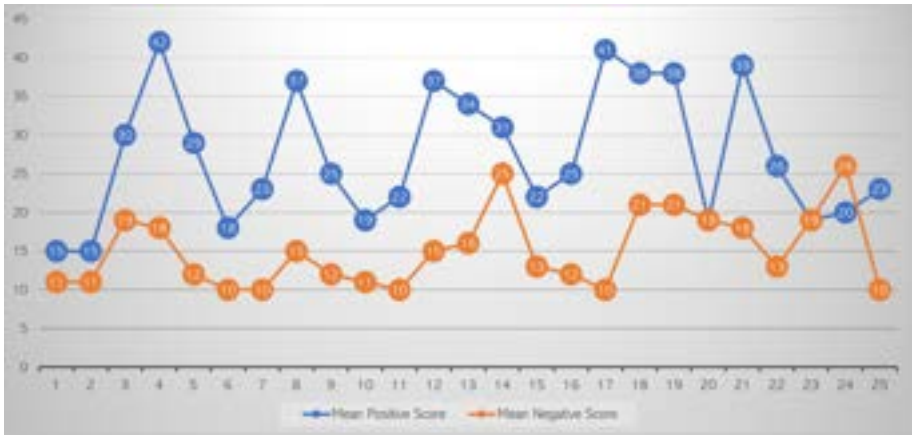


FIGURE 5.81: PANAS Score : Medium Interaction Intermittent Noise

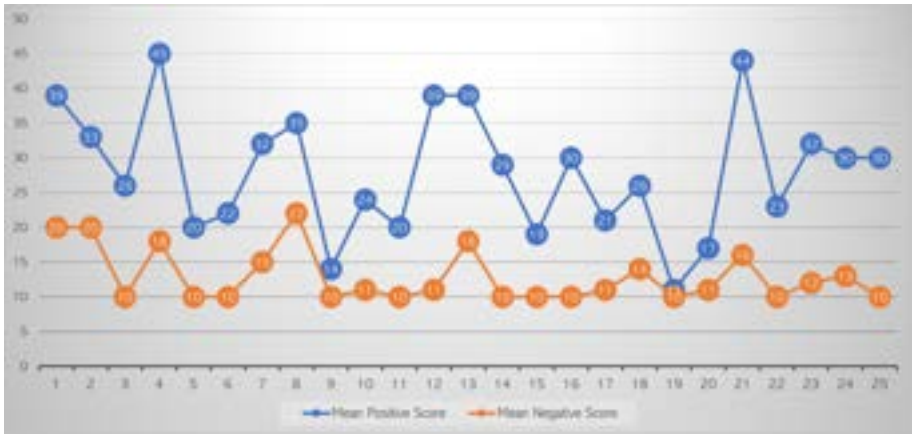


FIGURE 5.82: PANAS Score : Medium Interaction Low Frequency Noise

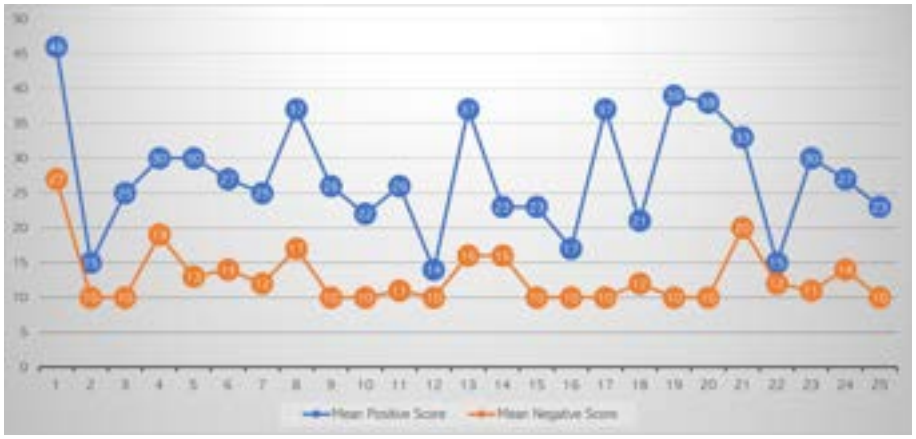


FIGURE 5.83: PANAS Score : High Interaction Continuous Noise

From Fig 5.83 to 5.86 we have the results of high interaction case. We can infer that a significant group of users have lower values for negative effect schedule indicating that a good level of interaction in the virtual space can play a part in inducing positive emotional responses in a user. Except for high interaction intermittent noise condition most of the cases have good share of participants with lower values for negative affect schedule.

