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iVIWE - Intelligent Virtual Immersive Work Environment

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Abstract

In the last few years, we have witnessed significant growth in the number of meetings and work sessions that are taking place remotely with the aid of digital tools.

This is especially true for the current year, with the outbreak of the COVID-19 pandemic, which saw an increase of 90% of downloads on enterprise-focused platforms. The current acceleration in the usage of these services exposed their flaws and limitations with an impact on the remote meeting dynamics. Traditionally, teams have their sessions based on a grid of webcams and a 2D list of contacts, which lacks the habitual immersive experience that we usually get when working face to face and so it feels very detached, and it is hard to evaluate how successful and productive a meeting was.

Therefore, this project's main goal is to improve the user's experience when interacting with others while meeting online. Furthermore, it also aims to study a tool for supervisors to overview the meeting, with information and statistics that allow them to manage their teams best, look out for possible problems and improve remote online work performance.

There are currently efforts to improve the quality of online meetings with features such as background noise suppression, ability to blur or customise backgrounds, creation of meeting rooms, live captions, Etc. While necessary, these features do not overly change the software's essential feature in question: video conference.

The approach proposed in this project will focus on creating a 360º VR meeting environment through the implementation of an extension for Mozilla Hubs using Spoke, an online 3D scene editor that permits the creation of custom social scenes. Additionally, it will investigate the current platform's user metrics and probe team leaders, CEOs, managers, Etc regarding preferred and optimal user metrics for extraction.

With all this in mind, the results obtained from this thesis were: the development of a prototype that is inserted into a VR360º environment, the development of two surveys with and the extensive study of the best metrics that sum up the interpersonal dynamics in three axis-spatial exploration (360), Non-verbal language (Webcams) and personal interaction (Chat) as well as the analysis of the Hubs platform and its related services. Regarding the survey results, 68.3% of people affirmed they felt only moderate or little exhaustion after one meeting, however, at the end of a week of meetings, 48.8% felt extremely or very exhausted. The sentiment of inertia after a meeting is also felt very strongly by 63.3% of the participants. Furthermore, 31.6% claim they have a really hard time reading others' body language in these online meetings and 57.6% feel very little involvement in the meeting itself. However, when asked about their feelings on an immersive virtual reality meeting environment, their answers were very polarizing, half the participants felt it would be a good idea and encouraged it and the other half thought it would worsen their experience.

Keywords: Human-centered Computing, Virtual Reality
ACM:
CCS → Human-centered Computing → Interaction Design → User Centered Design
CCS → Computing Methodologies → Computer Graphics → Graphic Systems and Interface → Virtual Reality
CCS → Human-centered Computing → Human Computer Interaction → Interaction Paradigms → Virtual Reality

Resumo

Nos últimos anos, tem-se testemunhado um crescimento significativo no número de reuniões e sessões de trabalho que estão a ser realizadas remotamente com a ajuda de ferramentas digitais.

Esta afirmação é especialmente relevante e importante no ano atual, 2020, com o surto global de COVID-19 que consequentemente levou a um aumento de 90% de downloads em todas as plataformas de reunião virtual.

A recente aceleração no uso destes serviços expôs as suas falhas e limitações no que toca à dinâmica das sessões online. Tradicionalmente, as suas reuniões virtuais são feitas através de uma grelha 2D de webcams e uma lista de contactos. Esta interface não transmite a experiência habitual e imersiva que temos quando trabalhamos presencialmente, o que resulta numa sensação de desconexão e é difícil avaliar quão bem-sucedida e produtiva uma reunião foi.

Assim sendo, o objetivo deste projeto é melhorar a experiência de um utilizador quando interage com outros em contexto online. Para além desse, também visa funcionar como uma ferramenta para supervisores terem uma visão global de uma reunião, com informação e estatísticas que lhe permitam gerir a equipa da melhor forma, melhorar o desempenho desta e ser alertado para possíveis ou eventuais problemas.

Há atualmente esforços para melhorar a qualidade de conferências virtuais com *features* como supressão de barulho de fundo, possibilidade de costumizar ou desfocar o segundo plano, criação de *meeting rooms*, legendas em tempo-real,Etc. Embora necessários, estes atributos não mudam o principal aspeto do software em questão: a vídeo conferência.

A abordagem proposta para este projeto vai ser o foco principal na criação de um ambiente de reunião 360º em Realidade Virtual através da implementação de uma extensáo da Mozilla Hubs usando Spoke, um editor online de cenas 3D que possibilita a creação de cenas sociais customizadas. Adicionalmente, será feita uma investigação acerca das métricas extraídos dos utilizadores pelas plataformas atuais mais populares e uma sondagem a CEOs, líderes de equipas, *managers*, etc. a respeito das métricas a extrair que estes acham mais relevantes e úteis para a sua equipa e emprego.

Com isto em mente, os resultados obtidos para esta tese foram principalmente: o desenvolvimento de um protótipo que está inserido num ambiente de 360º em Realidade Virtual, o desenvolvimento de questionários direcionados tanto para um utilizador comum, como para um*meeting host*, um estudo sobre as melhores métricas que resumem as dinâmicas interpessoas em três eixos - exploração espacial (360º), linguagem não-verbal (webcams) e interação pessoal (chat) e uma análise da plataforma Hubs em si e todos os serviços e plataformas relacionados. Em relação aos resultados dos questionários, 68.3% das pessoas afirmaram que se sentiam moderada ou pouca exaustão depois de uma reunião, mas ao fim de uma semana de reuniões, estes valores mudam, e 48.8% sentiam-se extremamente ou muito exaustos. O sentimento de inércia depois de uma reunião, também era um fator importante, sentido muito fortemente por 63.3% dos participantes. Para além disso, 31.6% dizem que têm muita dificuldade em ler a linguagem corporal dos outros participantes durante uma reunião virtual e aproximadamente 57.6% sentem-se muito pouco

envolvidos na reunião em si. Apesar disto, quando questionados acerca dos seus sentimentos e opiniões em relação a um ambiente imersivo de reuniões em realide virtual, as respostas foram muito constrastantes: metade dos participantes acharam que era uma boa ideia e encorajaram e a outra metade pensou que iria piorar a sua experiência.

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Firstly, I would like to thank my supervisor, Alexandra Oliveira, who went above and beyond and above again of what was expected and asked of her. Without her guidance and help throughout this whole project, this thesis would be just the abstract and maybe chapter 1 section 1. She was always available and always seemed glad to help - her advice and feedback was crucial every step of the way. I cannot thank her enough, it was a great pleasure to work with her and I can truly say I have learned a lot from her. She inspired me to keep working and improving.

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And lastly, I thank my family and friends, who cooked dinner for me when I was up late working, popped their heads into my bedroom to see if I needed anything, who worked with me for countless hours, went on never-ending walks or just kept me company. The ones who, even far apart, always sent *"How is it going? Do you need help?"* messages every week, or even every now and then to make sure I was alive. This pandemic made me realise that mostly the small things matter. I will thank you all in person when I see you, but I think it is important to keep this written here because it is permanent and a reminder. I will never be able to thank you enough.

Alexandra Mendes

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Abbreviations

2D	Two-dimensional
3D	Three-dimensional
AI	Artificial Intelligence
API	Application Programming Interface
AWS	Amazon Web Services
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
IM	Instant Messaging
IP	Internet Protocol
MVC	Model-view-controller
P2P	Peer-to-peer
PSTN	Public Switched Telephone Network
RTCP	Real-time Transport Control Protocol
RTP	Real-time Transport Protocol
SFU	Selective Forwarding Unit
SIP	Session Initiation Protocol
SUS	System Usability Scale
TCP	Transmission Control Protocol
UI	User Interface
UX	User Experience
VoIP	Voice over Internet Protocol
VR	Virtual Reality
WebGL	Web Graphics Library
WebRTC	Web Real-time Communication

Chapter 1

Introduction

1.1 Context

Web conferencing is a very general term for various technologies that allow for two or more users from anywhere in the world to hold a real-time meeting over the internet. These technologies are usually internet-based using TCP/IP connections, and delivered via software as a service - *SaaS* - or, otherwise, run within enterprise data centres in an on-premises delivery model [6, 7, 8].

There are several types of online conferencing and collaborative services such as webinars - *web seminars* -, webcasts and web meetings which serve multiple purposes: to conduct business meetings and seminars, lead presentations, provide online education and offer direct customer support via remote keyboard mouse control.

The history of Web conferencing since the 1990s is part of the history of technological advancement in general. Many aspects of these technologies rely on other more significant advances, such as the internet and improved hardware processing power. Early Web conferencing tools depended on the internet to send text messages, then audio and, eventually, high-resolution video.

Although several Web conferencing tools have proliferated over the years, and particularly this year, some companies like Skype, which offers free long-distance video calls via the internet and has been acquired by Microsoft in May 2011, have been around much longer. Many other popular brands have been developed for enterprise Web conferences. Many of these offer specific features such as call monitoring, multiparty collaboration, screen and file sharing and more.

Never before the year 2019 have web conferencing platforms been as talked about and used. This is mainly due to the coronavirus epidemic.

To give context, an epidemic is when an infectious disease spreads quickly to more people than experts would expect [9, 10, 11]. Moreover, a pandemic comes from the Greek *pan* - all - and *demos* - people - and is an epidemic that has spread across a large region, for instance, multiple continents or worldwide, affecting a substantial number of people.[12] Throughout human history, there have been several pandemics of diseases such as smallpox and tuberculosis. The most fatal pandemic in recorded history was the Black Death (also known as The Plague), which killed an estimated 75–200 million people in the 14th century [13, 14, 15].

The World Health Organization (WHO) declared COVID-19 to be a pandemic when it became clear that the illness was severe and had spread quickly over several countries in different continents. Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered coronavirus. Most people infected with the COVID-19 virus will only experience mild to moderate respiratory illness and recover without requiring special treatment. The same cannot be said for people with health complications or older adults, since they are at a greater risk of requiring hospitalization and death[16].

As of 28 June 2021, there have been at least 3,940,744 confirmed deaths and more than 181,946,544 confirmed cases in the COVID-19 pandemic. The pandemic has resulted in travel restrictions and nationwide lockdowns in many countries. These lockdowns forced most people not working in essential jobs to turn to remote work and online meetings [17]. This project's proposal was made in partnership with **3Decide**. 3Decide is an innovative and dynamic company based in Porto, Portugal that has existed for over a decade. It focuses on the development of technological solutions, with an emphasis on UI & UX and the integration of advanced visual content such as maps, 3D models, 2D blueprints, 360º photos and 3D point clouds.

1.2 Motivation

In the last few years, we have witnessed significant growth in the number of meetings and work sessions that are taking place remotely with the aid of digital tools. [18]

This is especially true for the current year, 2021, with the outbreak of the COVID-19 Pandemic which led most people to turn to services like Skype, Google Meet, Teams, Zoom, Slack, Discord and Mozilla Hub in order to continue their work, even from home. Terms like "social distancing", "zoom meeting", "remote work", Etc., have seeped into our day-to-day vocabulary and become the norm.

With this unexpected change, the number of new users skyrocketed, which was an excellent opportunity for the platforms mentioned earlier, but also exposed the flaws in these types of services as well as the long term effects of social distancing on people's mental health.

A crucial flaw that may not seem important is the current presentation and "feel" of the experience: we are usually faced with a grid of webcams and a 2D list of contacts. This way of engaging with other people lacks the habitual immersive interaction we usually get when working face to face. It feels very detached, so it is tough to maintain an engaging conversation.

Besides technical issues that prevent meetings from going as smoothly as they could (poor internet connection or audio, lagging, low video quality) and a general lack of knowledge on how these technologies work, the psychological and social aspects of these interactions cause an impact on both the individual and the overall group, because even though we are connecting, it is not as satisfying. [19][20] [21]

With video calls, we only have sight and hearing to work with (which are dependent on the user turning on the camera and microphone), and even then, reading facial expressions and tone of voice is more challenging. Not to mention the fact that other essential cues, like body language

and general appearance, are entirely gone. The lack of these social cues can very easily lead to misunderstandings. [20] Besides, it is also harder to focus and pay attention to one's work when the distractions of daily life surround them: pets, family members, the laundry that should have been done, someone knocking at the door, Etc.

All these factors and more contribute to a decrease in productivity and an increase in stress levels, which influences how people react to feedback and comments. As such, working towards a more interactive and more 3D-like experience would be a considerable improvement in terms of work quality and efficiency and the workers' mental well-being.

Simultaneously, by extracting data and metrics from these online interactions, these services also can give companies insights into how to manage these virtual encounters best, improve a team's productivity and detect anomalies and problems.

This would also be a way to improve work quality and watch over the workers' mental well-being, which is, ultimately, this project's goal. However, legal and ethical questions are always raised when dealing with this type of topic, because of user privacy and the moral implications of monitoring a worker's every move online. Due to these complications, this phase will not be put into effect, only explored theoretically.

By analysing statistics, companies (and also teachers, for example) can have a better idea of how well the meeting went, if the people were energised, if someone seemed to be discontent or sad, who worked best with who and with this knowledge improve the performance and interpersonal dynamic of everyone involved. These statistics may include metrics such as how many people turn on their microphone, interact with other people, turn on their camera, how many times they write in the chat, answer questions, how long they stay in the meetings, how many are doing something else online, etc.

1.3 Objectives

The proposal's main objective is to improve the user's experience when interacting with others while meeting online so that they can feel a little more connected, despite the physical distance.

To this end, the following objectives contribute to achieve the thesis' main objective:

- The development and distribution of a questionnaire directed towards the general user in order to gain an overview perspective of videoconferencing platforms and related subjects like their mental well-being, experience working remotely, etc.
- The intensive study of Mozilla Hubs and their different platforms and services, which entails understanding thoroughly how each works, how they are connected, their available functionalities and every other relevant aspect.
- The implementation of functionalities taking into consideration the meeting's three main characteristics : **the virtual environment in itself**, **the team dynamic** and **the individual's sense of purpose and role in the team**.
- The coordination and cooperative effort to work with 3Decide to create a suitable environment, either in regards to the visual aspect and to the functionalities developed.

- The development and distribution of a final survey, whose role is to evaluate the final solution and the participant's reaction and thoughts to it

Furthermore, it also functions as a base for a tool for teachers/supervisors/managers, etc to have an overview of the meeting with information and statistics that allow them to best manage their teams, look out for possible problems and consequentially improve the performance of remote online work.

This second objective is not the main focus of this thesis and so this point will be explored theoretically mainly in the state of the art chapter and left for future works with this platform, meaning no algorithms for metric extraction were implemented.

Additionally, a survey regarding videoconferencing and user analytics was developed and sent out to meeting hosts, meaning people whose role in a videoconference is generally that of a host, such as CEOs, team leaders, managers. This survey's goal is to gather the host's thoughts on what best user data they would find useful about their employees and team members and their general experience organizing these virtual meetings.

1.4 Document Structure

This thesis is divided into seven main sections: **1 Introduction**, **2 State of the Art**, **3 Methodology**, **4 Mozilla Hubs**, **5 Perspectives on videoconferencing in the current global context**, **6 Intelligent Virtual Immersive Work Environment**, **7 Conclusions**.

The first section, the 1 **Introduction** , describes the project's 1.1 - **Context**, 1.2 - **Motivation** and lists its 1.3 - **Objectives**.

The 2 - **State of the Art**, highlights : the importance of 2.1 - **Group social dynamics** in online meetings and their effect and influence on the group's members and their work, the **current state of the video telephony software platforms** - enumerating, comparing, and describing the five most popular services' key feature and 2.2.3 - **Mozilla Hubs** platform, with a guide for the user regarding the Hubs interface and possible actions made available to them.

The 3 -**Methodology** chapter is comprised of the following sections: 3.1 - **Proposed Solution**, which details an outline of the proposed solution model for an intelligent virtual immersive work environment by listing possible features to implement, 3.2 - **Approach**, where an explanation as to how the work was conducted is given, as well as how the final work was evaluated.

The 4 - **Mozilla Hubs** chapter focuses on the 4.1 - **Software Architecture** and describes how each of the services that make up the Hubs platform work and how they are linked.

The fifth chapter, **Perspectives on videoconferencing in the current global context** focuses on the analysis of two questionnaires and so is divided into two sections: 5.1 - **General User's Perspective**, 5.2 - **Meeting Host's Perspective**.

The **Intelligent Virtual Immersive Work Environment** chapter is comprised of the following sections : 6.1 - **Deployment**, where an explanation of how a local development environment is

achieved is given, 6.2 - **Functionalities**, which lists and demonstrates how each functionality is implemented, 6.3 - **Evaluation**, which analyses the user feedback on the final product.

Finally, in the **Conclusions** section, a conclusion of the work done and expected results is provided, with an additional subsection discussing 7.2 - **Future Work** and possible improvements.

Chapter 2

State of the Art

This chapter focuses on the definition of a group, how it operates and basic social aspects. Furthermore, it connects these concepts with the current necessity for working online through video-conferencing services and the hurdles and struggles that come with this type of interaction, as well as new phenomenons that resulted from the coronavirus pandemic.

Additionally, a study of the current web-conferencing platforms regarding user metrics and available features is done. This study focuses on the most popular services.

Lastly, there is an overview of the Hubs by Mozilla platform, with a guide for the user regarding interface and current features. Also, there is a brief mention of similar platforms.

2.1 Group Meeting Social Dynamics

Although a group's definition is not a definite and agreed-upon concept, the basic characteristics are *two or more individuals connected by and within social relations*. [20]

Groups have the potential to be more than the sum of their parts, but each part defines the whole. A group with a naturally boisterous, mean-spirited, hard-working, chill or close-minded member will be different from the group with a domineering, self-sacrificing, lazy, anxious, or creative one. A group with many members who have only recently joined will be different from one with mostly long-term members. In short, this means that a group's dynamic is directly dependent on each group member's characteristics.

Group dynamics are the interpersonal processes that occur in and between groups over time. This includes:

- **Formative processes**, referring to the need to belong and affiliate in groups, contextual factors that promote the formation of groups and the development of group cohesion;
- **Influence processes**, which relates to aspects of group structure, conformity and dissent, social power, obedience to group authority and leadership;
- **Performance processes**, such as group productivity, social motivation, teamwork, and collaborative decision making;

- **Conflict processes**, which can be intragroup when within a group or intergroup when between groups;
- **Contextual processes** that depend on the group's physical setting and specific purpose.

When meeting online, a group always has a purpose: either work-related, like completing a task or discussing the next step in a process, or for entertainment and socialization reasons only. Either way, this means that to achieve said goal, the group is interdependent: each individual's outcomes, actions, thoughts, feelings and experiences are partially determined by others, which in turn, determines the group's outcomes and actions.

For this motive, roles, norms and other structural aspects are defined within the group. These characteristics lie at the heart of most groups' dynamic processes.

When joining a group, a member usually spends most of their time trying to understand their place in the group's structure and their role requirements. This because failure to meet that role's demand and expectations can lead to exclusion from the group.

Furthermore, having structure helps the group develop a sense of team identity. Team identity is crucial to motivate a group to work together towards their goals.[20]

Face-to-face teams form and function differently from virtual teams because traditional and virtual teams face different social processes. One of the critical reasons for the negative outcomes of a virtual team is their social context: they have weaker team identity, the members are not familiar with one another, have less affection towards each other and weaker social ties. Although strong social ties can be achieved, this will take longer than in face-to-face teams.

A crucial factor in an online team's success is how they manage internal conflicts. Relationship and task conflicts decrease both the worker's satisfaction as well as well-being. A possible source of social conflict is negative emotions, which online can form more quickly due to the lack of social cues present in real-life interactions like movement, body posture, etc. - non-verbal language. Interestingly, these negative emotions' contagious effect is spread very easily between team members, which affects the team output, such as performance, creativity, and cooperation. A way to prevent internal conflicts is through communication, feedback and an active and apt team manager or leader who steps in at the first sign of problems.

Although virtually the coordination process of a team takes longer than in face-to-face teams, this task is an essential one seeing as online there seems to be a higher level of detachment from the group as well as the project. Having a clear guide and set of objectives that are to be reached can help lead the team to success and foster good teamwork. A successful team focuses on the task they wish to conclude, on structured goals, and on developing a routine.[22]

2.1.1 Team Dynamics and *"Zoom Fatigue"* in current pandemic context

The group dynamics, characteristics and disadvantages associated with an online team mentioned above are to be expected no matter the context. Currently, however, a recent phenomenon dubbed *"Zoom Fatigue"* has appeared as a result of the COVID pandemic. This occurrence is defined by feelings of tiredness, worry or burnout associated with overusing virtual platforms.[19][23]

As a result of this condition being felt by most workers who have been forced to work remotely for a prolonged period, several studies are being done to understand this new fatigue. These studies come from diverse disciplines: from acoustics and business to psychiatry and social sciences. [19]

Audio has been proposed as the main reason for the draining nature of virtual meetings. This because even slight delays in virtual verbal responses affect our interpersonal perceptions negatively, with or without any internet or technical issues.[21]

Another explanation given is cognitive factors such as the increased ability to multitask online, which threatens an individual's attention capacity and is likely to contribute to fatigue.

Additionally, by revisiting the process of mental fatigue, one can also suggest that a substantial psychological component of said state, rewards-cost trade-off, is at the root of this phenomenon.

Essentially, with any behaviour, a trade-off is made between the likely rewards versus the costs of engaging in a certain activity. Even miner actions done subconsciously are made based on these estimates to maximize reward over cost.[19]

The connection between this reward assessment and the mental fatigue is psycho-biological: the activation of dopaminergic pathways in brain structures associated with reward increases alertness, energy and motivation - the opposite of fatigue, which means, less reward regarding a member's work results in more fatigue. This is important for two reasons; firstly, there is a lack of perceived reward relative to cost during video conferencing; secondly, face-to-face interactions, compared to online meetings, naturally activate more brain regions involved in reward. More active social connection is associated with more perceived reward, which decreases a worker's sense of fatigue.[19][24]

Also, regarding perceived reward, non-verbal communication is an essential contributor. Social cues like touch, joint attention, body posture, help process emotional content, and analyse others' responses to a team member's work. These cues are difficult to visualise, and subtle facial expressions and full bodily gestures may not be captured on video. Additionally, these factors improve a team's connection and likeability to one another, which boosts team identity and teamwork.

Simply put, virtual meetings can be associated with low reward and high cost.[19]

2.2 Current Virtual Meetings Platforms

Currently, there are a lot of virtual meeting platforms one can choose from when needing to organize an online session : ***Skype***, ***Microsoft Teams***, ***Google Meet***, ***Facetime***, ***WebEx***, ***Zoom***, ***Slack***, ***Join.ME***, ***Mozilla Hubs***, ***Discord***, etc.

The best and most adequate for a user depends on what their meeting's purpose is and how they wish to interact with their team because every virtual meeting software offers something unique and operates differently from the others. Microsoft Teams, for example, allows one to create teams and channels where each team can work independently on their tasks but still be able to access the main channel where everyone else is. Skype, on the other hand, grants users the ability to make

phone calls and leave voicemails, while Slack provides a lot of useful features - like alarm clocks, bots, threads [25] - that eases work between employees.

With the global pandemic, however, these platforms have been put in the spotlight, which has lead to the exposure of their flaws and shortcomings. This increased attention and high demand have made this medium highly competitive, with companies trying to fix bugs, add features and upgrade and update rapidly in order to keep up with everything else that is available on the market.

The software mentioned in the following sections has been chosen due mainly to two reasons: popularity and the general user's familiarity with it (which is a result of online research about this topic, a few inquiries to students and teachers regarding their most used technologies for remote work and personal experience) and relevance to this project.

2.2.1 Features

In order to better a virtual meeting platform, there is a need to understand the current state of this medium, which can be done by listing and comparing available features in each selected meeting software.

The following tables group important features by functionality: **Basic** features (2.1) which are present in every single one of these systems and are crucial for the functioning of a system of this type, **Visual** features (2.2) like face filters, which are key seeing as this project has a huge focus on the user's experience and immersivity when interacting with others online through these platforms, **Useful and Interactive Additional** features (2.3) such as virtual hand raising, which are also important because they add to the user's experience without necessarily being connected to the visual aspect of the software, **Organization** related features and **Security and Control** related features. These last two are not as relevant for the project as the other tables, but contain useful information about the current state of the art, and so can be found in the Annex (A.1 A.2).

Zoom is a video telephony software program developed by Zoom Video Communications. It provides the user with the following amenities: virtual meetings (with chat), training seminars, webinars, conference rooms, etc. It also allows for the users to share messages, documents and other types of files during the meetings. Zoom is free to use, with unlimited meetings for anyone, however, without a premium plan, every meeting has a 40-minute time limit. Despite this, it is ranked #1 in costumer reviews. [26]

Microsoft Teams is a proprietary business communication platform developed by Microsoft, as part of the Microsoft 365 family of products. It offers a workspace chat and videoconferencing, file storage and application integration. It's a secure hybrid environment where the user can engage in collaborative and inclusive meetings with Team meetings. Teams' biggest competitor is Slack, which works in a similar way. The biggest drawback would be its confusing structure and organization. Unlike Zoom, its meeting time limit is 24 hours. [27] [28]

Google Meet is a video-communication service developed by Google. It's an updated and improved version of Google Hangout. To get started you must have a google account, which is free. With a free plan, one can have an unlimited number of meetings, live captioning during meetings, controls for meeting hosts, etc. Google Meets is a big competitor for Zoom, seeing as

they work in basically the same way. However, when it comes to a meeting's time-limit, Google Meet recently announced they extended the usual 60 minute-time limit allowed for free plans to 24 hours until the end of June 2021.[29] [30]

Skype is a proprietary telecommunications application that specializes in providing video chat and voice calls between computers, tablets, mobile devices, the Xbox One console and smart-watches over the Internet. It also provides instant messaging services, allowing users to transmit text, video, audio and images to each other. It is one of the oldest platforms of this kind, launching in August 2003, and so it is widely spread and well-known. A user can have free video chats with up to 50 participants and no time limit.

WeBex Meetings is an enterprise solution for video conferencing, online meetings, screen share and webinars much like Zoom and Google Meet. And just like Zoom, it has a similar meeting time-limit for free plans - 50 minutes. Similarly like the previously mentioned technologies, it has cross-device compatibility, built-in meeting security and the ability to screen share. [31]

As shown below in Table 2.1, there are a couple features present in all platforms such as screen and file sharing, with Zoom and Google Meet giving the user the additional option to multi-share, meaning multiple users sharing screens simultaneously. Additional basic features indicated are call recording, audio-only conferencing as well as group and private messaging. Therefore, it can be concluded that these characteristics are essential for any system whose purpose is that of online virtual meetings.

So, when choosing a platform to plan a future meeting, the only differentiating factors for a user are each software's interface and participant and time limits. Both Google Meet and Zoom allow for 100 participants in a meeting, Skype on the other hand, only 50. Furthermore, Microsoft Teams lets 250 people participate at the same time in a meeting while WeBex allows for 150 users.

Feature	Platforms				
	Skype	Zoom	Microsoft Teams	Google Meet	WebEx
Screen Sharing	X	X	X	X	X
File Sharing	X	X	X	X	X
Chat Function	X	X	X	X	X
Group & Private Messaging	X	X	X	X	X
Audio-Only Conferencing	X	X	X	X	X
Call Recording	X	X	X	X	X
Unlimited Number of Meetings	X	X	X	X	X
Contact Channels (Chat groups)	X	X	X	X	X

Table 2.1: Basic Features

Like mentioned previously, a significant part of a user's experience when meeting others virtually is the interface and visual features offered by the chosen platform. And it is this part of the participant's interaction that will try to be improved in this project seeing as it has such a big impact on the productivity of the team as well as the individual's mental wellbeing. With that in

mind, Table 2.2 lists multiple features that affects the participant's image and relation with others. Features like face filters and background effects can brighten someone's day. A notable addition to Microsoft Team's visual features is the **Together Mode**, which uses AI segmentation technology to digitally place participants in a shared background, making it feel like the participants are all in the same room. Below is an image (2.1) that illustrates how this property works.

Feature	Platforms				
	Skype	Zoom	Microsoft Teams	Google Meet	WebEx
Audio and Video HD Call	X	X	X	X	X
Video and Audio Preview Screen		X	X	X	X
Background Effects	X	X	X	X	X
Touch Up my Appearance		X			
Together Mode			X		
Spotlight Speaker	X	X	X	X	X
Face Filters		X			

Table 2.2: Visual Features

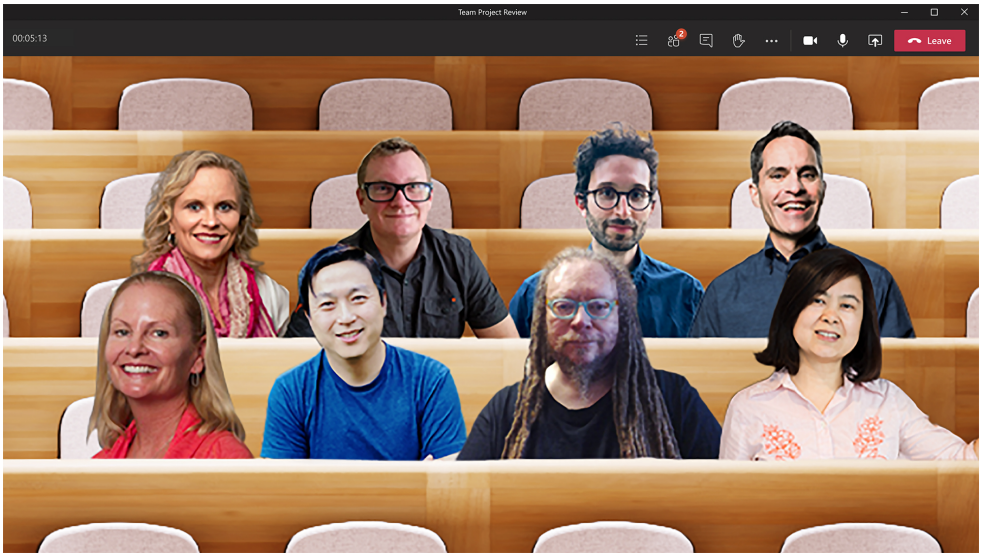


Figure 2.1: Microsoft Team's Together Mode

Despite all these visual aids and upgrades, the online meeting experience still feels very detached and cold because common to every platform is a 2D grid of camera feeds that hardly compare to a real social interaction with others. Additionally, poor camera quality and network issues increase this feeling of disconnection and isolation that remote work creates (Figure 2.2). [19]

Figure 2.2: Typical online meeting interface

In spite of the criticism mentioned in regards to these platforms' interfaces, an effort to improve and better the users' experience can be clearly seen, especially with the addition of features such as chat translation, polling, virtual hand raising and real-time subtitles. The latter is especially important for deaf participants. The inclusion of an interactive whiteboard is also of note since it helps in improving teamwork (Table 2.3).

Feature	Platforms				
	Skype	Zoom	Microsoft Teams	Google Meet	WebEx
Virtual Hand Raising	X	X	X	X[2]	X
Polling	X[2]	X		X[2]	X
Interactive Whiteboard	X	X	X	X	X
Smart Messaging[1]	X	X[3]	X		
Live Subtitles/Translation	X		X	X	X
Chat Translation	X		X		
Search Chat	X	X	X		

Table 2.3: Useful and Interactive Additional Features

[1] GIFs and stickers, @Mentions, Custom Reacts, Emoji Reactions, Rich Text Editing
[2] Premium versions only
[3] Reactions only

2.2.2 Metrics Extracted

The metrics extracted by the aforementioned platforms are vital because these translate into statistics and graphs which give the user an idea of that account's activity, either in objective terms like the number of meetings attended or more subjective terms like meeting quality.

In the section below, is a detailed description of all the statistics, graphs and charts that resulted from the extraction of user metrics by each platform.

This is an important study because it helps to understand which metrics can be more useful to infer a user's productivity and mental wellbeing and why the platform chose them.

2.2.2.1 Zoom

Overall

- **Active Users -** The number of current users on the account, the number of recent users and the total number of users on the account.
- **Meetings -** The number of meetings that were hosted on the account within the set date range, the total number of meeting minutes and the total number of participants who attended the meeting.
- **Toll-free Minutes -** The number of toll-free minutes used during that period by participants in the meetings.
- **SIP-Connected Audio Minutes -** The number of overall meeting minutes for connections through the Zoom SIP trunk.
- **CRC Port Usage -** The number of overall CRC ports used.
- **Webinars -**The number of webinars that are hosted by the account and the number of webinar participants.
- **Recording Storage Used -** The Cloud recording storage used on the account by users and the total storage available on the account.

The date range for these statistics and graphs can be changed at the top of the Dashboard homepage. It can be set for **the lats 7 days**, **30 days**, **180 days** or **12 months**.

Meetings

Top 10 Users

Displays the current top 10 users in the following categories (Figure 2.3):

- **Meeting Minutes -** The total amount of meeting minutes (including participants), for meetings hosted by the user.
- **Meetings -** Total amount of meetings hosted.
- **IM Sent Messages -** Most sent chat IM messages.
- **IM Received Messages -** Most received IM chat messages.