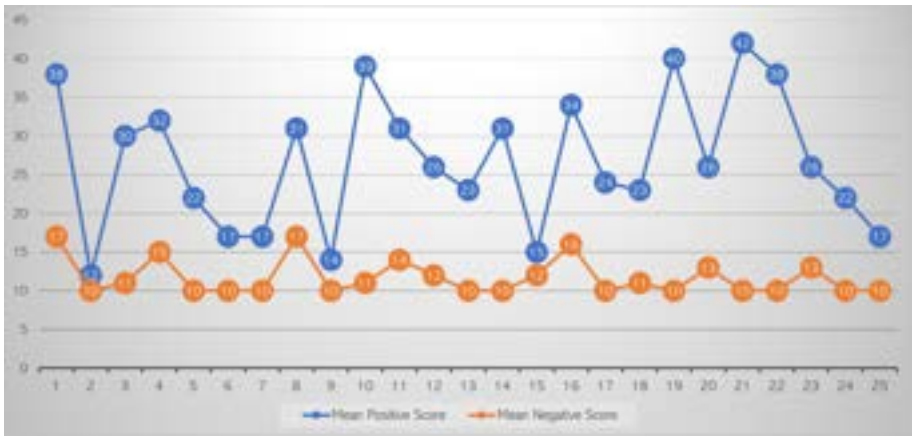


FIGURE 5.84: PANAS Score : High Interaction Impulsive Noise

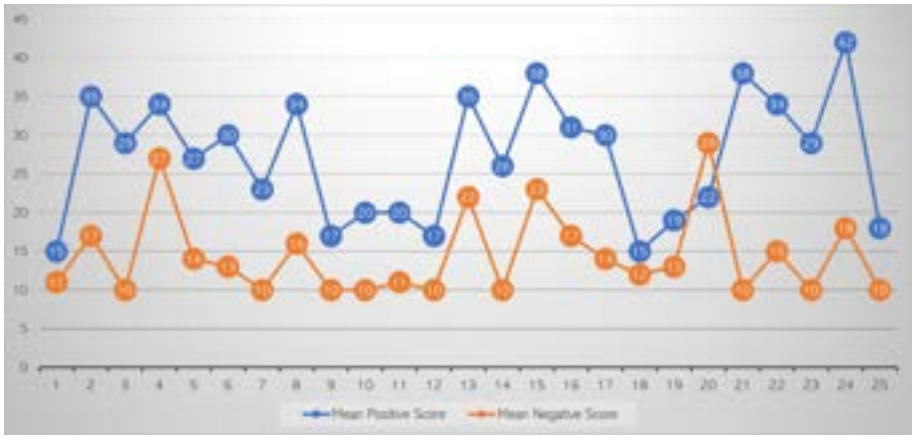


FIGURE 5.85: PANAS Score : High Interaction Intermittent Noise

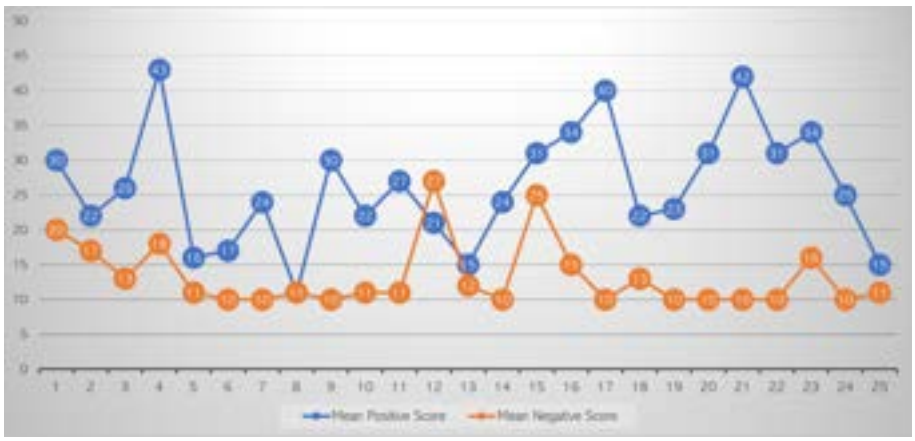


FIGURE 5.86: PANAS Score : High Interaction Low Frequency Noise

In the following section, I'll go in details on the results of the significant elements from SPSS for PANAS. From 5.87 we can infer that the negative effect of being distressed is higher in the medium interaction case and lower in high interaction. This might have been due to the fact that the user's were asked to perform a simple cognitive(mathematical) task in the environment and the noises placed in the scene could have added some amount of pressure or anxiety in the user. With the high interaction case, the users are part of story line that offers them with a good level of independence in interacting with the environment thereby providing a gaming in VR experience.

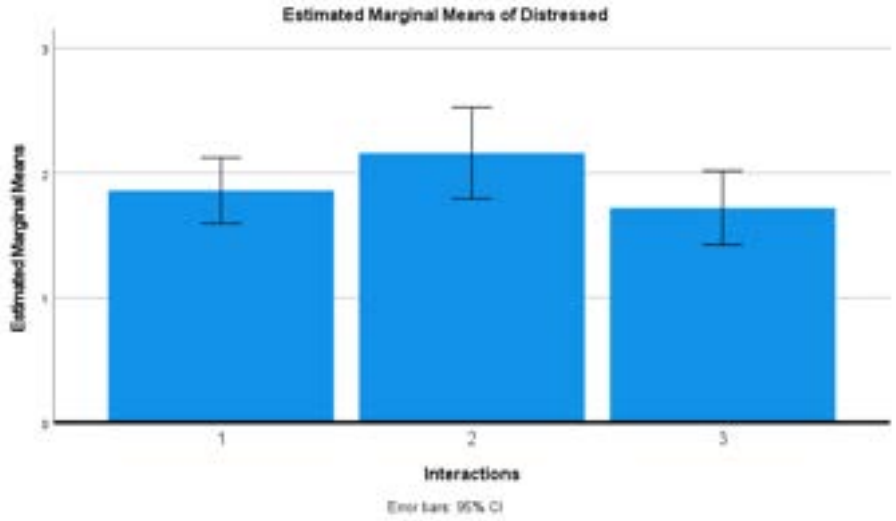


FIGURE 5.87: Marginal Means : Negative Affect - Distressed

Although the level of excitement is quite high in all the interactions we can still infer from Fig 5.88 that the level of excitement has risen as the level of interaction intensity increases.

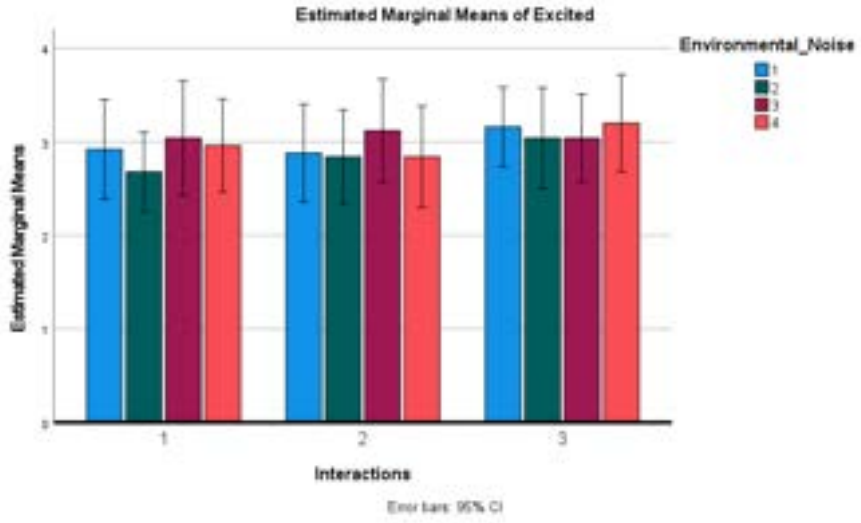


FIGURE 5.88: Marginal Means : Positive Affect - Excitement

And for the same reasons as explained for negative affect distressed, the task given in the medium interaction case and noise placed in the environment could

have triggered such a response. From fig 5.89 we can infer that the users are pretty upset in the medium interaction continuous noise and intermittent noise case.

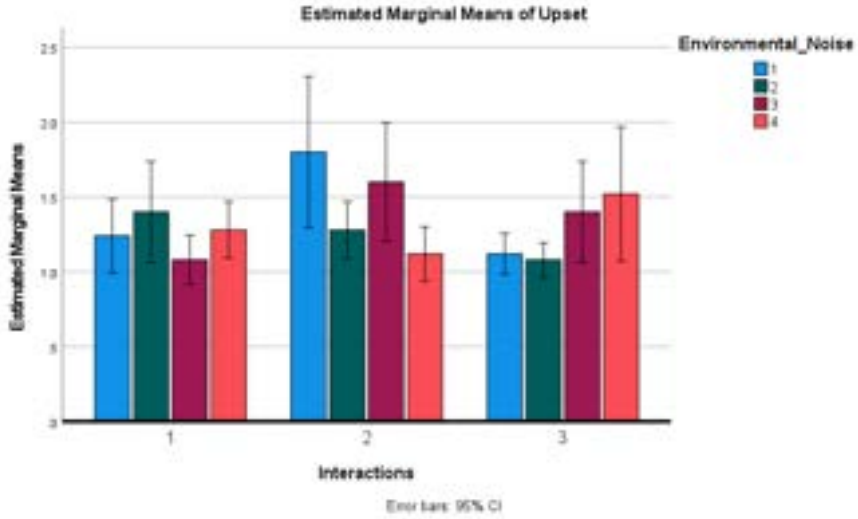


FIGURE 5.89: Marginal Means : Negative Affect - Upset

Another negative affect named irritable is much significant in the medium interaction cases. Indicating us that some visual or audio or interaction elements placed in the medium interaction continuous noise and intermittent noise case is inducing a negative effect on the user.

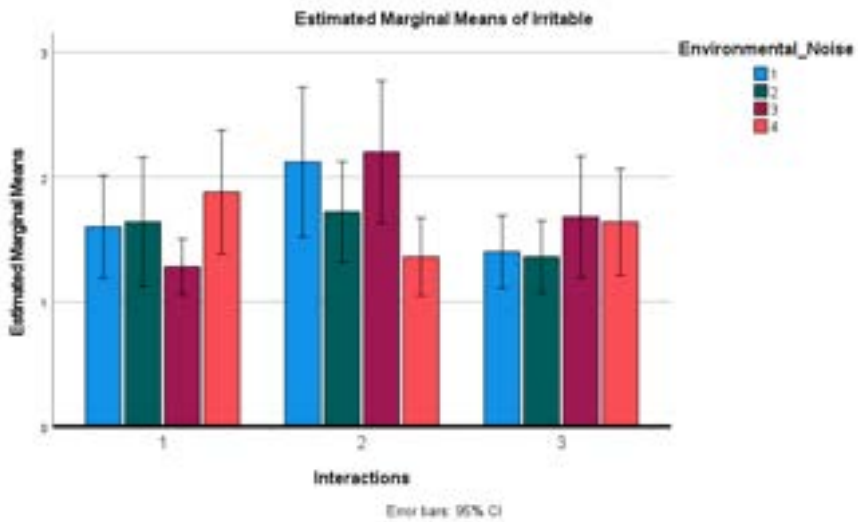


FIGURE 5.90: Marginal Means : Negative Affect - Irritable

Also, another negative effect named jittery is also significant in the medium interaction case. Thereby giving us a good sign of indication that the elements in this conditions have annoyed the users to a greater extent than others.