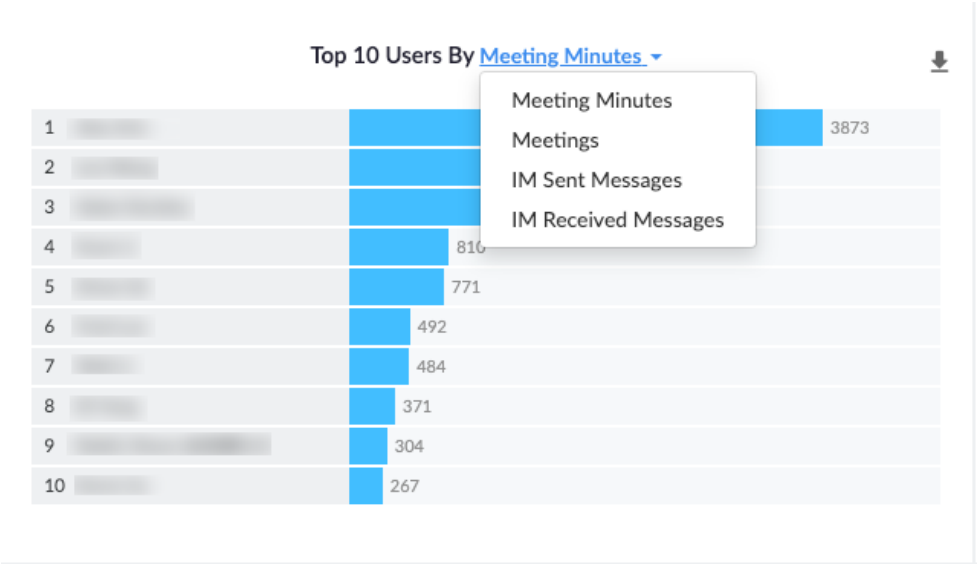


Figure 2.3: Top 10 Users - Meeting Minutes Source:[1]

Usage

Displays the overall account's usage over the date range in the following categories (Figure 2.4):

- **Meetings -** Number of meetings hosted.
- **Meeting Minutes -** Number of meeting minutes (including participants).
- **Participants -** Number of participants that joined meetings hosted by on the account.
- **IM Messages -** Number of IM messages sent and received by users on the account.
- **Groups-** Top 10 user groups, sorted by most meetings hosted by the groups.
- **Participant Info -** Displays the number of attendees, including a break down of those who enabled audio, video, or screen share from their device.
- **Audio Type -** Displays the number of attendees who used specific audio options including, Toll, Toll-Free, Call Out, VoIP, SIP.
- **Department -** Top 10 departments, sorted by most meetings hosted by the departments.

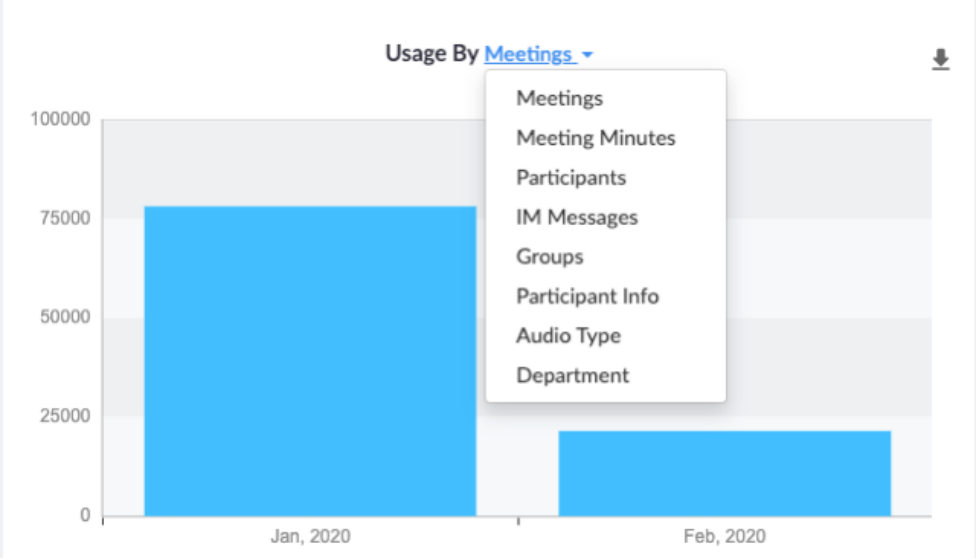


Figure 2.4: Usage Statistics Source:[1]

Top 10 Locations

Displays the top 10 countries used by total IM participants or Meeting participants (Figure 2.5).

Figure 2.5: Top 10 Locations Source:[1]

Meetings Year-to-Date Trend

Displays the number of host meetings from the beginning of the current year to the date chosen. The date range of the graph can be adjusted at the top of the graph (Figure 2.19).

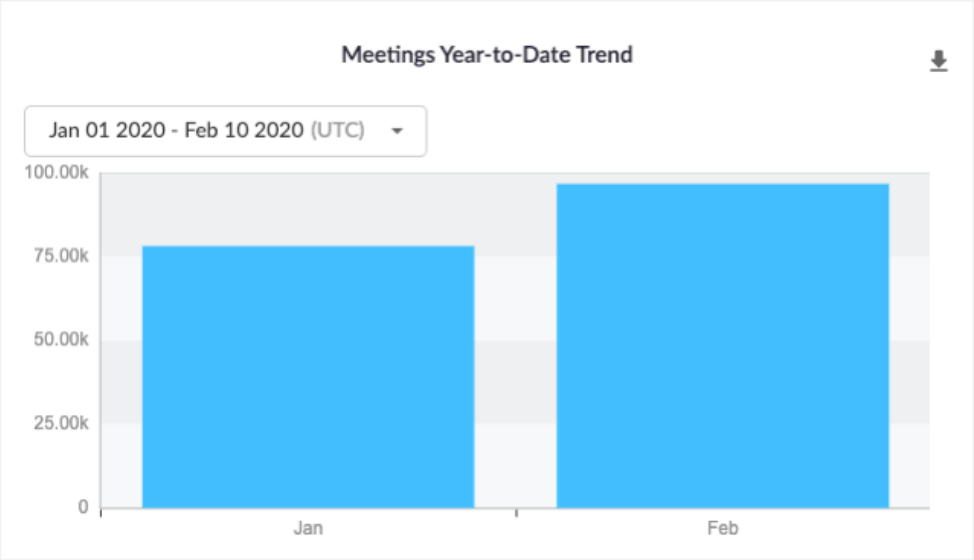


Figure 2.6: Meetings-Year-to-Date Trend Source:[1]

Devices

Displays a percentage breakdown of the types of devices used to attend meetings held on the account by users (Figure 2.7).

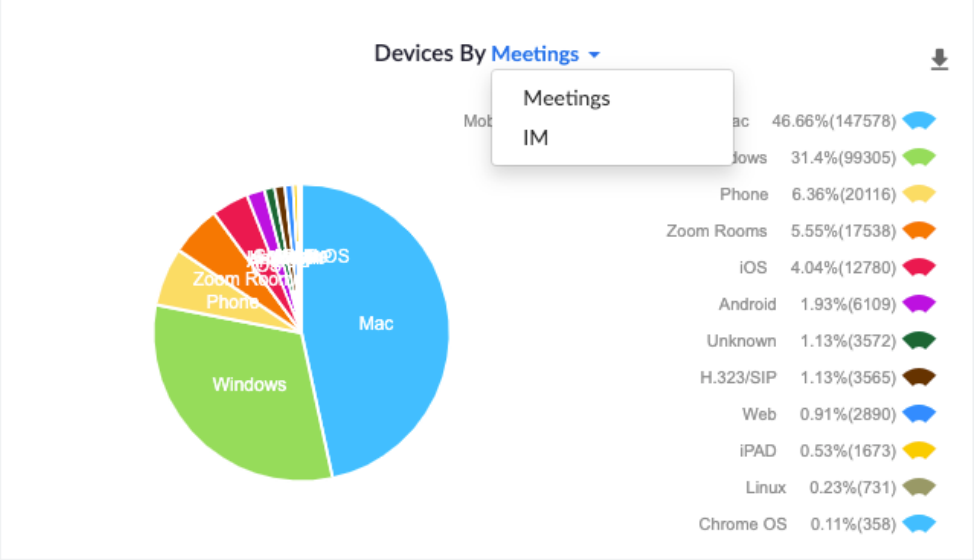


Figure 2.7: Devices Used Source:[1]

Version By Client

Presents a percentage breakdown of the Zoom software version used on the devices participants have used to join meetings hosted on the account (Figure 2.8).

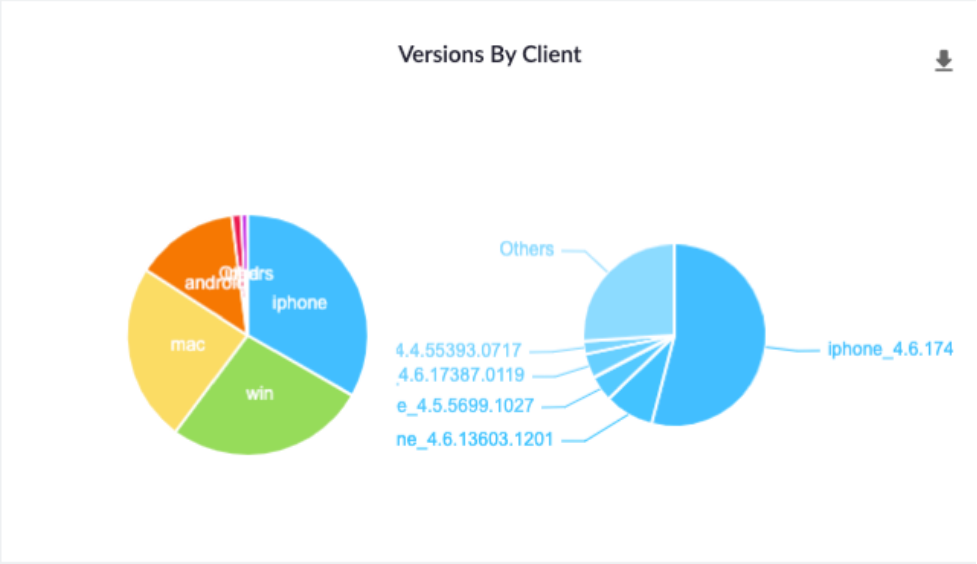


Figure 2.8: Version By Client Source:[1]

Zoom Meetings Client Customer Satisfaction Trend

The overall satisfaction rate of participants joining meetings hosted by the account (Figure 2.9).

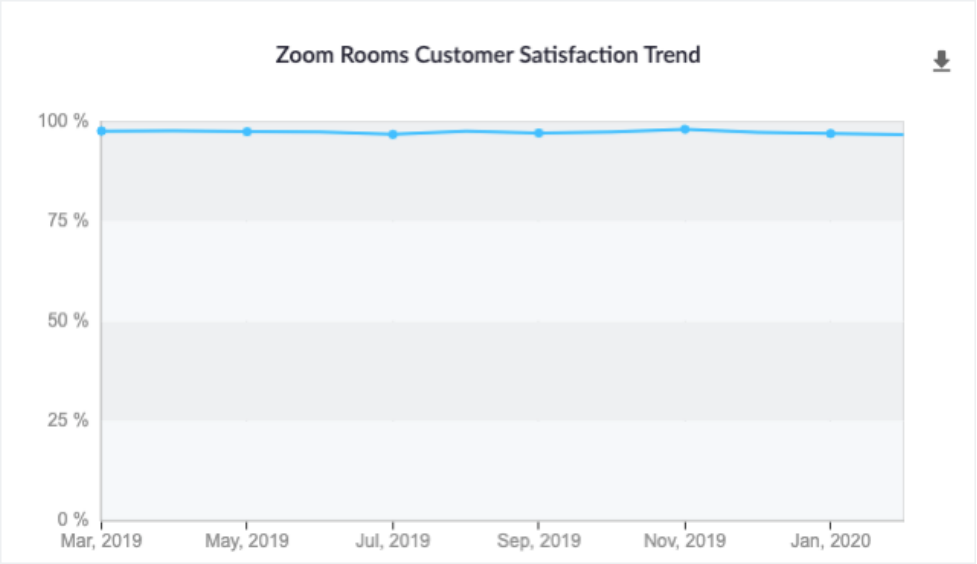


Figure 2.9: Zoom Meetings Client Customer Satisfaction Trend Source:[1]

Zoom Meetings Client Feedback

Presents a list of the number of participants' current accounts of negative feedback at the end of a conference, including shifts in patterns for those problems (Figure 2.10).

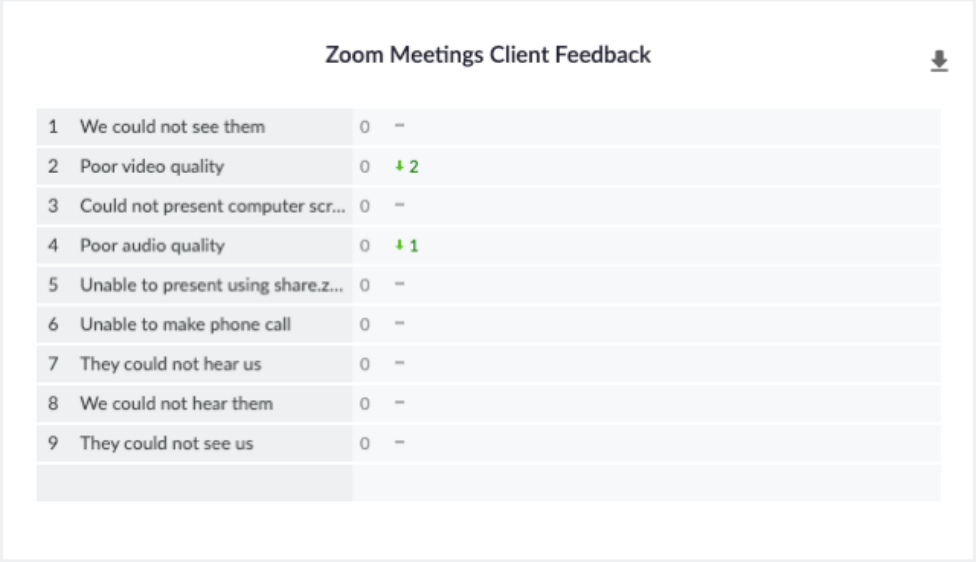


Figure 2.10: Zoom Meetings Client Feedback Source:[1]

Meetings and Webinars Issues Trend

Shows the number of issues reported by a participant's client over the set date range (Figure 2.11). The graph can be set to show:

- **Call Reconnection -** Participants who's device disconnected from the meeting but reconnected before being dropped due to timeout.
- **Video Issue -** Participants with video quality and/or stability issues.
- **Audio Issue -** Participants with audio quality and/or stability issues.
- **Screen Share Issue -** Participants with screen sharing quality and/or stability issues.
- **High CPU -** High usage of CPU resources by a participant's device.

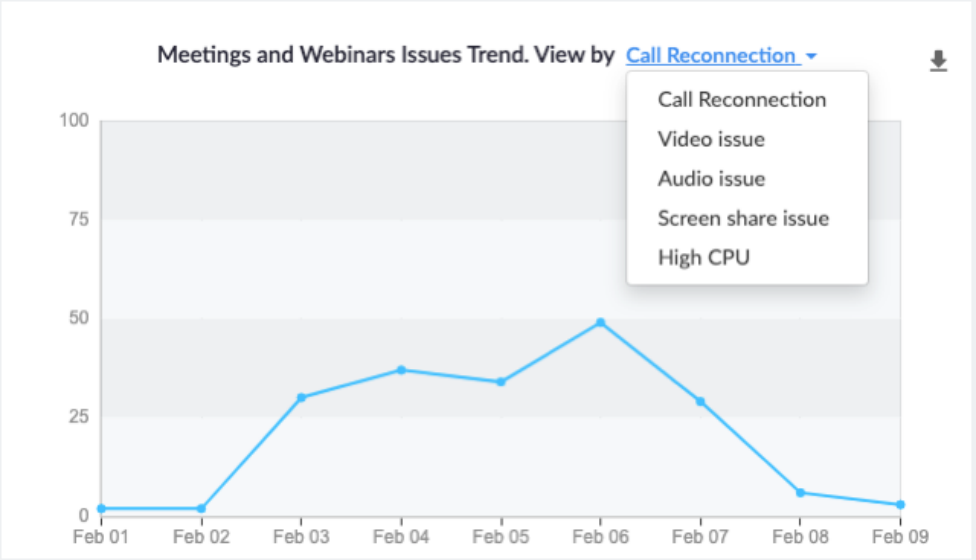


Figure 2.11: Meetings and Webinars Issues Trend - Call Reconnection Source:[1]

Zoom Rooms

Displays graphs and maps, offering a breakdown of Zoom Rooms use as well as reports on problems and feedback. If a business has several sites, the data may be collected to show a particular location (country, city, campus, building, Etc).

Top 25 Zoom Rooms Usage by Minutes

Displays the top used 25 Zoom Rooms in the organization. Next to each room, the overall usage in minutes is shown (Figure 2.12). Hovering over the bar will show the breakdown of meeting minutes used by the Zoom Room, as well as the usage of in-room screen sharing in minutes.

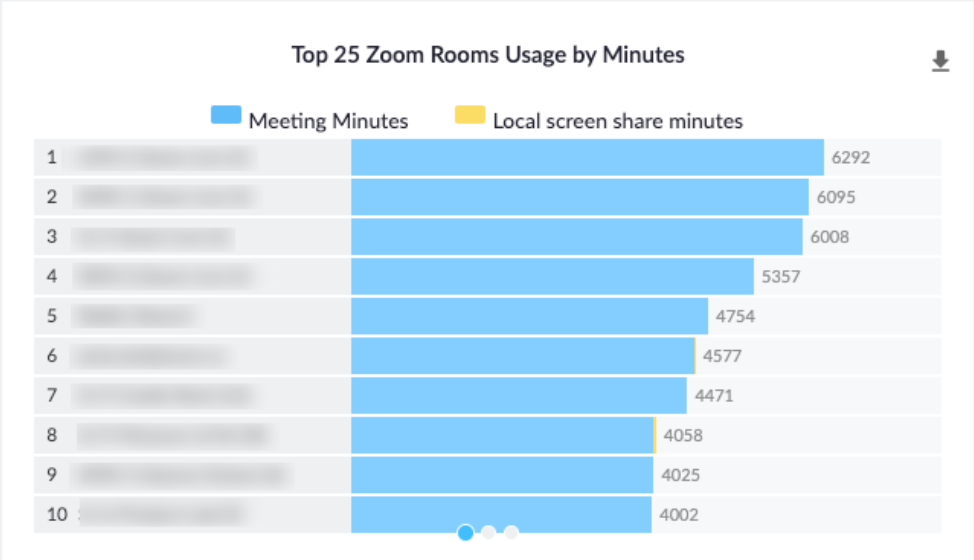


Figure 2.12: Top 25 Zoom Rooms Usage By Minutes Source:[1]

Zoom Room Usage

Displays the overall Zoom Room usage by the account (or specific location) over the specified time (Figure 2.13). Zoom Room usage can be displayed in the following categories:

- **Minutes -** The number of minutes used.
- **Checked In -** The amount of Checked-in/Released.
- **Sharing Minutes -** The number of minutes using local share in the Zoom Rooms.
- **Activity -** The number of active and inactive Zoom Rooms.
- **In-Room Participants -** The amount of reported in-room participants overall in Zoom Rooms.
- **In-Room Avg. Participants -** The average amount of in-room participants per Zoom Room.

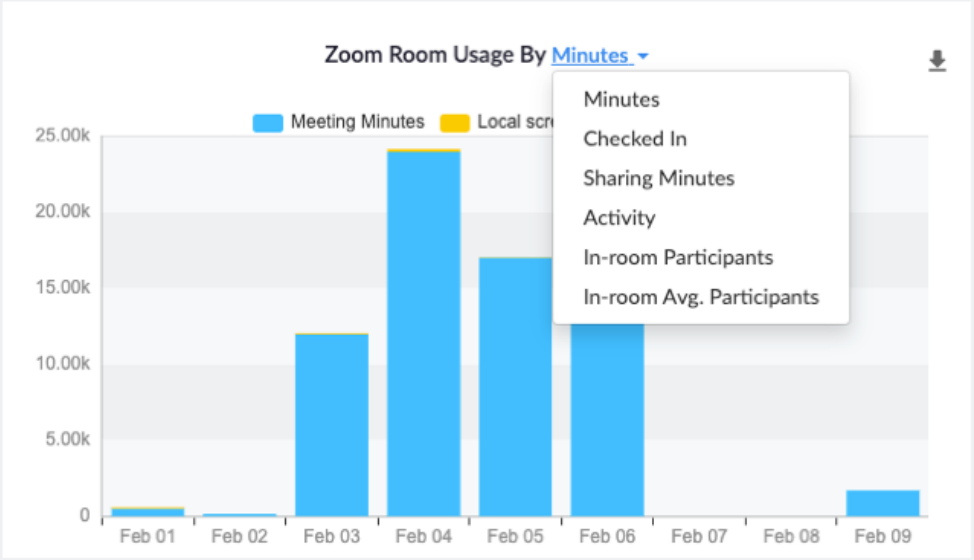


Figure 2.13: Zoom Room Usage Statistics - Minutes Source:[1]

Top 25 Zoom Rooms

By default, the graph displays the top 25 Zoom Rooms that have reported issues. The graph can also be changed to show the top 25 issues reported by Zoom Rooms, as well as the top 25 Zoom Rooms with the most in-room participants over the selected date range (Figure 2.14).

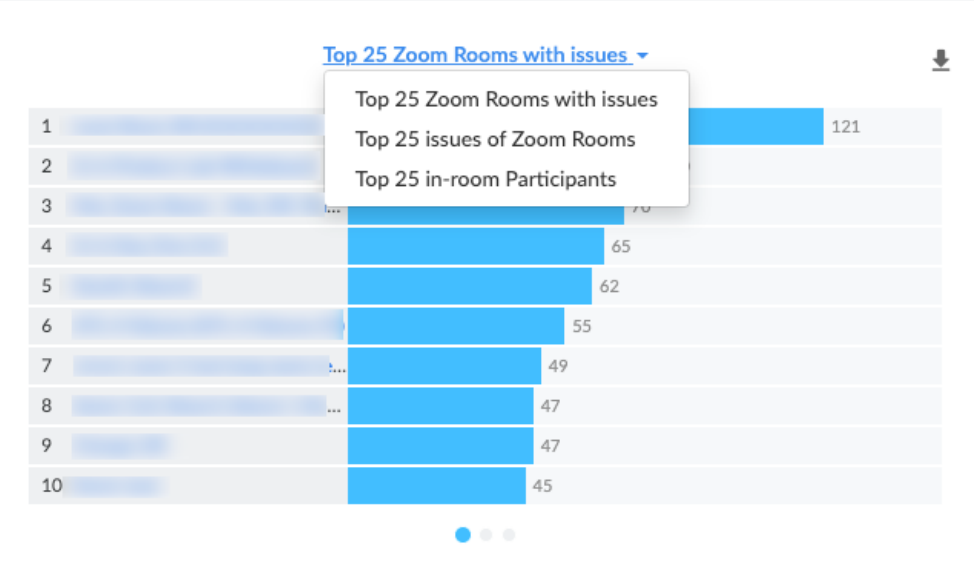


Figure 2.14: Top 25 Zoom Rooms Statistics - With Issues Source:[1]

Zoom Rooms Feedback

Displays the number of current reports of the selectable feedback issues by Zoom Room participants at the end of the meeting, including trend changes for those issues (Figure 2.15).

Figure 2.15: Zoom Rooms Feedback Statistics Source:[1]

Zoom Rooms Customer Satisfaction Trend

Displays the overall satisfaction rate of participants joining meetings hosted by the account (Figure 2.16).

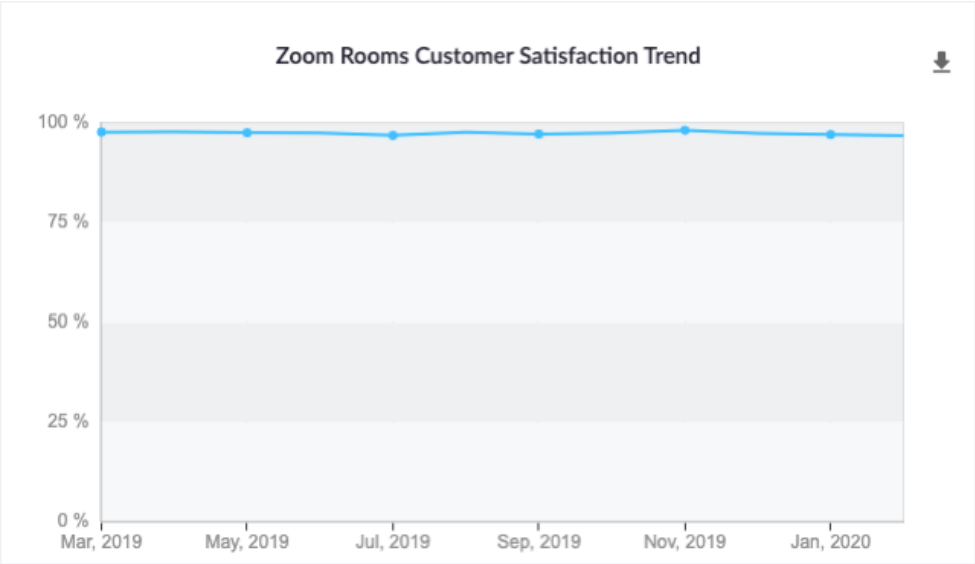


Figure 2.16: Zoom Rooms Customer Satisfaction Trend Statistics Source:[1]

Top 25 "Not Good" Zoom Rooms

Displays the top 25 (or less if there are not 25) Zoom Rooms, that have issues reported by the participants in the room (Figure 2.17).

Figure 2.17: Top 25 "Not Good" Zoom Rooms Statistics Source:[1]

Versions

Displays a percentage breakdown of the Zoom Room software versions of the Zoom Rooms on the account (Figure 2.18).

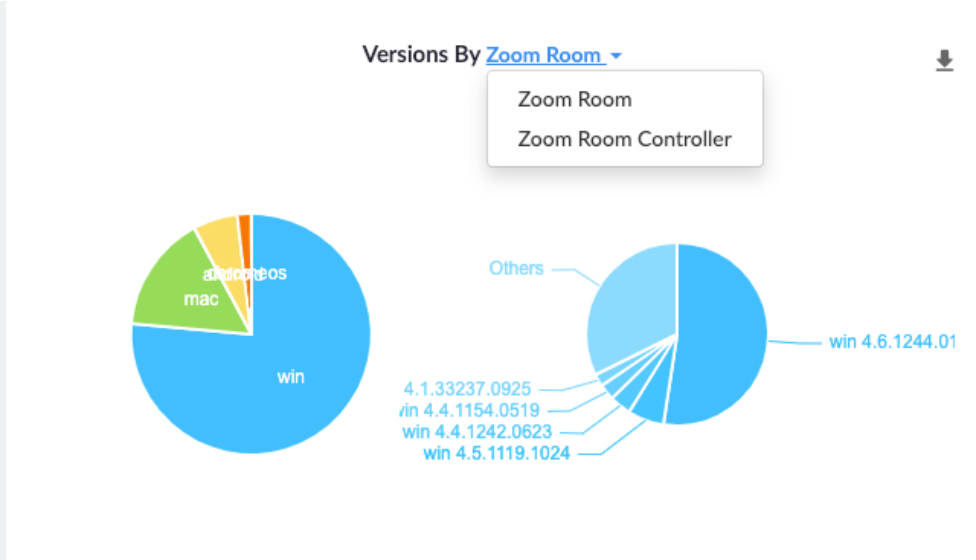


Figure 2.18: Zoom Rooms Version Statistics Source:[1]

2.2.2.2 Microsoft Teams

Workplace Analytics Overview

Microsoft has a cloud-based service, **Workplace Analytics**, that allows analysts to give insights about how their users spend their time and whom they spend it with. According to Microsoft, this is based on **Outlook** and **Microsoft Teams'** usage and empowers business leaders, managers, teachers with strategies for sales, user engagement, and productivity initiatives [32].

Workplace Analytics can be divided into the following categories:

- **Data privacy -** Informs how to protect and keep personal data private and how Workplace Analytics complies with applicable laws and regulations.
- **Set up and maintenance -** Informs how to set up and maintain Workplace Analytics, assign licenses, assign roles, prepare and upload organizational data, and change privacy and other settings.
- **Business insights -** Gives analysis scope information and research-based behavioral insights into how the user's organization currently gets work done and how to maintain or change work patterns over time.
- **Data analysis -** Informs how to analyze data with Workplace Analytics Explore the stats and Peer analysis, and how to create custom queries for more detailed analysis.
- **Plans -** Gives insight into how to create, manage, and track targeted change management plans to help reduce meeting load and increase focus time.
- **Frequently asked questions -** Lists the most frequently asked questions and their answers about Workplace Analytics roles, privacy, setup, and analysis tools.

The service allows for data exploration through the Workplace Analytics dashboards and creation of custom queries and query templates, allowing users to target their company's specific behavioural metrics. Because Teams is a more complex service than Zoom, seeing as it works as a workspace as well as a videoconferencing platform, it extracts metrics from other user activities besides user behaviour during meetings. Due to this, it collects more data from the user than the other services and consequentially can give a more extensive report on the user's overall behaviour.

For this project's purpose, only the metrics extracted during a meeting matter and as such, only analytics directly mentioning them will be referred and explained in detail, but it is important to note that those metrics are not the only ones analysed by the platform.

Data Analysis

Referred above, Data Analysis, gives a starting point with quick insights about the team and relevant data.

The following are available in Workplace Analytics:

- **Week in the life** summarizes day-to-day collaboration in the organization.
- **Meetings overview** summarizes meeting norms within your organization.

- **Management and coaching** summarizes collaboration between leaders, managers, and employees.
- **Internal networks** shows network connections between different people within a company.
- **External collaboration** summarizes employees' network patterns with people outside the company.
- **Teams collaboration** shows communication trends about how your employees use Teams for communication and collaboration.

Meetings overview

Meetings overview summarizes meeting norms within a team or organization. This section gives insight into meeting quality by viewing metrics about specific meeting components that can help determine the efficiency and effectiveness of meetings: **duration**, **number of attendees**, **redundancy**, **multitasking and conflicting meeting hours**, as can be seen in the following image (Figure 2.19). Employees who sent at least one email or instant message during a week are considered active and are included in the data for the weeks they are active.

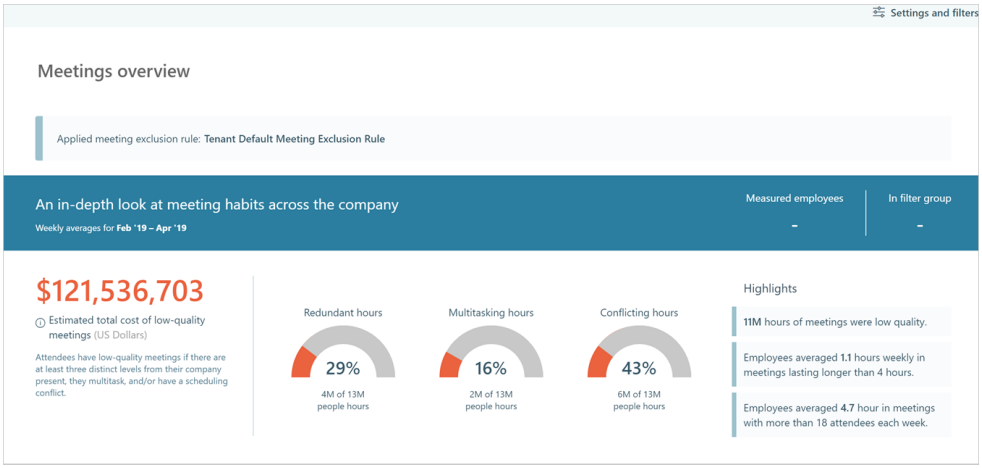


Figure 2.19: Meetings Overview Source:[2]

Low-quality meeting hours

This section summarizes the number of low-quality meeting hours for the team and shows the percentage of meetings with any of the three components of low-quality meetings (Figure 2.20).

Low-quality meetings hours are the number of hours a user spent in meetings where they qualify as **redundant**, are scheduled to be in **conflicting meetings**, or are **multitasking**. If a participant meets one or more of these conditions during a meeting, the meeting is counted as low-quality.

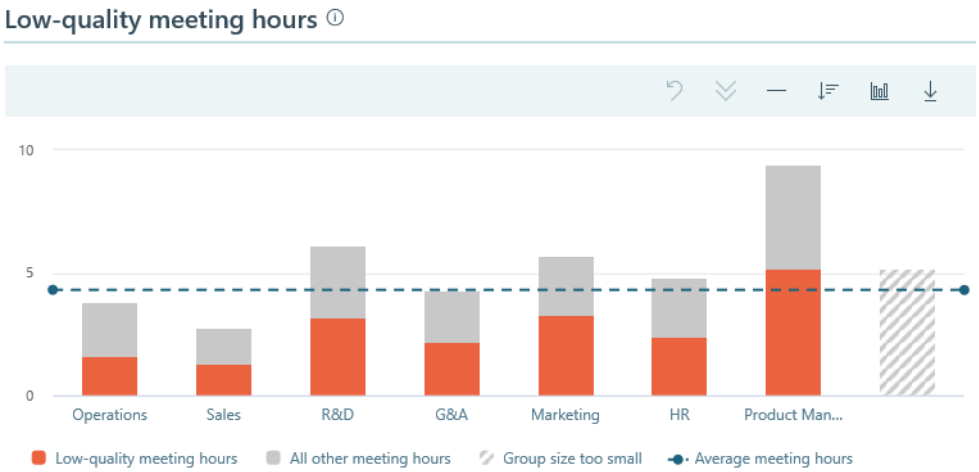


Figure 2.20: Low Quality Meeting Hours Source:[2]

Hourly rate

Managers have the option to include and **HourlyRate** column in the organizational data, which they can use to calculate the total cost of low-quality meetings as shown in Meetings overview. If the HourlyRate column is included, cost is calculated as the sum of a user's default hourly rate for the team multiplied by low-quality meeting hours.