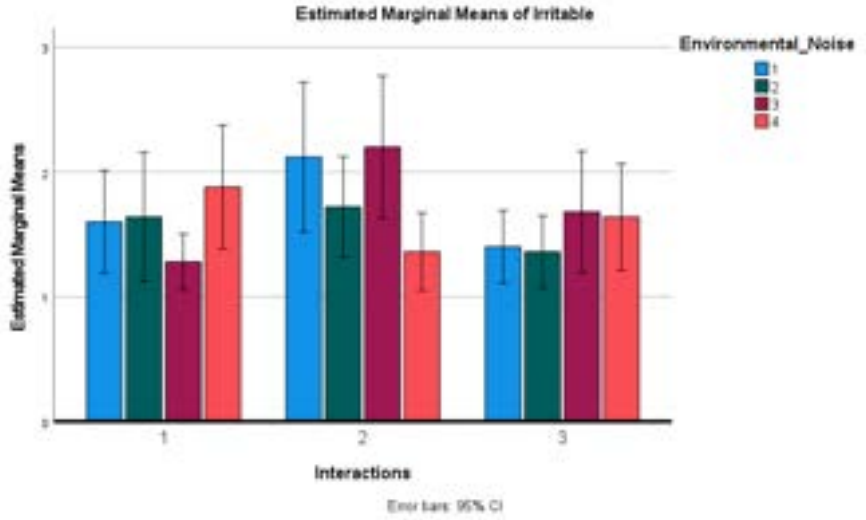


FIGURE 5.91: Marginal Means : Negative Affect - Jittery

5.7 Self Assessment Manikin

From self assessment manikin we estimate the level of happiness, excitement and dominance exerted by the user when performing the tasks given. In first section I'll present the results from the user survey and a quick analysis of those data. In the second part, I'll discuss about the analysis of the SAM data done sing SPSS.

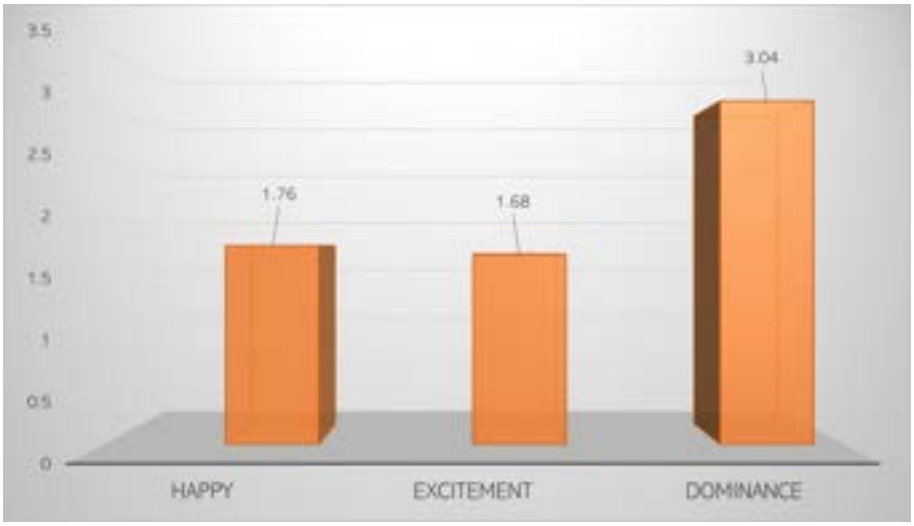


FIGURE 5.92: Mean Scores: No Interaction Continuous Noise

From Fig 5.92 to 5.95 we have the results for no interaction condition. On a quick look at all of these graphs we can infer that the values of happiness and excitement is completed lower almost all the conditions. The value of happiness seem to have risen in the intermittent and low frequency noise condition, although not by a big margin we can still assume that the noise types of condition 1 and Condition 2 in the no interaction case could have played some part in their lesser values. A greater level of excitement is not show in any of the no interaction case this might be due to the fact that users have nothing to perform in this case other silently observing the

virtual space. Happiness average: (M = 2.11), Excitement average: (M = 1.96) and Dominance average: (M = 3.12).