Meetings hours by number of attendees

Each duration segment in the chart shows the time a user spent in meetings with the specified number of attendees (Figure 2.21).

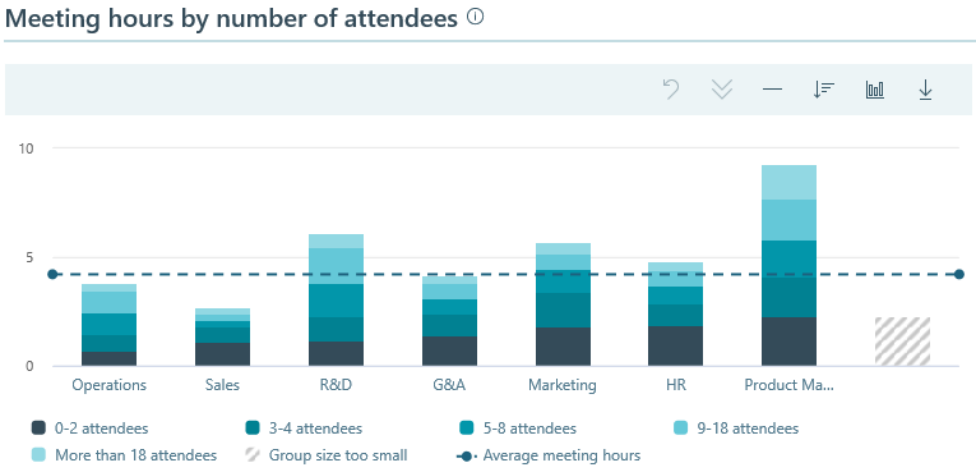


Figure 2.21: Meeting hours by number of attendees Source:[2]

Meetings hours by duration

Each duration segment in the chart shows the total time a participant spent in meetings of the specified number of hours (Figure 2.22).

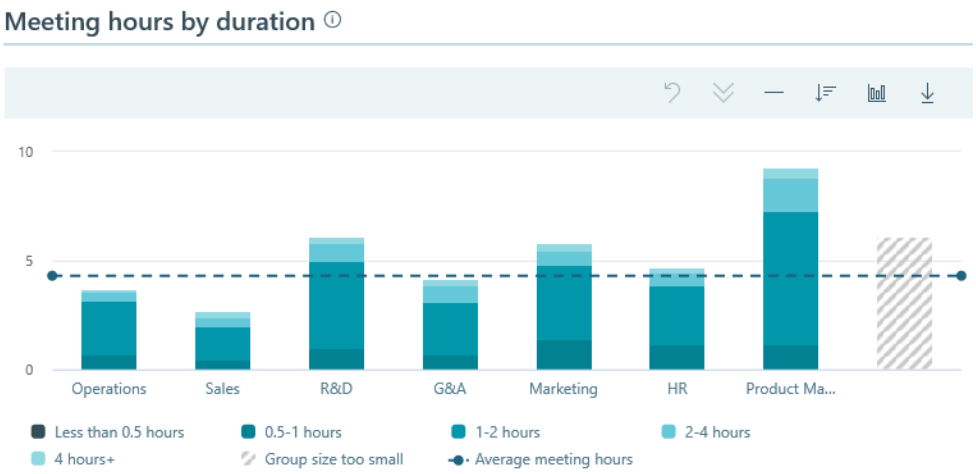


Figure 2.22: Meeting hours by duration Source:[2]

Redundant meeting hours

Redundant meeting hours is the time a user spent in meetings where at least three distinct levels in the person's team attended (Figure 2.23).

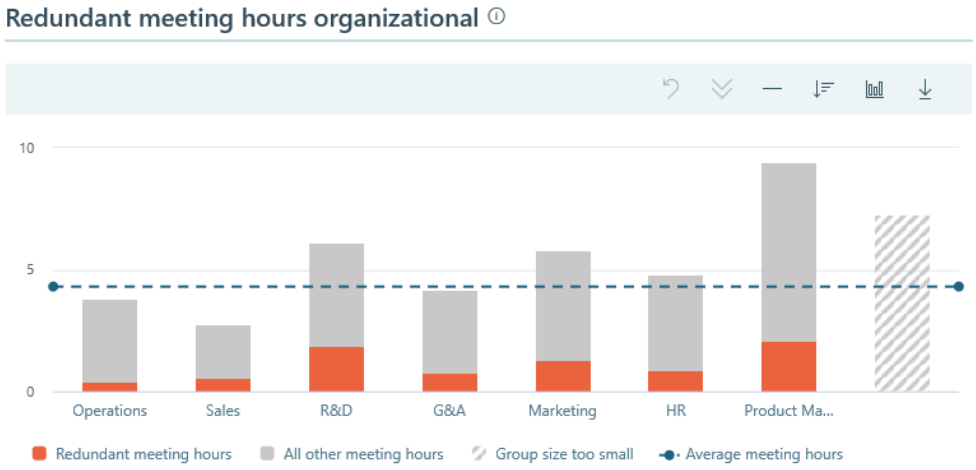


Figure 2.23: Redundant meeting hours Source:[2]

Conflicting meeting hours

Conflicting meeting hours shows the number of meeting hours where the user had overlapping meetings in their calendar. The count includes the entire duration of all overlapping meetings, not just the amount of time that overlaps (Figure 2.24). This number includes all non-declined meetings, which includes those with accepted, tentative, and no responses to the invites.

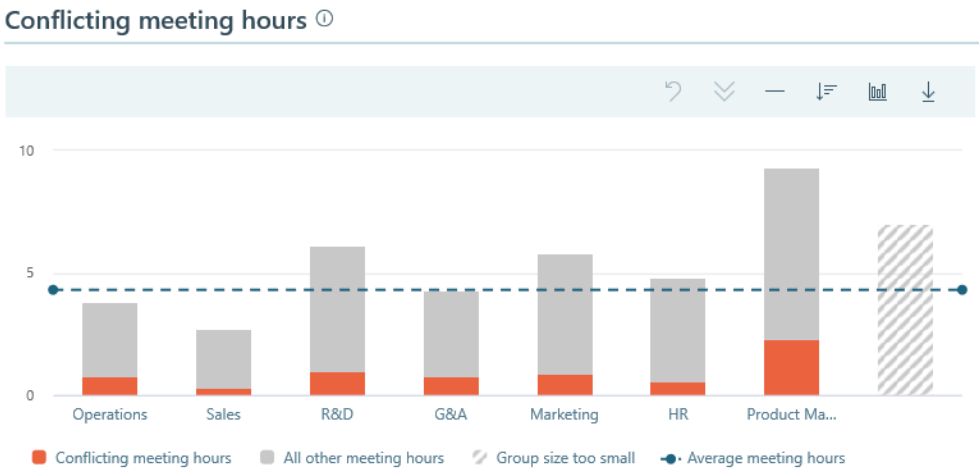


Figure 2.24: Conflicting meeting hours Source:[2]

2.2.2.3 Skype

The following Skype's metrics are for the current week (and trend totals for the previous six weeks):

System Usage Metrics

Registration

- **Unique user logons -** Total number of users with at least one logon session. A user with multiple logon sessions counts as one user, the same as a person who had just a single logon session

Peer-to-peer

- **Total sessions -** Total number of peer-to-peer sessions conducted, regardless of session type
- **IM sessions -** Total number of peer-to-peer instant messaging (IM) sessions
- **Audio sessions -** Total number of peer-to-peer audio calls
- **Video sessions -** Total number of peer-to-peer video calls. Note that video sessions are also counted as audio sessions: each video session is counted as one video session and one audio session
- **Application sharing -** Total number of peer-to-peer sessions that included application sharing.
- **Total audio session minutes -** Total amount of time spent in peer-to-peer audio sessions
- **Avg. audio session minutes -** Average amount of time spent in peer-to-peer audio sessions

Conference

- **Total conferences -** Total number of conferences (regardless of conference type) that were held

- **IM conferences -** Total number of instant messaging (IM) conferences
- **A/V conferences -** Total number of conferences that included audio or video
- **Application sharing conferences -** Total number of conferences that included application sharing
- **Web conferences -** Total number of web conferences
- **Total organizers -** Total number of users who organized at least one conference. Users who organized more than one conference are counted as one unique organizer, just like users who only organized a single conference
- **Total A/V conference minutes -** Total number of minutes devoted to audio/video conferencing. The Total A/V conference minutes metric summarizes all the audio/visual conference types, including: A/V conferences; IM conferences; app sharing conferences; data conferences; and PSTN conferences
- **Avg. A/V conference minutes -** Average number of minutes per audio/video conference
- **Total PSTN conferences -** Total number conferences that allowed dial-in access
- **Total PSTN participants -** Total number of people who participated in conferences that allowed dial-in access
- **Total PSTN participant minutes -** Total amount of conference time spent by dial-in users. For example, if one dial-in participant spent five minutes in a conference and another participant spent three minutes in the same conference, the total PSTN participant time would be eight minutes

In addition to the System Usage metrics, the following metrics display total for the current day and the previous six days (if you select Weekly View) or for the current week and the past six weeks if you select Monthly View.

For the next items, it is important to distinguish between two different kinds of failure:

- **Expected Failure -** An expected failure is typically a failure only in the most technical sense. For example, someone starts a conference but hangs up before anyone can join. Technically that's a failure: the conference was initiated, but not completed. However, that's an expected failure: if the organizer cancels the conference before anyone can join then the user would not expect that conference to be completed
- **Unexpected Failure -** An unexpected error is what the name implies: an error that, based on the circumstances, the user would not expect to occur. For example, a conference could not be held because the organizer's meeting policy could not be retrieved. That's an unexpected error: a participant should always be able to retrieve another user's meeting policy

When a specific type of failure is not mentioned, it means that both types are being taken into consideration on that metric.

Per-User Call Diagnostics

- Users with call failures - Total users with call failures, Conference organizers with call failures
- Users with poor quality calls - Total users with poor quality calls

Call Diagnostics

- **Peer-to-peer -** Total failures, Overall failure rate, IM failure rate, Audio failure rate, Application sharing failure rate
- **Conference -** Total failures, Overall failure rate, IM failure rate, Audio failure rate, Application sharing failure rate
- Top five servers by failed sessions

Media Quality Diagnostics

To measure a call's quality, one of the following metrics must present abnormal values: **Round trip**(ms), **Degradation**(MOS), **Packet loss**, **Jitter**(ms), **Healer concealed ratio**, **Healer stretched ratio**, **Healer compressed ratio**.

- **Peer-to-peer -** Total poor quality calls, Poor quality call percentage, PSTN calls with poor quality
- **Conference -** Total poor quality calls, Poor quality call percentage, PSTN calls with poor quality
- Top worst servers by poor quality call percentage

2.2.2.4 Google Meet

Meeting Information Statistics

- Meeting code
- Date
- Status
- Start and end times
- Duration
- Organizer's email
- Recording status (if meeting was recorded)

If given or used, the **average rating feedback from participants** and information about live streaming appears in this section as well. Live stream views are counted anytime someone joins the meeting to watch. A single user can have multiple views.

Meeting Participants Statistics

The Meet quality tool captures the following information:

- Participant's actions - Turning the microphone or camera off or on
- Screen sharing details - Length of time the participant shared their screen

- Network protocol changes (UDP, TCP)
- Network connection type - Wired, Wi-Fi, cellular connections
- If the participant was admitted after knocking, who admitted them
- If the participant was ejected from the meeting, who ejected them
- Audio and video transmission details
- Screen sharing transmission details

Timeline Statistics

Timeline that visualizes how the meeting developed over time. Up to six participants are shown by default and can be sorted by name or join time.

Participants section shows: when participants joined, participant's devices, mute and unmute actions.

Activities section shows: screen sharing beginning and end times, recording beginning and ending times, live streaming beginning and ending times.

Technical Statistics

Information on the network and system, audio and video, and any presentations.

Network Congestion	Percentage of time when network constraints prevented a Meet client from sending higher-quality video.
Round-trip time	Length of time for a packet to travel to Google and come back.
Jitter	Variation of the network latency for packets flowing between a client and Google.
CPU Load	Average CPU load on the user's device.
Type	Shows if a participant joined from: Meet hardware, Jamboard, Phone, Phone used for audio with a video stream, Computer, Android, iOS, Interop gateway, Unknown device
Bitrate	Amount of audio or video information received or sent, in bits per second.
Packet loss	Percentage of packets lost on the network, including packets sent and received between a client and Google.
Captured energy	Audio captured by the microphone. • *None* —The microphone isn't capturing audio or cannot be detected. • *Low* —The microphone is capturing energy but it's low, possibly due to the participant being quiet or far from the device or the microphone's gain setting being too low. • *Good* —Microphone is in the acceptable volume range.
Played out energy	Audio volume received and sent to the audio card. This number doesn't reflect the peripheral selection or muted speakers. • *None* —The received audio had no volume, which can be due to no one speaking (expected behavior) or an issue with the microphone (unexpected behavior). • *Low* —The audio received had very low volume, which can indicate that participants were inaudible or rarely speaking. • *Good* —The received audio was in an acceptable volume range.
Frame rate	Number of video frames per second sent or received by a client.

2.2.2.5 WebEx

It was not possible to find information publicly available. A premium account is necessary.

2.2.3 Mozilla Hubs

2.2.3.1 Concept

Mozilla's Hubs is a **VR collaboration platform** that runs in a browser. It allows the users to create, share and access a 3D room that others can join by using a URL. Hubs can be used to host a conference, teach a class, showcase art, or hang out with friends. It requires no installation process and has no gatekeeping.

Most importantly and relevant, is that it is an **open source project** and allows developers to improve and build upon what already exists. Additionally, it is also extremely customizable, which allows for much freedom and will be very useful for this project [33].

2.2.3.2 Similar Platforms

While Mozilla Hubs is a great, free, open-source project that allows friends, colleagues and strangers to share virtual rooms and hangout, watch videos and play with 3D objects, it is not the only of its kind. There are more than 10 alternatives to Hubs, not only websites but also apps for a variety of platforms. The following is a list of similar concepts. Ultimately, Hubs by Mozilla was chosen over these possibilities due to the open-source nature of their code, popularity and available features.

- **Second Life -** Second Life is a free 3D virtual world where users can socialize, connect and create using free voice and text chat. It was released 17 years ago, on June 23 2003. It is a fairly well-known and popular platform, however, they have not made available their code and its popularity over the years has decreased.[34]

Figure 2.25: Second Life environment

- **VRChat -** VRChat is a free-to-play multiplayer online virtual reality social platform, released on January 16 2014. Due to *YouTube* and *Twitch* it has gained a lot of popularity nevertheless, just like Second Life, their code is not open source.[35, 36]

Figure 2.26: VRChat environment

- **OpenSimulator -** It is an open-source multi-platform, multi-user 3D application server for hosting virtual worlds and the Metaverse. Unlike the two previous platforms, OpenSimulator is simply a server, designed to be easily expanded through the use of plugin modules, but nonetheless, a server.[37, 38]
- **Workadventure -** It is a retro computing 2D virtual environment where users can work, meet, establish video conversations, etc. It is free and also open-source, however, it is not a virtual reality platform.[]

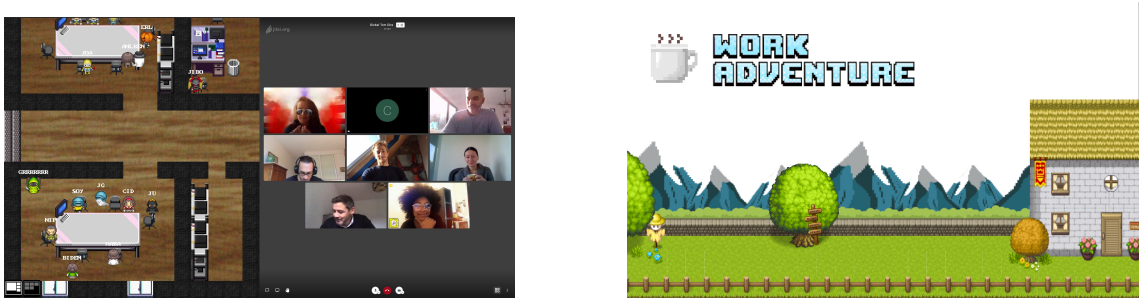


Figure 2.27: Workadventure environment

2.2.3.3 Features

Hubs makes it easy to connect and share images, videos, 3D models, and more. Its spatialized audio feature is also exciting and realistic because it allows users to have conversations with everyone in the space or break out into smaller groups. Regarding practical details, it runs in any browser and is designed for every headset [3].

Devices

Because of the tools used to develop the platform (WebVR and WebXR), this service is available for every and all Mixed Reality headsets, which includes from Oculus Rift and HTC Vive to Daydream and Cardboard Viewer. Alternatively, if there are no headsets of any sort at hand, the user can use their desktop or mobile phone. However, the downside of this is the loss of interactivity and realism that comes from using a Mixed Reality headset.

User Interface

The image below (Figure 2.28) represents a generic user's interface, listing and identifying the main features that are presented to the user when in a Hubs room.

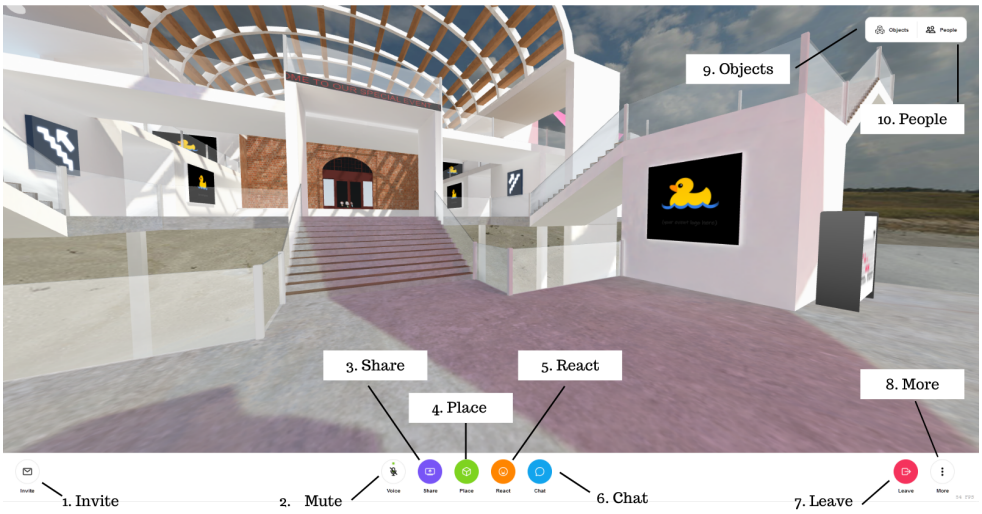


Figure 2.28: Mozilla Hubs' User Interface Source:[3]

The following list details the main features identified in the Mozilla Hubs' User Interface image (2.28).

1. **Invite -** Opens a dialog box with information on sharing the room with friends.
2. **Mute -** Toggles a user's microphone on/off.
3. **Share -** Enables the user to share their desktop, webcam, or phone camera with room members. The shared media will appear like a video in the room. Click this button again or use the object menu to remove the media.
4. **Place -** Opens a search tool to find media the user can bring into the room. Select from 3D models, scenes, avatars and gifs, or provide a URL or file for an image, video, model or scene. Additional objects that can be placed are listed below:
   - **Pen -** Allows to draw in 3D space. The user can change the pen's size and color, undo strokes, and generate 3D models from a drawing.
   - **Camera -** Creates a camera object that can take photos and videos of the room then add them to the room as objects. When a user takes a photo or video, a link also appears in the chat. By clicking the camera button again the camera object is removed.
5. **React -** Opens a menu where a user can select an emoji to spawn in the room.
6. **Chat -** Enables communication via text chat, create objects or enter commands. Commands include:

/leave - Disconnects from the room.
/grow - Increases user's avatar size.
/shrink - Decreases user's avatar size.
/duck - Creates a duck object.
/debug - Toggles physics debug rendering.
/vrstats - Toggles stats in VR.
/scene <scene url> - Changes the scene (moderators only).
/rename <new name> - Renames the room (moderators only).
/audiomode - Toggles left-right spatialization, but keep distance-based attenuation (experimental).
/audioNormalization <factor> - Equalizes audio levels (experimental)
/fly - Toggles fly mode.

7. **Leave -** Leaves the current room that the user is in
8. **More -** Opens a panel to display additional commands that are available. From this menu, one can favorite a room, modify user preferences, access help, and other settings. If the user is the room owner, this menu will also include settings related to the room permissions and current scene.
9. **Objects -** Displays a list of the media items that exist in the room. By clicking on the objects in the list additional options appear.
10. **People -** Displays information on the people in the room and lobby. Shows the number of room members, their names, and their device type.

Menus

In this section, it is presented a detailed account of the **Object Menu**, **Camera Menu**, **Drawing Menu**, **Video Menu** and **Invite Menu** by listing their features and describing the actions available to the user when choosing a particular feature.

Object Menu

The image below (Figure2.29) represents a generic object's menu interface, listing and identifying the main actions at the user's disposal when selecting a specific object.

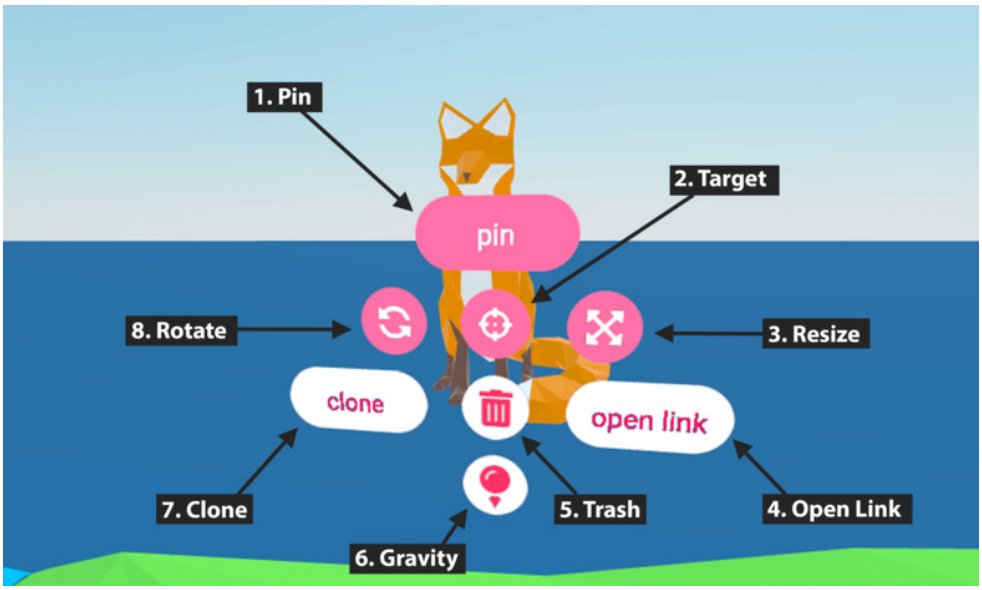


Figure 2.29: Mozilla Hubs' Object Menu Source:[3]

The following list details the main features identified in the Mozilla Hubs' Object Menu image (Figure 2.29).

1. **Pin -** Makes the object stay in the room when a user leaves. By default, objects disappear when their creators exit.
2. **Target -** Opens a focused view of the object. This menu item is present for media objects.
3. **Resize -** Resizes the object.
4. **Open link -** Opens the URL of the object in a new browser tab.
5. **Trash -** Removes the object from the scene.
6. **Gravity -** Makes the object fall to the floor.
7. **Clone -** Makes a duplicate of the object.
8. **Rotate -** Rotates the object.
9. **Magnify -** Displays a view of object low in the user's view. This menu item (not shown) is present for media objects.
10. **Convert to drawing -** Converts the object back to a drawing. This menu item (not shown) is present if the object originated from a drawing.

Avatar Menu

The following image (Figure 2.30) represents a generic user's avatar interface, enumerating and identifying the main actions available to the user when selecting another user's avatar.

Figure 2.30: Mozilla Hubs' Avatar Menu Source:[3]

The following list details the main features identified in the Mozilla Hubs' Avatar Menu image (Figure 2.30).

1. **Volume -** Changes the volume of the user's audio. (Doesn't affect the volume for others in the room.)
2. **Hide -** Hides another user's avatar and audio. This only applies to the current session; once the user refreshes, they will see them again. Other room members can still see and hear the user.
3. **Mute -** Mutes the user's microphone so that they are no longer heard by anyone in the room. (Moderators only.)
4. **Kick -** Temporarily kicks a user from the room. (Moderators only.)

Camera Menu

The image below (Figure 2.31) represents a generic user's camera menu interface, enumerating and identifying the allowed actions for a user when taking a photo or video.

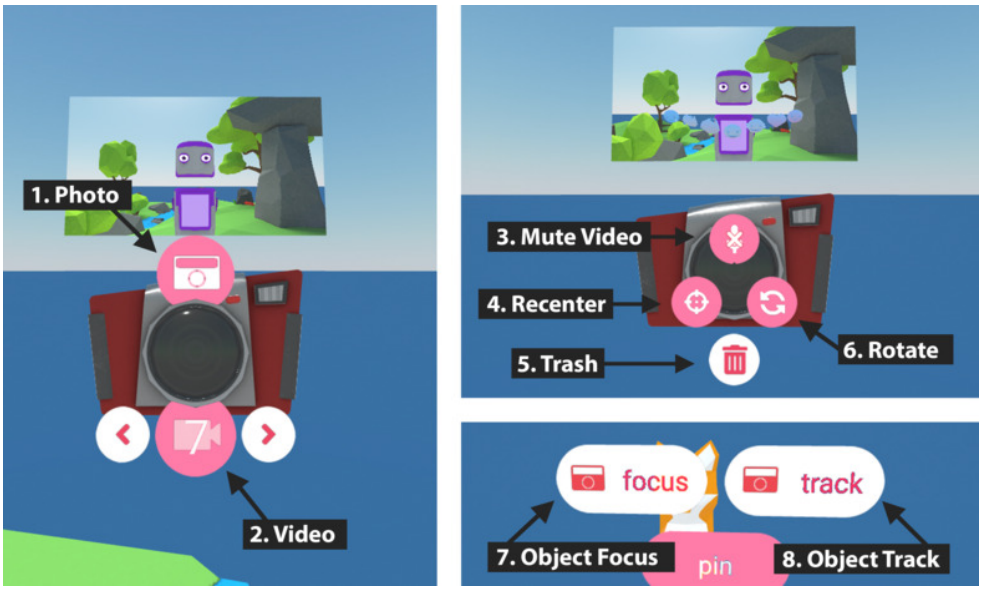


Figure 2.31: Mozilla Hubs' Camera Menu Source:[3]

The following list details the main features identified in the Mozilla Hubs' Camera Menu image (Figure 2.31).

1. **Photo -** Takes a still image then adds it to the room as an object.
2. **Video -** Records a video then adds it to the room as an object. To adjust the recording length, the user can use the arrows. Video recordings are temporarily saved to browser storage; a recording in progress may be lost if the browser runs out of space.
3. **Mute Video -** Controls whether audio is included in the video.
4. **Recenter -** Reorients the camera to face the user.
5. **Trash -** Removes the camera from the scene.
6. **Rotate -** Rotates the camera.
7. **Object Focus -** Reorients the camera to face the object or user.
8. **Object Track -** Makes the camera rotate to follow the object or user.

Drawing Menu

The image below (Figure 2.32) represents a generic user's drawing menu interface, enumerating and identifying the allowed actions for a user when drawing. The drawing menu allows the user to create 3D objects on the spot by sketching them on the Hubs room space.

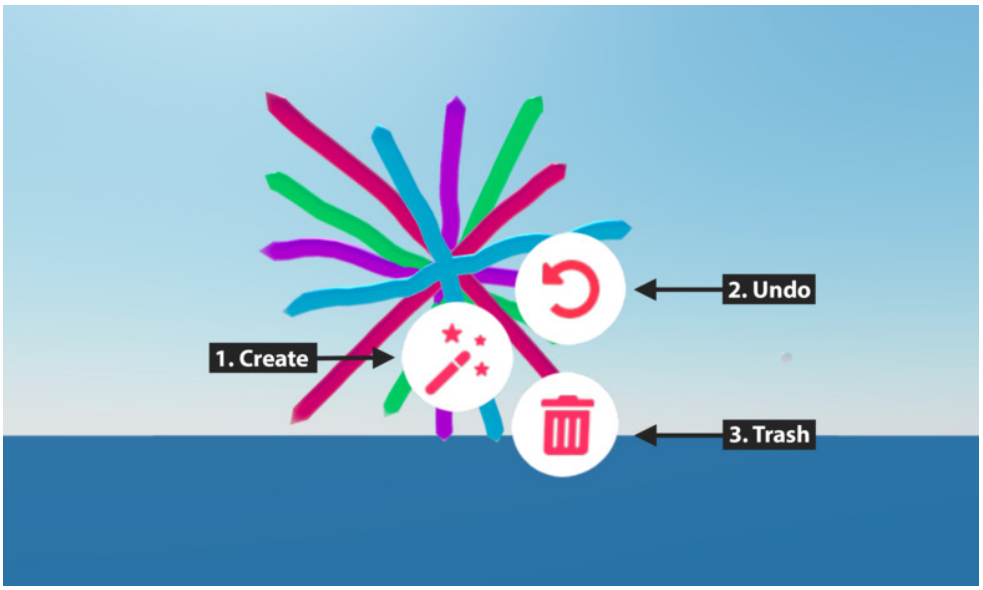


Figure 2.32: Mozilla Hubs' Drawing Menu Source:[3]

The following list details the main features identified in the Mozilla Hubs' Drawing Menu image (Figure 2.32).

1. **Create -** Makes the drawing into a 3D object.
2. **Undo -** Removes the last stroke.
3. **Trash -** Removes the drawing from the scene.

Video Menu

The image below (Figure 2.33) represents a generic user' video menu interface, which presented by hovering one's cursor on a video, showing the available video controls. The image numbers and identifies the different features on said menu.

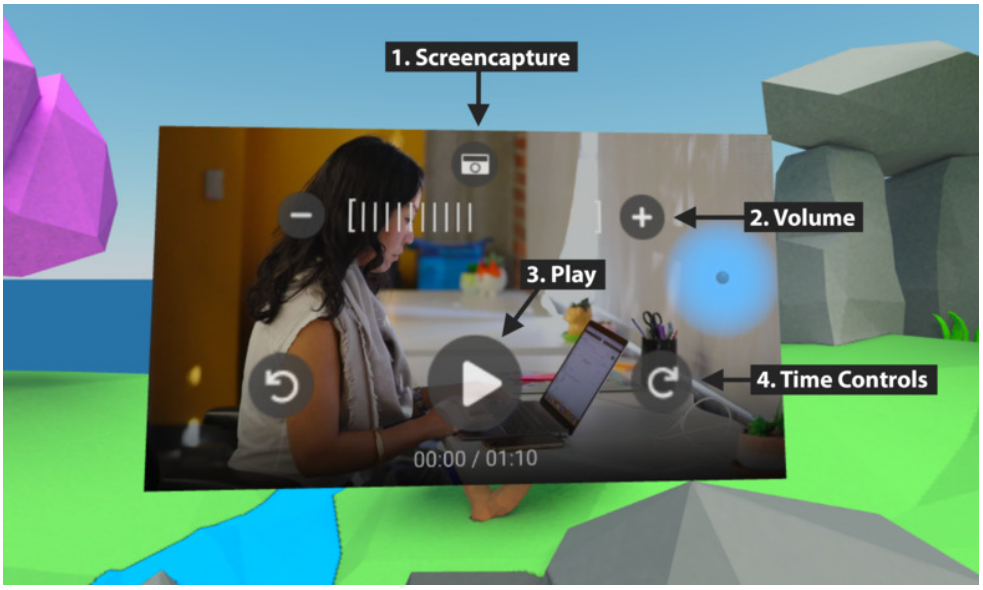


Figure 2.33: Mozilla Hubs' Video Controls Source:[3]

The following list details the main features identified in the Mozilla Hubs' video controls image (Figure 2.33).

1. **Screencapture -** Takes a screenshot of the video and then adds it to the room as an object.
2. **Volume -** Changes the volume of the audio playback for the user. (Does not affect the volume for others in the room.)
3. **Play/Pause -** Plays/pauses the video.
4. **Time Controls -** Jumps forwards/backwards in the video.

Emoji Spawners

A menu of emoji spawners is displayed when the user displays object or avatar menus, as shown in the figure below (Figure 2.34).

Figure 2.34: Mozilla Hubs' Emoji Spawners Source:[3]

The emoji menu lets a user spawn a grabbable emoji that emits particles when shaken. The emoji is deleted a few seconds after the user lets go of it.

Invite Menu

The "Invite" button opens a dialog with the information the user needs in order to share the room with others, so they can join them in the room.

2.2.3.4 Development

The Mozilla Hubs platform is ideal for this dissertation because it is an open-source project and highly customizable. Furthermore, the Mozilla team offers services that help developers create their own platform based on Hubs. These services include Spoke and Hubs Cloud.

Spoke is a built-in scene editor that allows for the creation of environments that can be used in Hubs rooms. The editor runs entirely in the browser and permits the developer to upload their

own 3D models, images and files to use in their own projects. Furthermore, Spoke also contains building kits and integrations with content providers to help build the perfect space.