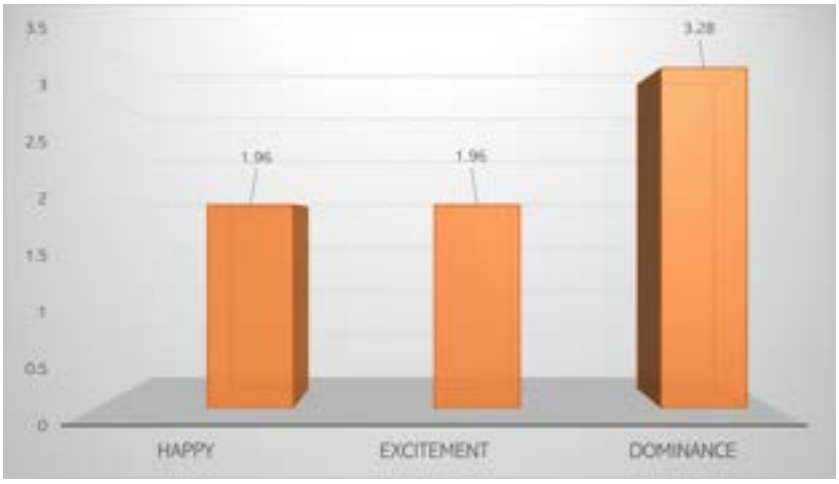


FIGURE 5.93: Mean Scores: No Interaction Impulsive Noise

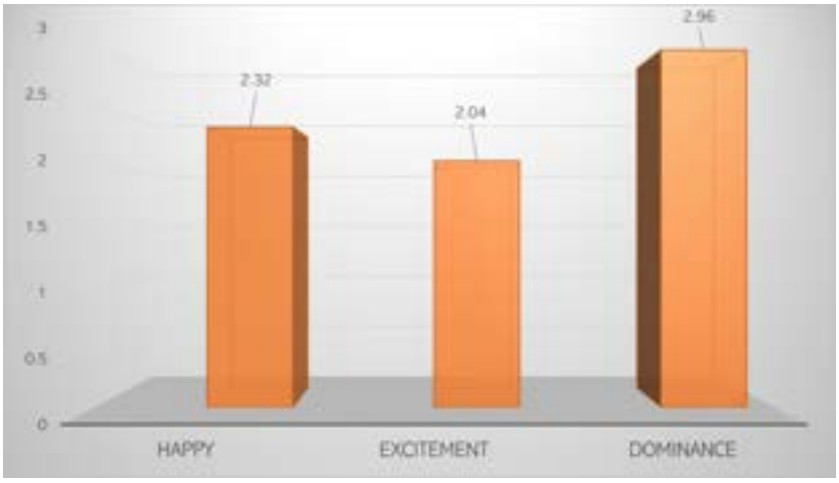


FIGURE 5.94: Mean Scores: No Interaction Intermittent Noise

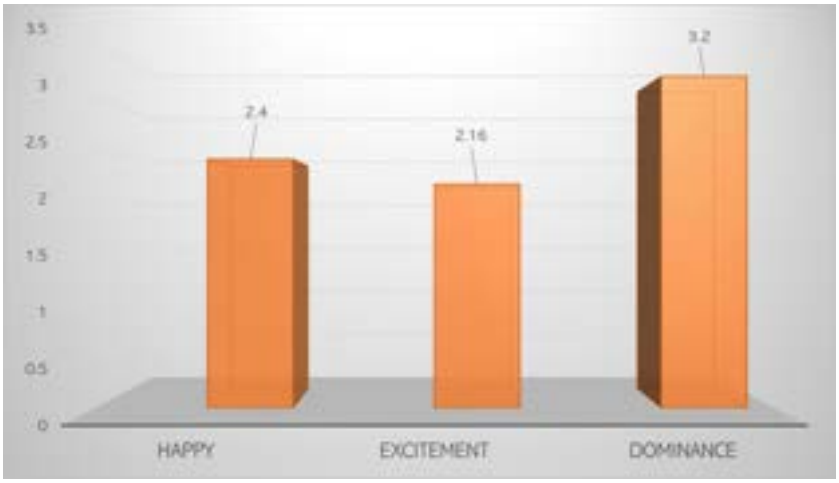


FIGURE 5.95: Mean Scores: No Interaction Low Frequency Noise

From Fig 5.96 to 5.99 we have the results for medium interaction condition. We quickly infer that there is a sharp rise in the happiness value for all the conditions in this case. Although the value of happiness fluctuate between conditions, might have been due to the various design/visual elements placed in the scene we still can conclude that the inclusion of interaction in the scenes has driven their levels of happiness. The same goes to excitement too as the values have risen sharply in the medium interaction case. The value of dominance seem to remain constant in comparison with the no interaction case. Probably the users didn't feel much control over the situation in the virtual space.

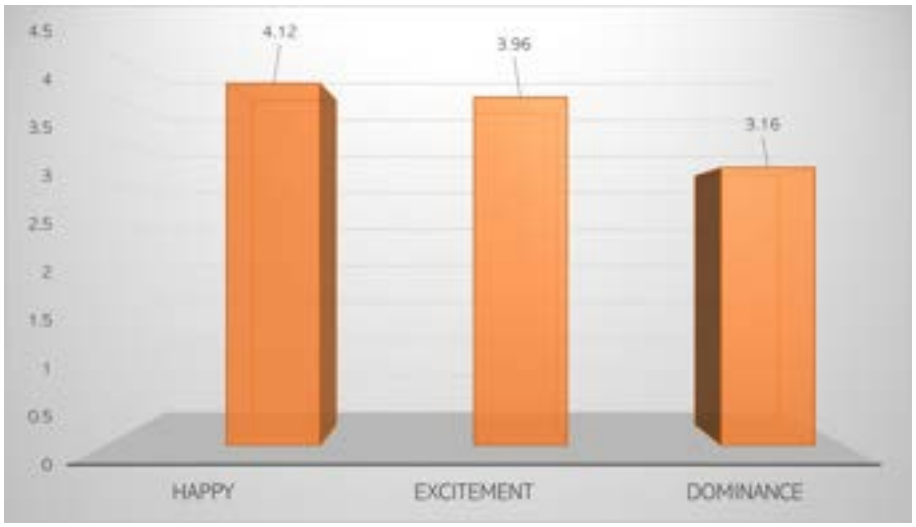


FIGURE 5.96: Mean Scores: Medium Interaction Continuous Noise

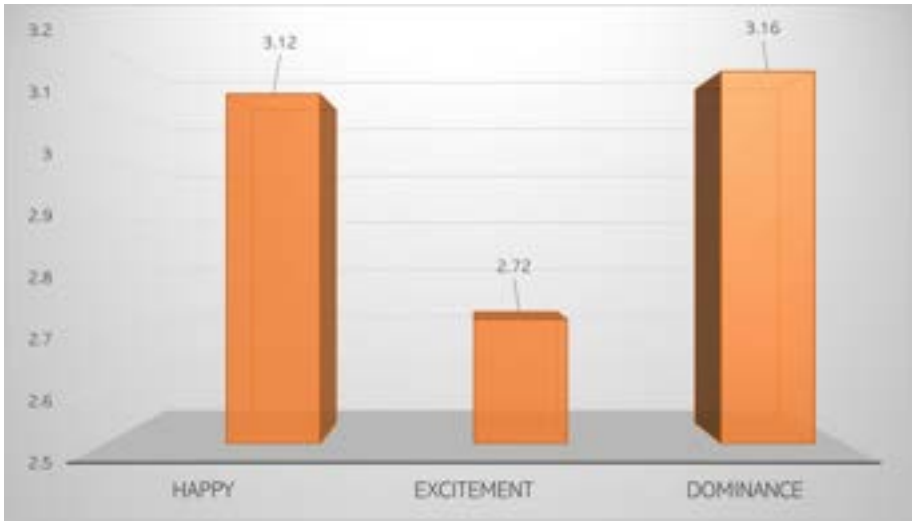


FIGURE 5.97: Mean Scores: Medium Interaction Impulsive Noise

The average scores received for happiness in medium interaction case is : (M = 4.12). The score for excitement is (M = 3.96) and the score for dominance is (M = 3.16). It is quite evident from this average scores that the level of happiness and excitement in the medium interaction case is much higher in comparison with the no interaction case.

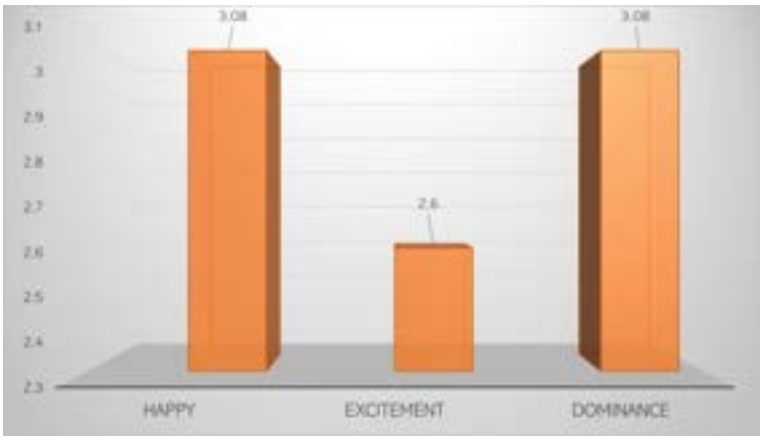


FIGURE 5.98: Mean Scores: Medium Interaction Intermittent Noise

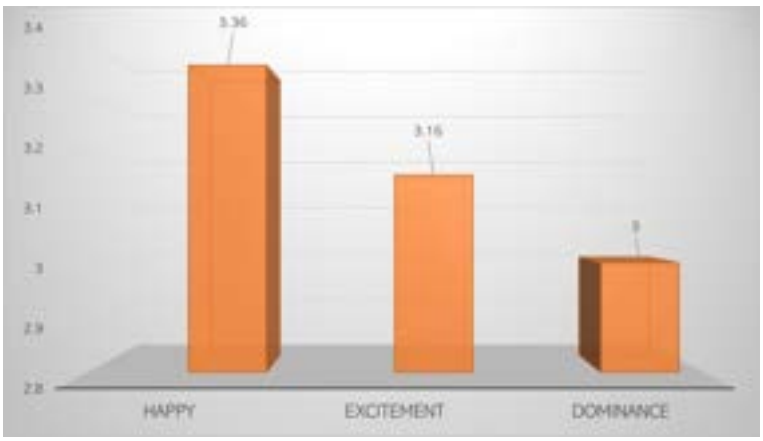


FIGURE 5.99: Mean Scores: Medium Interaction Low Frequency Noise

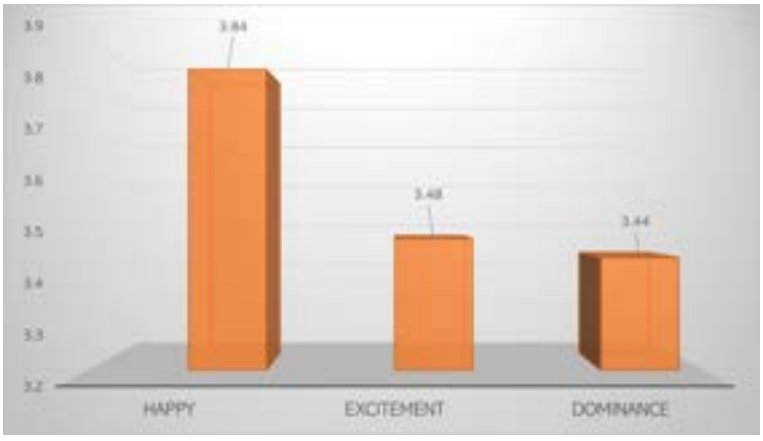


FIGURE 5.100: Mean Scores: High Interaction Continuous Noise

The average scores received for happiness in high interaction case is : (M = 3.54). The score for excitement is (M = 3.2) and the score for dominance is (M = 3.36). From these scores, it is also quite evident that the level of happiness and excitement in the high interaction case is much higher in comparison with the no interaction case. Although it remains similar in comparison with medium interaction we can conclude

that, an added level of interaction in the virtual space contributes significantly to happiness and excitement of the participants.

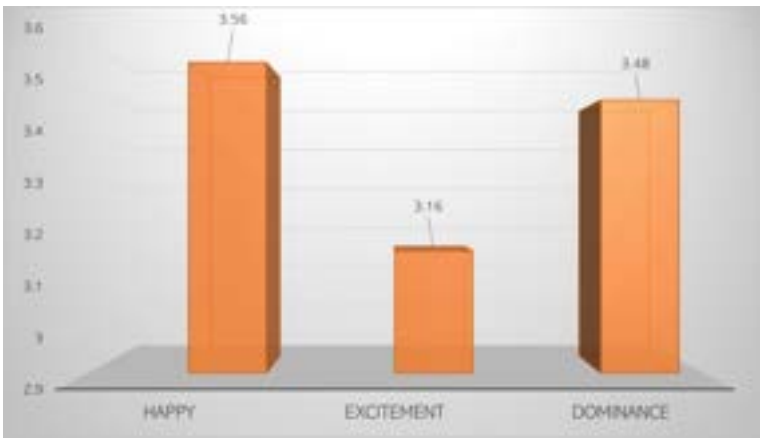


FIGURE 5.101: Mean Scores: High Interaction Impulsive Noise

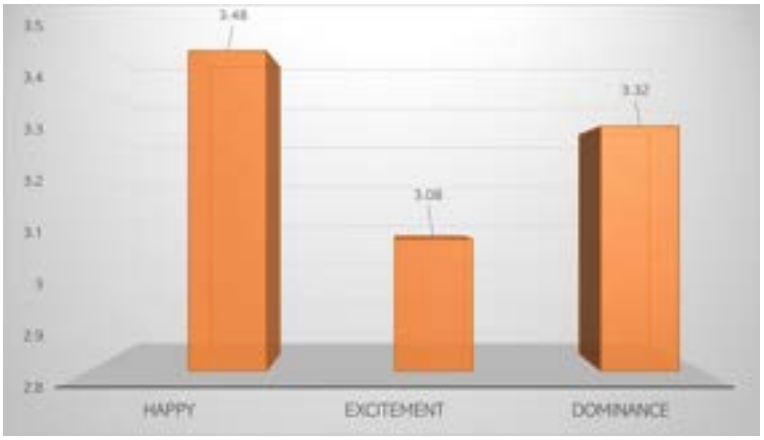


FIGURE 5.102: Mean Scores: High Interaction Intermittent Noise

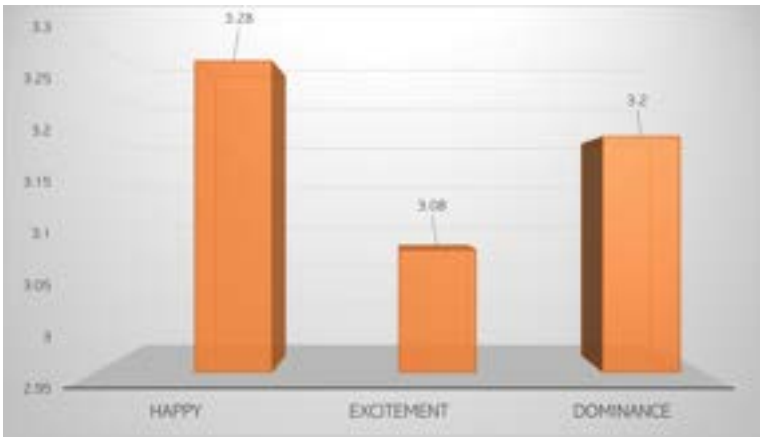


FIGURE 5.103: Mean Scores: High Interaction Low Frequency Noise

In the following section we will have a closer look at the values received from the data analysis using SPSS. Quite similar to our analysis on the happiness context

from the raw data showed in the previous section the SPSS analysis shows that the level of happiness has risen significantly as the level of interaction increases.

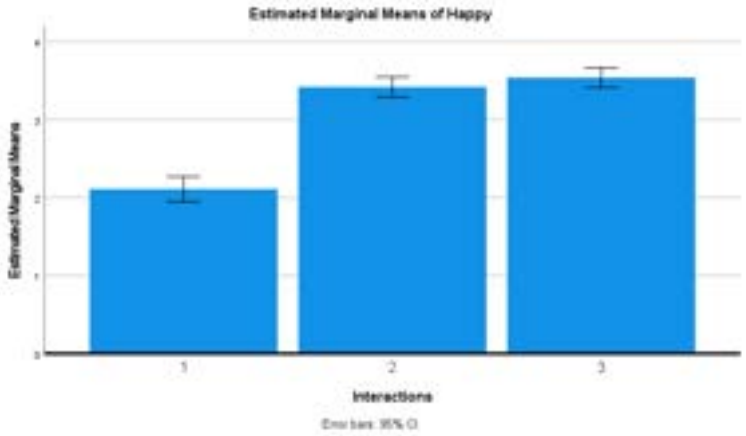


FIGURE 5.104: Marginal Means : Happiness

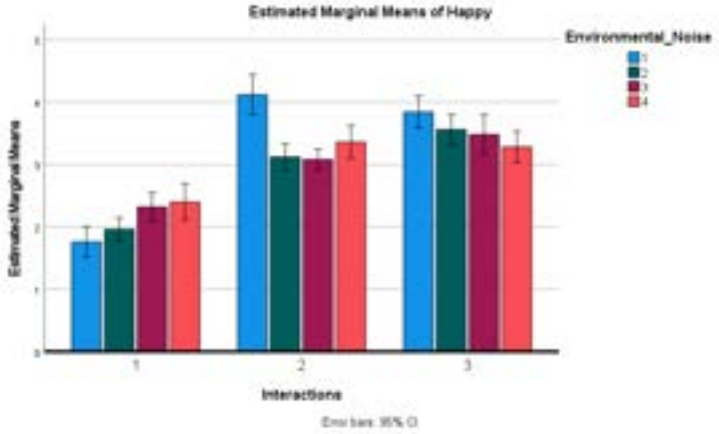


FIGURE 5.105: Marginal Means : Happiness with respect to interactions

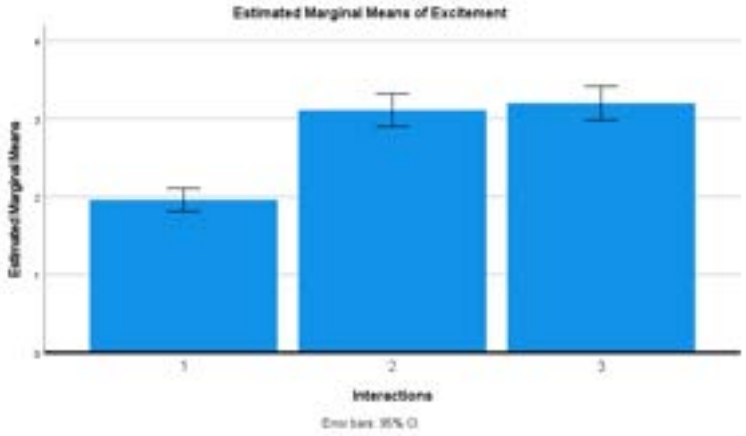


FIGURE 5.106: Marginal Means : Excitement

The results presented from SPSS for excitement too shows that its value did see a significant rise when the level of interaction increases. Although we don't find a specific pattern of its rise with respect to environmental noise we can assume that the elements presented in the scene such as visual/audio could have contributed to its rise or decline.