Clouds on the other hand, allows for the user to self-host their own version of the platform as well as add custom branding, use their own domain name, limit access to approved users and build their own features and functionality.

2.3 Summary

To conclude, regarding the group dynamics of online teams discussed at the beginning of the State of the Art section, a few assumptions can be made. The first is that group dynamics are a very complex subject. Its characteristics and functioning depend on the group's context, meaning face-to-face or virtual interactions. Many factors contribute to these dynamics, such as group structure and team members characteristics, for example. Additionally, given the current global situation regarding the COVID pandemic, group dynamics and a team's wellbeing and productivity have been impacted negatively. This has resulted in a recent phenomenon named *"Zoom fatigue"*. Which means that now, in addition to the challenges teams faced in a normal situation when meeting online (e.g. the weaker team identity and member connection to one another and the project), there is the added problem of mental fatigue and increased anxiety and depression. Several studies have given explanations as to why this condition is affecting so many, suggesting that most likely a worker's sense of reward is severely undermined, giving the illusion that they have put a considerable amount of work into a task for little or no recognition.[19]

Relating this to the study of the current platform's features, it can be concluded that none successfully tackle these issues. Neither Zoom nor Skype or Google Meet makes the users feel more connected and valued besides the fact that they allow for the users to speak and see group members.

As for the metrics extracted by each service, not many platforms focus on the aspects relevant to this project: a user's activity during a meeting. The general information that these services extract regarding a user's account does not inform of the user's behaviour during a meeting, only of that account's activity. These statistics do not allow to make conclusions as to how the user interacts with the team, or unusual patterns of behaviour.

While WebEx does not allow free public users to access their statistics and analysis, this is the only case of missing information. Zoom and Skype extract data related to the account and its usage (e.g. total conferences of that account, devices and brand used by that account). However, both Google Meet and Microsoft Teams are essential to this project for different reasons. Google Meet extracts helpful user's metrics that inform a manager of the members' specific behaviour during a meeting (e.g. the participant's actions like turning the microphone or camera off or on, length of time a participant shared their screen).
On the other hand, Microsoft Teams gives an in-depth analysis of team dynamics and provides insights into improving a team's productivity. This is only possible because Microsoft Teams is a more complex platform and has more information to pull from seeing as it is not only a

videoconferencing service. As such, it is important to this project in the sense that their analysis and suggestions are good guidelines and inspirations for one of the proposed solution's goals.

In regards to Mozilla Hubs, it was chosen as a base for this project because it gathers a lot of the features and functionalities mentioned in the dissertation's proposal: it is a meeting platform with an immersive and interactive virtual reality environment that is also highly customizable and most importantly, is an open-source project.

Chapter 3

Methodology

The methodology chapter takes what was mentioned in the previous chapter regarding team dynamics, *zoom fatigue* and how these two are connected and explores solutions to the lack of closeness and general exhaustion felt by participants in these times.

Additionally, it describes the approach to the work developed, enumerating the steps to reach the suitable final product.

Finally, in the last section of the chapter, it is explained how the final product is evaluated and the user's thought on the experience.

3.1 Proposed Solution

The solution model is an intelligent virtual immersive work environment developed with 3Decide's team using Spoke. This virtual room is an extension of the Hubs by Mozilla platform, with added features. These features prioritize the creation of a more immersive and realistic work environment and take into consideration the current problems of online teams' virtual problems, coupled with the COVID-19-related recent phenomenon, *Zoom Fatigue*.

To this end, three main aspects of online meeting have been identified :

- **The context/environment**
- **The individual**
- **The team**

The aforementioned components are what comprises a user's experience online when meeting others - where you are, who you are with and how you feel are what influence what you do.

A user interacts directly with the environment: the space where they are in affects greatly their mood and productivity. It should be as realistic and at the same time comfortable as possible, in order to create a sense of closeness and proximity between members and better team bonds.

Simultaneously, how the individual feels and what they understand is their role in the team and meeting will dictate what they do and how they participate.

Lastly, the team and their work dynamic, is what glues the meeting together, and what impacts an individual the most.

The main objective of this project is to create a 360º VR work environment by improving upon these aspects. To this end, a few enhancements and/or upgrades are to proposed. For the context/environment:

- To add realism to the experience, which can sometimes feel disengaging, the environment will reflect the user's circadian rhythm and location by mirroring the time zone outside.
- To improve a member's sense of reward and team motivation, a virtual representation of a checklist with that meeting's tasks and issues will be created. This monitoring of the conference's work flow will be available to all participants and would be the team's leader responsibility to oversee. It would provide an outline for the meeting and improve focus.

To improve an individual's sense of identity and role in the group:

- Positive feedback and reward mechanisms could be added. This would be done as a means of rewarding a member's participation (e.g. if a user speaks 5 times during a meeting, they will be able to choose exclusive filters or change their avatar) making them feel important and valuable to the discussion.
- The avatar can represent and act out the emotions according to the user's speech (either verbal or written) by means of incorporating sentimental analysis [39]

To improve the team identity and connection between members:

- Differentiate the team's distinct roles through, for example, different avatars available for each role. This would strengthen team identity and establish team structure and one's role in it, bettering team dynamics.
- Ability to visualize the direction of interaction, meaning, when speaking directly to another member, the user's avatar could automatically turn to them.

3.2 Approach

The first step to the practical phase of this project was to look into Mozilla Hubs and understand how the different services work and are connected : **Hubs**, **Hubs Cloud** and **Spoke**.

This entailed investigating the **software architecture** of Hubs, reading Hub's documentation, analysing the hubs repository's structure, **creating a virtual environment** on Spoke - so as to understand how the environments are created, Spoke's functionalities, the models available, etc - and discover how one would use Hubs Cloud and its advantages over regular Hubs.

After this knowledge of the platform was acquired, two use cases were chosen :

- Implementation of a dressing room, where different avatars according to the user's role are available.
- Implement a dynamic sky feature to the virtual environment.

Having chosen the desired features, the next step was to have a local development environment where the functionalities above mentioned could be implemented and tested. After achieving this, the next logical step was to implement in order the features.

Concurrently, a questionnaire was developed and sent out to the general population. This questionnaire was used as a guideline and helped when making the choices throughout the work.

This is because it gave an insight into how the online conferences have impacted people mentally and in terms of productivity in regards to their work, as well their thoughts on VR technology, immersive environments and the features and areas that are lacking in the current videoconferecing platforms.

Another important part of the implementation process is the creation and the dispatch of questionnaires to companies' CEOS, managers, team leaders, etc. These surveys assess the companies' interests regarding visual features to be added to the meeting environment but most importantly, the user metrics they see more value in extracting and analysing.

In chapter 5, an in-depth analysis of each of these reports is given as well as the conclusions drawn from them.

Furthermore, it is essential to mention that all the progress was accompanied by the 3Decide team. Regular meetings were scheduled to give updates to the state of the work and discuss the next steps and the better ways to do them.

3.2.1 Evaluation

In order to evaluate the validity and goal fulfilment of the proposed solution, feedback reports were asked of the participants. They tested the virtual environment created and filled out a Google form with questions based on the first two questionnaires and also the **System Usability Scale** - SUS.

These reports are available in chapter 6, where the results are shown and explained.

3.3 Summary

To summarise, this chapter focuses on suggesting six possible features to be implemented in a virtual environment that could potentially add to, and improve a user's experience and create a more immersive space. These functionalities are grouped according to what they seek to improve in the aspects of the meeting that make up the user experience when meeting online : the individual, the environment, and the team.

The approach shows in a brief description, the major steps that constitute the work developed and the functionalities that were implemented.

And finally, the evaluation section mentions the final survey that was made to analyse the product's suitability to the proposed goal of this project : an intelligent virtual immersive work environment.

Chapter 4

Mozilla Hubs

This chapter highlights the Hubs platform. It was first mentioned in 2 the state of art chapter, but there it only focused on the user interface and briefly mentioned the other related services like Spoke and Cloud. Here, the software architecture is explained, each service is described - their purpose, how to run them, the technologies used, Etc - and an analysis of how they are all connected is done.

The knowledge explained here is what made possible the implementation of the proposed functionalities mentioned previously in the 3 methodology chapter.

4.1 Software Architecture

Mozilla Hubs is an online 3D collaboration platform that works for desktop, mobile, and VR platforms. Regarding Hub's software architecture, it is composed of three different components that work together: **two servers** responsible for the user-user communications and a **hubs client-side service** responsible for the graphics.[40]

Concerning backend services, as mentioned previously, there are two servers - ***Reticulum*** and ***Janus WebRTC***. Reticulum is responsible for all non-voice/video traffic between users while Janus deals with all the voice and video messages. As for frontend services, there is **Hubs**, which is the client-side of the software and what the client interacts with. Additionally, there is also Spoke, an online 3D scene editor, that allows a user to create the scenes which will be used in Hubs.

The following diagram 4.1 is a simple visual representation of the software architecture. In the next subsections, each of Hub's components will be explained.

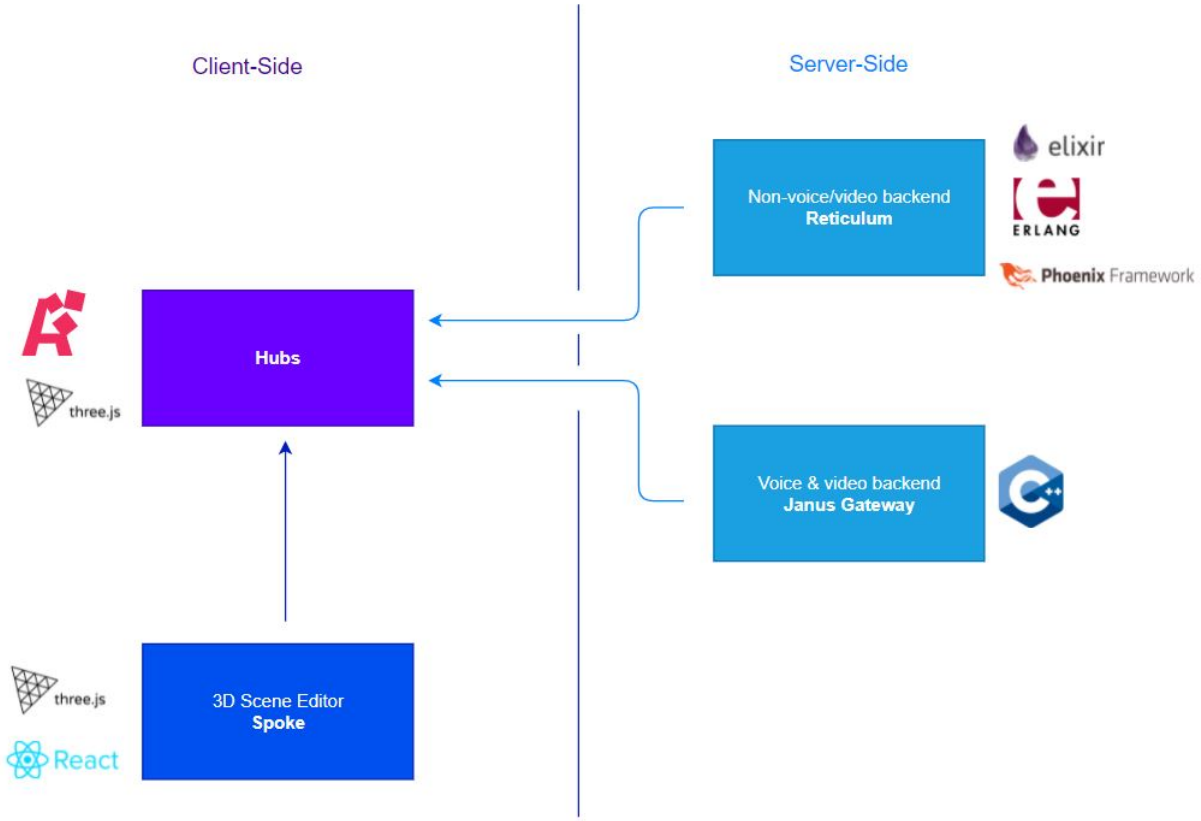


Figure 4.1: Software Architecture

4.2 Hubs Client

The hubs client-side service was made using **Networked-Aframe** which is a framework for writing multi-user VR apps in HTML and JS built on top of A-frame.[41]

Networked-Aframe **supports WebRTC and/or WebSocket connections**, **voice chat**, **audio streaming** to let users talk in-app, is **bandwidth sensitive**, meaning only sends network updates when things change, **cross-platform** - works on all modern Desktop and Mobile browsers as well as VR equipment like Oculus Rift, Oculus Quest, HTC Vive and Google Cardboard. It is also **extendable**, which means it allows for the syncing of any A-Frame component without changing the component code at all. [41]

A-Frame is a web framework for building virtual reality experiences. It is based on top of HTML, which makes it simple to get started. It is a **powerful entity-component framework that provides a declarative, extensible, and composable structure to *three.js***. Additionally, it allows developers to have unlimited access to Javascript, DOM APIs, three.js, WebVR and WebGL.

Originally, it was conceived within Mozilla, but is now maintained by the co-creators of A-Frame. It is an independent open source project and has grown to be one of the **largest VR communities**. [42]

Furthermore, and to give even more context, **three.js** is a cross-browser JavaScript library and API used to create and display animated 3D computer graphics in a web browser using WebGL.[43]

Currently, all simulations are done on clients - there is no server-side simulation of any kind (e.g. physics) - the servers function basically like a message bus that the clients use and that does slight modifications and authorization to messages along the way before being broadcasted to all peers. Ownership over objects and other incidental concerns to orchestrate the in-game experience among peers is all based upon the client protocol implementation.

On every client is being run a real physics simulation. The main difference between clients is which clients at a certain point are responsible for simulating a given object versus receiving messages about said object.

Regarding the platform's interface, it is thoroughly explained in the 2.2.3.3 features subsection of the Mozilla Hubs section 2.2.3 on the 2 state of the art chapter.

4.3 Spoke

As mentioned before, *Spoke* is an online 3D scene editor. It was developed by the Mozilla Mixed Reality Team and allows the user to build environments using 3D models, architecture kit pieces, lights, images, videos, GIFs and more, it is similar to a simpler version of Unity - simpler because unlike Unity, it currently does not allow for the addition of scripts and programming, although it was once a feature they had.

Once the scene is finished, it can be uploaded to Hubs where anyone can access it, or be exported as a gITF 3D model. Spoke integrates *Sketchfab* and *Google Poly*, which allows the user to use their available assets without needing to create their own. The figure 4.2 shows Spoke's interface.