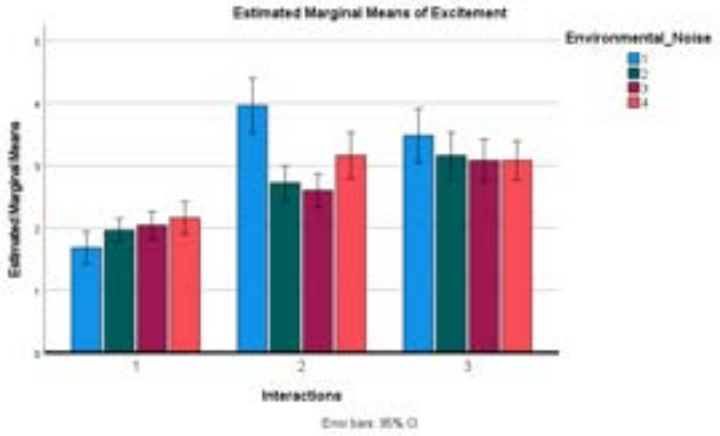


FIGURE 5.107: Marginal Means : Excitement with respect to interactions

5.8 Final Questionnaire

Finally, after the completion of all the tasks and conditions the users were asked to answer a final questionnaire asking for their opinion on their experience of the game.A simple questionnaire with 4 questions were contained in the final questionnaire. The questions asked in this questionnaire can be seen from appendix. The first question in the list had no negative answers so a detailed analysis is not given for that but the other three questions had varied opinion between users so a detailed analysis of the same is given below. The first question in the list was, were everyone able to understand the idea behind the research ? And the answer given by every one of the participants were yes.

Game Experience	
Responses	Participants
Wonderful	12
Good	10
Average	3

TABLE 5.14: User's rating on the game Experience

The next question that was asked to the participant was about their experience on the virtual reality game. And as we can see from Table 5.11 a good share of the user's enjoyed their virtual reality experience. About 48% of the total participants gave a rating score of 5 which equates to being wonderful. And 40% of the participants gave a rating score of 4 which equates to Good. And a meagre 12% of participants

gave a rating score of 3 which equates to an average experience. An hypothesis on why there might be a mixed opinion for this rating could also be due to the fact that the user's are made to execute the same set of tasks within the environment over and over.

On being asked about how easy was it to execute the tasks and goals specified in the user testing most of them agreed that it was easier and they had no trouble in getting it sorted out.About 52% of the total participants strongly agree that the goals and tasks were easier to understand and execute. And the rest 48% agreed it to, not strongly though but with a slighter emphasis on their statement.

Executing Tasks & Goals	
Responses	Participants
Strongly Agree	13
Agree	12

TABLE 5.15: User's rating on how easier was it to execute tasks & goals

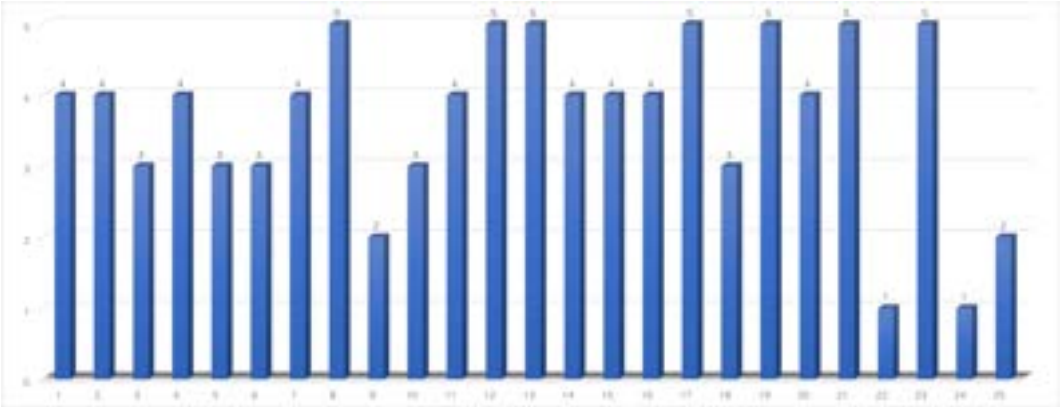


FIGURE 5.108: Easier to Navigate & Locate objects

And finally when asked about how easier was it to navigate and locate the objects in the scene to get the task completed we seemed to have received mixed opinions on it. Although a major share of the participants found it was easier there still was an handful number of participants that found it to be a daunting task. About 28% of the participants strongly agree to this statement and 36% agree to it with a slighter emphasis. The sum of participants that answered with a positive impression to argument is 16. Of the rest 9 participants, 5 members (20%) were neutral about the argument, 2 members (8%) slightly disagree and another 2 members (8%) completely disagreed to this statement.

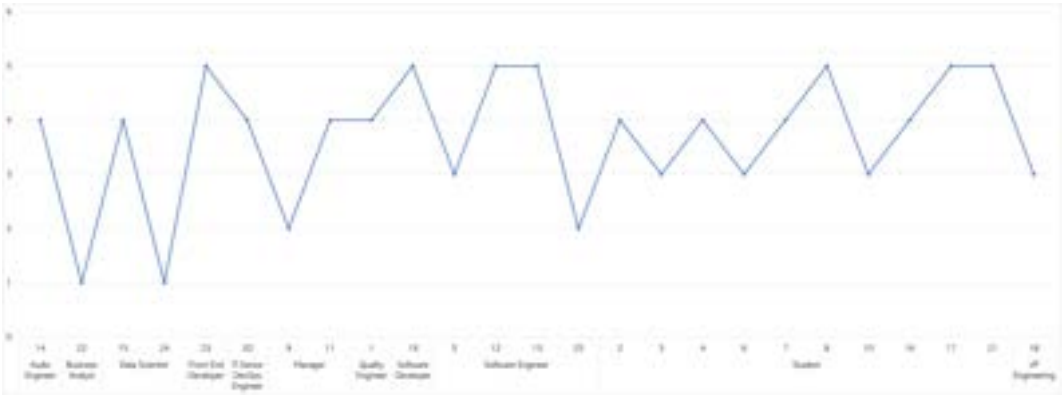


FIGURE 5.109: Breakdown by Profession

On further breaking down the answers given for the last question and sorting them by profession we can understand that people that are currently employed in some technical areas found the task of identifying and locating the objects to be a bit cumbersome. And the people that are currently associated as students found it to be easier to navigate and identify objects. This can be seen from Fig 5.14.

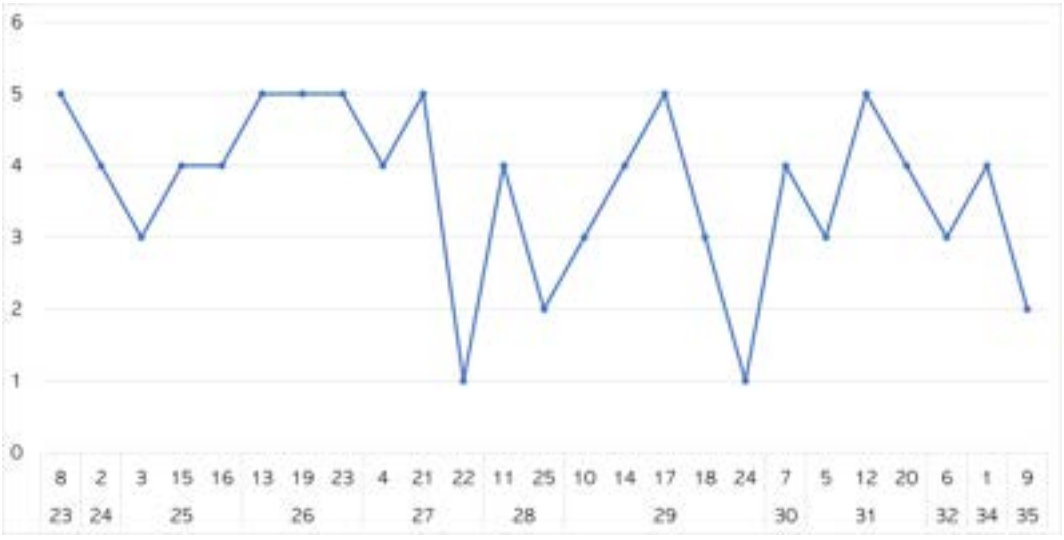


FIGURE 5.110: Breakdown by Age

Another breakdown by age gives us an idea that most of them who are on the younger side seemed to have enjoyed the task of navigating through the virtual space and enjoyed the challenge of locating the objects that were hidden in the scene. Some people over the age of 28 till 35 seemed to have found the task of locating objects to be a daunting task and haven't really enjoyed them.

Discussion of Results, Conclusion & Next Steps

6.1 Discussion of Results

After looking into the details of the results we are in more comfortable position to answer many of the research questions we posed in this study. In terms of interaction intensity we get a clear picture that with the increase in the level of interaction intensity the user experience have risen to a great extent. When induced in the zero interaction state most of the users showed a great amount of displeasure but with having them placed in scenes requiring interaction most of them felt very active and engaged also showing lesser amounts of displeasure. This proves that although adding audio elements in the scenes increase presence and immersion the effect can grow further if the scenes present the users with the opportunity to interact with objects in the virtual space.

R1 - Although in some cases we manage to infer that the use of continuous and impulsive noise increase the level of displeasure but this effect is still not found across some participants. We can conclude that the varying level of noise intensity has a significant effect on people that are mostly sensitive to environmental noises in general.

R2 - In terms of design guidelines, the most important factor to be included is presenting opportunities in the virtual space for the user to interact with. When creating experiences or content the designers and developer should get creative and present a huge scope of opportunities for the user to interact in the virtual space. Also with the development of new hand based tracking systems in the Oculus Quest device it is advisable to leverage this functionality to execute the interaction. Using a hand based interaction will give an added advantage of convincing the users that they are operating in the virtual space rather from outside. And finally make use of better quality textures and models to construct the environment to add more depth and believability into the environment.

R3 - A significant rise in degree of presence and user experience has been noticed by placing options for the user to interact with the virtual space. The tasks and other underlying elements of the story-line might be challenging and confusing to the user but with the inclusion of interactions we can note that the users emoting a higher degree of presence and immersion.

Results from NASA Task Load - With the results from NASA task load we can infer that the rise in interaction level shows a significant increase in the level of mental and physical demand. This is quite obvious because the higher the interaction intensity we placed more elements in the scene for the user to interact with and more opportunities for them to connect with the virtual space. This could also be

inferred from the results on their mean effort per interaction which gets higher as the level of interaction intensity grows. And finally from the level of frustration we get to infer that the participants were heavily frustrated in the no interaction case in comparison with other. And the level of frustration is much higher in the continuous and impulsive noise condition over the intermittent and low frequency noise.

Results from Presence Questionnaire - Almost all the conditions had equal level of presence based on the data we have from this questionnaire. We do have some varying results at some places but we don't have a conclusive evidence on why they are a bit deviated from normal. But as expected the sense of acting in the virtual space is a bit lesser in high interaction indicating that the extensive use of hand held controllers in the high interaction case might have caused the users to think that although they are operating in the virtual space, many actions are still triggered from the outside. So, it would be a good opportunity for the designer and developer to look into the recent updates of the Oculus Quest device and start leveraging the functionalities of hand tracking to an increased level of presence.

Results from PANAS Questionnaire - As far as PANAS is concerned most of the users found the medium interaction to be casuing more negative emotions in the user. This is could be due to the placement of a simple math based cognitive task in the scene and probably some of the users might have found the task to be challenging or annoying in general. But in general all the conditions managed to add some good positive effects as well.

Results from SAM Questionnaire - Reiterating the same facts listed above that: The increase in interaction level saw a huge increase in the happiness and arousal level of the participants. It is therefore a strong evidence that the placement of opportunities to interact with the virtual space tends to emote a positive feeling among the precipitants.

6.2 Next Steps, Future Works and Further Improvements

While our research findings suggest positively towards user experience and presence in VR with increased interaction and a more subtle audio noise level, it is somewhat limited in the aspect of how and where the test was conducted, in a closed laboratory at the university. An extension of this research is to take the field tests into other public context that contains a wider array of spectators and varying level of noises with a more natural depiction, and could involve people with different experience level in using the virtual reality device. We need to ensure that the VR experiences/content created should also match the context of the place where the experiment could be conducted.

Replication of audio source through the VR device although worked in parts it would be nice to look into auralization procedures[24] to better design and simulate the experience of acoustic phenomena rendered as a sound-field in a virtualized space as this is a much better option in making coherent sound environments within virtual immersion systems.

6.2.1 Asset improvements

Almost all of the assets were taken and reused from the asset store and were free of charge. If a professional game studio was to use ready-made assets from the store they would have no hesitation to pay the price accordingly for the quality. Unfortunately, our lack of funds didn't allow us to invest in higher-quality assets and we had to make us of whatever we could find. Also, the physics of our objects

such as the collision boxes or general behaviours when they have interacted with the VR controllers could be improved accordingly.

6.2.2 Game-play improvements

A major part in improving the game-play would be to make the game a bit more accessible and intuitive. During the user testing the user had to be given rather some simple directions and instructions on what options they had in each scene depending on the noise and interaction level and guide them on where to go next if they got lost by having some visual feedback. One idea would be to work over the general level design to be more linear. Although this would prevent the user from going down the wrong rabbit hole it would also limit his choices undermining his immersion and feeling of being free and possibly domination. Another solution could be displaying directions, tasks and explanations directly in the game. The user could play the game more autonomously but still there would be deductions in the immersion and level of presence. Additionally, the interaction with the world and objects has a lot of room for improvement. Not all objects are grabbable and for some objects, the player had to get very close to be able to pick it up; some objects weren't even assigned with a collider or a collider not perfectly suited to its shape.

6.2.3 Virtual Questionnaire

It would be a better option to have the questionnaire filled from the virtual space rather than having the user to answer to the survey by other means. The process of filling the questionnaires seemed to have significantly reduced the amount of time taken to complete the entire user study. So, I personally feel that with the use of survey within the vr will cut down on the time taken by a significant margin.

6.3 Conclusion

The findings of the studies in this thesis suggest that a certain type of noises such continuous and impulsive noise have had some level of impact on user experience by reducing the level of immersion in the virtual reality space. Furthermore, we found out that people with no experience in virtual reality devices at the start of the experiment may feel a little out of place and awkward for a while, once they get accustomed to this new experience, he or she will forget about the surroundings and people present with them and they will start engaging in the virtual space with much level of comfortness.

We got a clear picture that when the level of interaction is increased the amount of mental demand required to complete the tasks have risen to a greater deal. Although we don't have a conclusive evidence on which noise types could have triggered for this raise but the increase is spread out among all noise types used in the study. The same applies for the physical demand as well, which rose significantly. With all this information we can conclude that the increase in the level of interaction triggered in the raise of task load across all participants. Also, a significant level of frustration in the no interaction case helps us understand that a zone with no options to interact with the virtual space reduce the level of user experience by a greater deal. And most of the user have shown a high degree of frustration in continuous and impulsive noise cases over intermittent and low frequency noise cases.