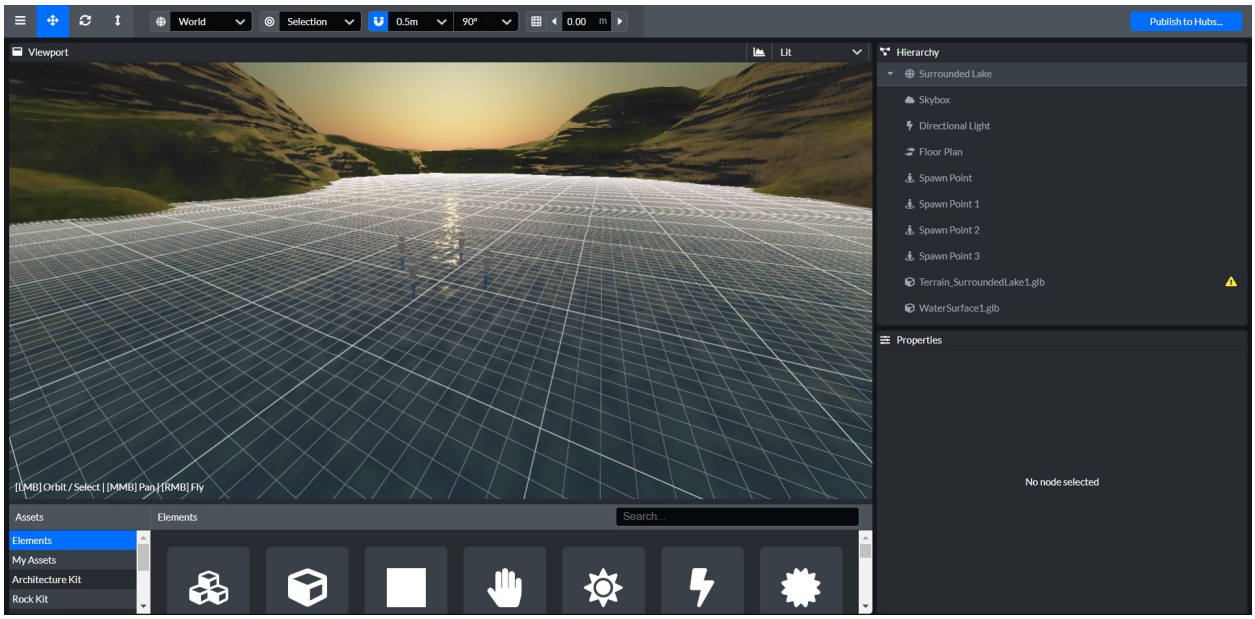


Figure 4.2: Spoke Interface

Spoke is a Single Page Web App built with **React** and **ThreeJS**. Its code is split between **UI**, **Editor** and **API wrapper**. For a better understanding of this platform's functioning, it is important to attend to the project's structure with a simple explanation for each folder's purpose.

spoke/
src/
api/ - Code for interacting with Reticulum and other Hubs services
Api.js - The main class for interacting with Hubs services
assets/ - Static assets
editor/ - ThreeJS editor codebase
caches/ - In-memory caches for editor content
commands/ - All editor actions have a corresponding command for undo/redo functionality
controls/ - User input and viewport controls
gltf/ - Custom Spoke glTF loader/exporter and related utilities
heightfield/ - Raycast based heightfield generator
helpers/ - ThreeJS helper Object3Ds for visualizing lights and other elements
kits/ - Code for packaging glTF kits
nodes/ - Nodes represent the Object3Ds surfaced to users as Elements
EditorNodeMixin.js - Mixin to turn any Object3D into a Spoke Node
SceneNode.js - Root Node that also contains the scene serialization/deserialization logic
objects/ - Custom ThreeJS Object3Ds
recast/ - Recast Navigation (NavMesh generation library) related code
renderer/ - ThreeJS Renderer / shader / WebGL related code
Renderer.js - Spoke's WebGLRenderer wrapper

utils/ - Various ThreeJS / Spoke editor related utilities
Editor.js - The main editor class controlling the internal state, commands, serialization, export, etc.
History.js - Undo/Redo system class
MeshCombinationGroup.js - Mesh combination optimization utility class
StaticMode.js - Static Object3D tagging utilities, used in combination with MeshCombinationGroup
ui/ - React UI codebase
assets/ - Components/utilities related to the Assets Panel
auth/ - Components/utilities related to authentication
contexts/ - React Contexts for global app state
dialogs/ - Components for various Spoke dialogs
dnd/ - React Drag-n-Drop related utilities
hierarchy/ - Components/utilities related to the Scene Hierarchy Panel
hooks/ - Various generic React hooks for use in React Components
inputs/ - Components related to input fields used throughout the Spoke app
landing/ - Components related to the Spoke landing page
layout/ - Components used for laying out other React components
navigation/ - Common navigation components used for non-editor pages
onboarding/ - Components/utilities used for the Spoke editor onboarding
projects/ - Components/utilities used on the Spoke projects pages
properties/ - Components used in the Properties panel (this includes editors for each element)
router/ - react-router related components and utilities
toolbar/ - Spoke's editor toolbar related components and utilities
viewport/ - Components/utilities used in the Viewport panel
whats-new/ - Components/utilities used in the what's new page
App.js - The root component of the Spoke single page app, including the Routes
EditorContainer.js - The root component of the Spoke editor
GlobalStyle.js - Global css styles
theme.js - The styled-components theme
utils.js - Utility methods used in the ui
config.js - Main Spoke configuration file. Where new elements/asset sources are configured.
configs.js - Hubs Cloud related <configuration
index.html - The HTML entry point for the Spoke single page webapp
index.js - Main application entry point

The React **UI** code can be found in the */src/ui* folder. The entry point to the app UI is *App.js*, which contains the React context providers and routes. These contexts include the *ApiContext*,

that provides access to the **Api** class.

The *EditorContainer.js* is the root component for the Spoke editor. It is responsible for fetching the files needed to load or create a project referenced by the current URL. It also had a number of other project related event handlers. Aside from handling the app state for projects, it also creates and manages an instance of the **Editor** class, which is the entry point to all of the ThreeJS editor logic.

4.4 Reticulum

Reticulum is a **hybrid game networking and web API server**, focused on Social Mixed Reality.[44] This Phoenix-based backend is responsible for managing state and presence. It is a mesh network of erlang/elixir/phoenix nodes.[44]

Erlang is a **programming language** used to build massively scalable soft real-time systems with requirements on high availability. Erlang's runtime system has built-in support for concurrency, distribution and fault tolerance.[45, 46]

Elixir is a **functional**, **concurrent**, **general-purpose programming language** that runs on the virtual machine used to implement the Erlang programming language. It builds on top of Erlang and shares the same abstractions for building distributed, fault-tolerant applications. Elixir also provides productive tooling and an extensible design.[47, 48]

Phoenix on the other hand, is a **web development framework** written in Elixir. Phoenix uses a server-side model-view-controller (MVC) pattern. Based on the Plug library and the Cowboy Erlang framework, it was developed to provide highly performant and scalable web applications. In addition to the request/response functionality provided by the underlying Cowboy server, Phoenix provides soft real-time communication to external clients through WebSockets or long polling.[49]

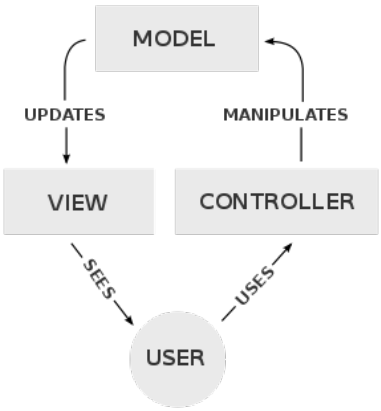


Figure 4.3: MVC software design pattern - Popular for web applications

Reticulum is responsible for all non-voice/video traffic between users. When a user connects to a room, they are connecting to a load-balanced node on this mesh over websockets, and messages are relayed between all users in that room across the mesh via a pub/sub system called

phoenix channels. Pub/sub is shorthand for **publish/subscribe** messaging, an asynchronous communication method in which messages are exchanged between applications without knowing the identity of the sender or recipient.[44]

Furthermore, Reticulum has behind it a **PostgreSQL database**, which, alongside a file store for the two methods of durable storage - managed also by Reticulum -, is responsible for persistent state. When a user updates permanent room state, pins objects, etc, they are interfacing with APIs in Reticulum to update bits on those two backing stores.

4.5 Janus

Janus is an **open source, general purpose, WebRTC server**.[50] It was conceived to be a general purpose server and as such, it does not provide any functionality other than implementing the means to set up a WebRTC media communication with a browser, exchanging JSON messages with it, and relaying RTP/RTCP and messages between browsers and the server-side application logic they're attached to. Any specific feature/application is provided by the server side plugins, that browsers can then contact via Janus to take advantage of the functionality they provide.

It was implemented using **C** because the goal was to have a small footprint and that could be equipped only with what was really needed, hence the pluggable modules. Janus' aim is to allow the user to deploy either a full-fledged WebRTC gateway on the cloud, or a small nettop/box to handle a specific use case.

The current version of the server is tailored for Linux systems but can also be compiled and installed on MacOS machines as well. Windows however, is not supported.

Regarding Hubs and its role, Janus serves as a **WebRTC proxy used for centralizing network traffic in the Hubs client**. It is responsible for all voice and video messages meaning, all users present in a room are connected to the same physical SFU node running Janus. **SFU** stands for **Selective Forwarding Unit** and is a method for connecting users in real-time interactions, using a server to route media streams between those users. Media and data is sent from one user or peer to a server that acts as a relay point for all the other peers connected to that server.[51]

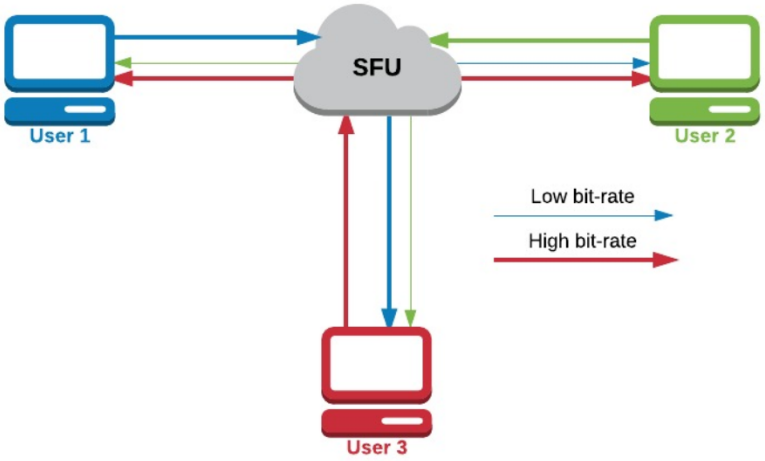


Figure 4.4: SFU method

4.6 Hubs Cloud

Hubs Cloud is another component of Mozilla Hubs, albeit an optional one, like Spoke, which means it is not crucial to the functioning of the platform, works as a plugin.

Cloud allows the user to run their own hub on a private server. This comes with a few key features:

- Allow the user to use their own domain name
- Customize features such as security and media
- Customize the branding, styling and color
- Customize the content library of avatars and scenes
- Run a custom version of the software to add features and functionality

Currently, Hubs Cloud is offered on **AWS** and **DigitalOcean**. However, the DigitalOcean deployment is only in alpha version, which means the level of support is lacking, specially when compared to the AWS version.

Regardless of which deployment method is chosen, once the server is running and the user navigates to their hub's hosted domain name and logs in, figure 4.5 shows the Hubs Cloud Admin Console page, which is what should appear.

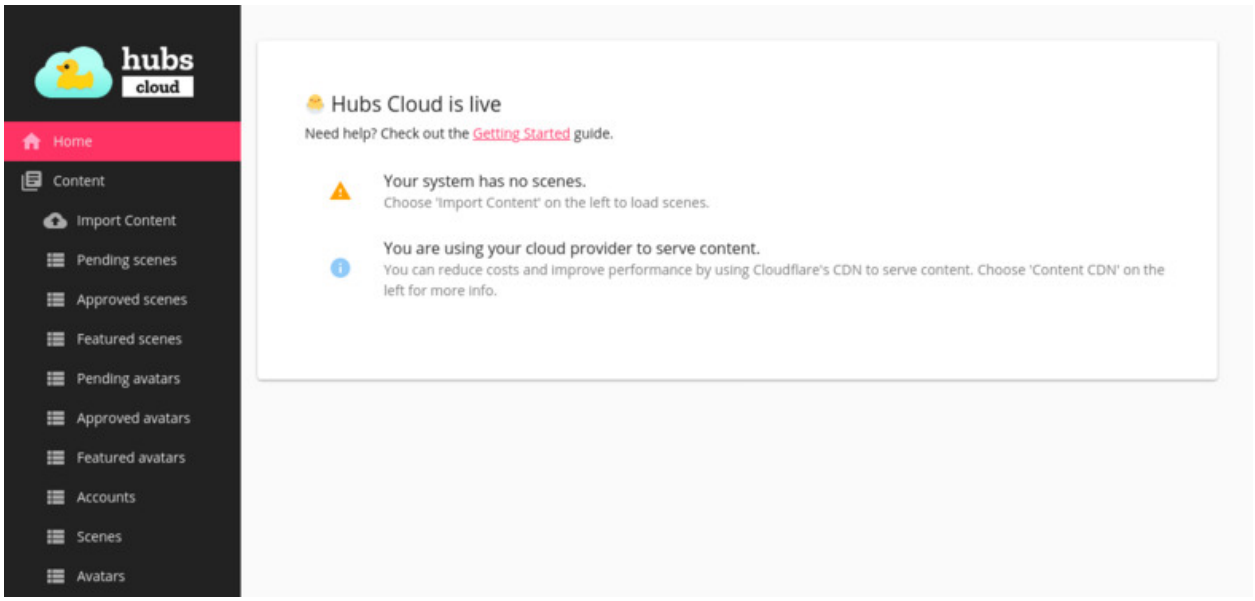


Figure 4.5: Hubs Cloud Admin Console page Source:[4]

As mentioned before, Hubs Cloud allows all the functionality of *hubs.mozilla.com* and also comes with **additional features** to **customize brading, the url, user accounts, the interface and code inside the hubs client**. The user is in control of their Hubs Cloud instance and its data via AWS or DigitalOcean insfrastructure, Mozilla only provides the template and automatic updates.

This means a developer can create and deploy custom versions of the Hubs Client by themselves by forking the hubs repository, making code changes, then deploying it to their live instance.

The custom client code will be based off the hubs-cloud branch which hosts Hubs client changes compatible with Hubs Cloud servers.

4.7 Summary

To conclude, Hubs by Mozilla is a very complex platform that is segmented into different parts that need each other to function properly like the Janus and reticulum server, as well as the hubs client side code and, in a way, Spoke, seeing as you would need to use the scene editor to create a scene in the first place.

Each of the different services mentioned work with several different technologies that require a high degree of knowledge of them in order to understand the project's intricacies and how these services and function in general and how they are connected.

Chapter 5

Perspectives on videoconferencing in the current global context

This chapter focuses on the feedback given by the different participants to the two questionnaires created. Each section explains the questionnaire's goals, their target demographic, the number of participants, how these surveys were sent out to be completed (*Facebook*, e.g.) and gives an analysis of the answers given to each question as well as an overall analysis with the conclusions reached of the survey as a whole.

5.1 General User's Perspective

In order to gauge the general user's experience and feedback regarding virtual meetings and their productivity, a questionnaire (B), available in the Appendix section, was elaborated.

This questionnaire's main goals included measuring the users' satisfaction with the current look and feel of the different videoconferencing platforms as well as their contentment with the available functionalities and tools of these services.

Some questions were based off of Stanford's **Zoom Exhaustion & Fatigue Scale** survey. [52][53] This survey is mentioned in a Stanford article in which it is discussed the four causes for *Zoom Fatigue* and their simple fixes. This article, as well as the survey mentioned in it, were helpful when devising the questions regarding mental health and virtual meetings.

These four causes mentioned are: the **excessive amount of close-up eye which is highly intense**, **seeing one's self during the video chats constantly in real, which is fatiguing**, **a person's usual mobility that is dramatically reduced with video chats** and, lastly, the **cognitive load, which is much higher in video chats**. The Zoom Exhaustion & Fatigue Scale, ZEF Scale, is a fifteen item questionnaire described in a paper published on the preprint website SSRN, and it advances research on how to measure fatigue from interpersonal technology, as well as what causes said fatigue.[53]

The survey was divided into 7 sections: **Demographics**, **Diagnosed health conditions**, **General experience using videoconferencing platforms**, **Virtual meetings & Mental health**, **Features and functionalities**, **Remote work productivity**, **Immersive virtual work environments**.

This questionnaire was done using Google Forms and sent out via dynamic email to all members of the *Faculdade de Engenharia do Porto* as well as shared with friends, family and colleagues through *Facebook*. It was answered by 158 people. Below is an analysis of the results obtained with graphs and the conclusions drawn from the questions asked, as well as discussions pertaining some of the topics approached, i.e., mental health for example.

5.1.1 Demographics

Demographics refers to particular characteristics of a population or, in this case, a sample of the population. This section is essential seeing as its main objective is to paint an overview picture of the Portuguese working population's experience with remote work and videoconferencing platforms, so the more diverse the sample, the better.

As shown in figure 5.1, the questionnaire was answered by almost the same number of men (47.5%) as women (52.5%), which is positive because it reflects the gender distribution of the population.

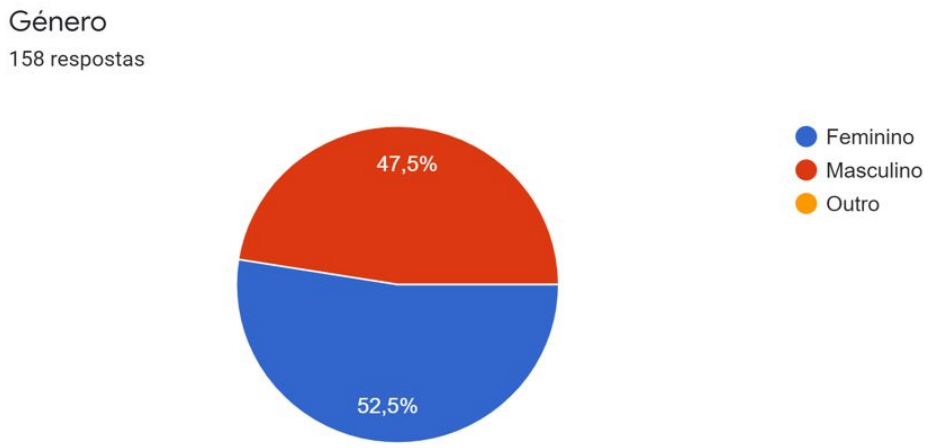


Figure 5.1: Gender of the participants

Regarding the age spectrum, which can be seen in figure 5.2, there is an imbalance: most of the participants range from the ages of 22 to 29 years old. This is because the survey was mostly sent to everyone that works and studies at Faculdade de Engenharia do Porto and so most of the participants were students. Nonetheless, there are still answers from older participants (the oldest being 57).