When it comes to the level of presence and immersion in the virtual space we don't have any conclusive evidence to make a solid call as most of them enjoyed

all the scenes equally (or at a similar rate). But we could still infer(only by a small margin) that an increase in the level of interaction causes the user to be less aware of the real world environment. But the increase in interaction rate caused the user to think that they were interacting in a virtual space from outside but not from inside. This is mainly due to the fact that we use controllers to control and track the user input which could reduce their level of experience.

The general idea we got from the results is that most of them were quite excited and happy when the interactions intensity was increased.So we hope that these findings, and the design guidelines can help future designers and researchers create VR experiences that take into account the viewpoints of various guidelines we have suggested here. Furthermore, the designers and researchers can have a better idea of experiential factors from the perspective of VR to make a more educated guess.

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Questionnaire

B.1 Demographics Questionnaire

Demographics

* Required

1. Participant ID *

2. Gender *

Mark only one oval.

- Female
- Male
- Prefer not to say

3. Age *

4. Profession *

5. How experienced are you with Virtual Reality technologies (Cave, Head-Mounted Displays, e.g. HTC Vive, Oculus Quest)? *

Mark only one oval.

	1	2	3	4	5	
Not at all						Very experienced

6. Are you sensitive to environmental noises in general ? *

Mark only one oval.

	1	2	3	4	5	
Not at all						Very Much

7. Do you think the areas you are prone to be (eg: School, Work or Home) is always noise ? *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very Much

8. How often do you notice that there is noise? *

Mark only one oval.

	1	2	3	4	5	
Never	◯	◯	◯	◯	◯	Always

B.2 ATI Questionnaire

2. Please indicate the degree to which you agree/disagree with the following statements. *

Mark only one oval per row.

	Completely Disagree	Largely Disagree	Slightly Disagree	Slightly Agree	Largely Agree	Completely Agree
I like to occupy myself in greater detail with technical	◯	◯	◯	◯	◯	◯
I like testing the functions of new technical systems.	◯	◯	◯	◯	◯	◯
I predominantly deal with technical systems because I have to	◯	◯	◯	◯	◯	◯
When I have a new technical system in front of me, I try it out intensively	◯	◯	◯	◯	◯	◯
I enjoy spending time becoming acquainted with a new technical system	◯	◯	◯	◯	◯	◯
It is enough for me that a technical system works; I don't care how or why.	◯	◯	◯	◯	◯	◯
I try to understand how a technical system exactly works.	◯	◯	◯	◯	◯	◯
It is enough for me to know the basic functions of a technical system.	◯	◯	◯	◯	◯	◯
I try to make full use of the	◯	◯	◯	◯	◯	◯

B.3 NASA TLX Questionnaire

3. Mental Demand : How mentally demanding was the task ? *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

4. Physical Demand : How physically demanding was the task ? *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

5. Temporal Demand : How hurried or rushed was the pace of the task ? *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very Much

6. Performance : How successful were you in accomplishing what you were asked to do? *

Mark only one oval.

	1	2	3	4	5	
Perfect	◯	◯	◯	◯	◯	Failure

7. Effort : How hard did you have to work to accomplish your level of performance? *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

8. Frustration: How insecure, discouraged, irritated, stressed,and annoyed were you? *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

B.4 IPQ Questionnaire

3. In the computer generated world I had a sense of "being there" *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very Much

4. Somehow I felt that the virtual world surrounded me *

Mark only one oval.

	1	2	3	4	5	
Fully Disagree	◯	◯	◯	◯	◯	Fully Agree

5. I felt like I was just perceiving pictures. *

Mark only one oval.

	1	2	3	4	5	
Fully Disagree	◯	◯	◯	◯	◯	Fully Agree

6. I did not feel present in the virtual space. *

Mark only one oval.

	1	2	3	4	5	
Did not feel	◯	◯	◯	◯	◯	Felt Present

7. I had a sense of acting in the virtual space, rather than operating something from outside. *

Mark only one oval.

	1	2	3	4	5	
Fully Disagree	◯	◯	◯	◯	◯	Fully Agree

8. How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.) ? *

Mark only one oval.

	1	2	3	4	5	
Extremely Aware	◯	◯	◯	◯	◯	Not Aware at all

9. I still paid attention to the real environment. *

Mark only one oval.

	1	2	3	4	5	
Fully disagree	◯	◯	◯	◯	◯	Fully agree

10. How real did the virtual world seem to you? *

Mark only one oval.

	1	2	3	4	5	
Completely Real	◯	◯	◯	◯	◯	Not Real at all

11. How much did your experience in the virtual environment seem consistent with your real world experience ? *

Mark only one oval.

	1	2	3	4	5	
Not Consistent	◯	◯	◯	◯	◯	Very Consistent

12. The virtual world seemed more realistic than the real world. *

Mark only one oval.

	1	2	3	4	5	
Fully disagree	◯	◯	◯	◯	◯	Fully agree

13. How real did the virtual world seem to you ? *

Mark only one oval.

	1	2	3	4	5	
Virtual	◯	◯	◯	◯	◯	Real

B.5 PANAS Questionnaire

3. Indicate your positive and negative feelings throughout your existence in the virtual space *

Mark only one oval per row.

	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
Interested					
Distressed					
Excited					
Upset					
Strong					
Guilty					
Scared					
Hostile					
Enthusiastic					
Proud					
Irritable					
Alert					
Ashamed					
Inspired					
Nervous					

Determined					
Attentive					
Jittery					
Active					
Afraid					

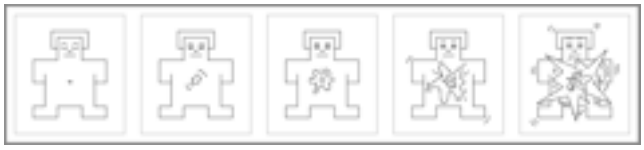
B.6 SAM Questionnaire

3. Select the picture that describes how happy you felt when you were in the virtual space *

Mark only one oval.

	1	2	3	4	5	
Unhappy	◯	◯	◯	◯	◯	Very Happy

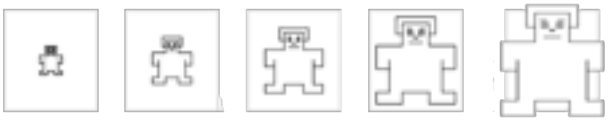
4. Select the picture that describes your level of excitement. *



Mark only one oval.

	1	2	3	4	5	
No excitement	◯	◯	◯	◯	◯	Very excited

5. Select the picture that describes how dominant you felt when playing the game. *



Mark only one oval.

	1	2	3	4	5	
Submissive	◯	◯	◯	◯	◯	Very Dominant

B.7 SUS Questionnaire

2. *

Mark only one oval per row.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
I think that I would like to use this system frequently.					
I found the system unnecessarily complex.					
I thought the system was easy to use.					
I think that I would need the support of a technical person to be able to use this system.					
I found the various functions in this system were well integrated.					
I thought there was too much inconsistency in this system.					
I would imagine that most people would learn to use this system very quickly.					
I found the system very cumbersome to use.					
I felt very confident using the system.					
I needed to learn a lot of things before I could get going with this system.					

B.8 Final Questionnaire

Final Questionnaire

* Required

1. Participant ID *

2. Were you able to understand the goal of this research? *

Mark only one oval.

- Yes
- No

3. Were the tasks and goals easier to understand and execute ? *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

4. How would you rate your experience on a scale of 1 - 5 *

Mark only one oval.

	1	2	3	4	5	
Awful						Wonderful

5. Was it easier to navigate and locate necessary objects in the environment ? *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree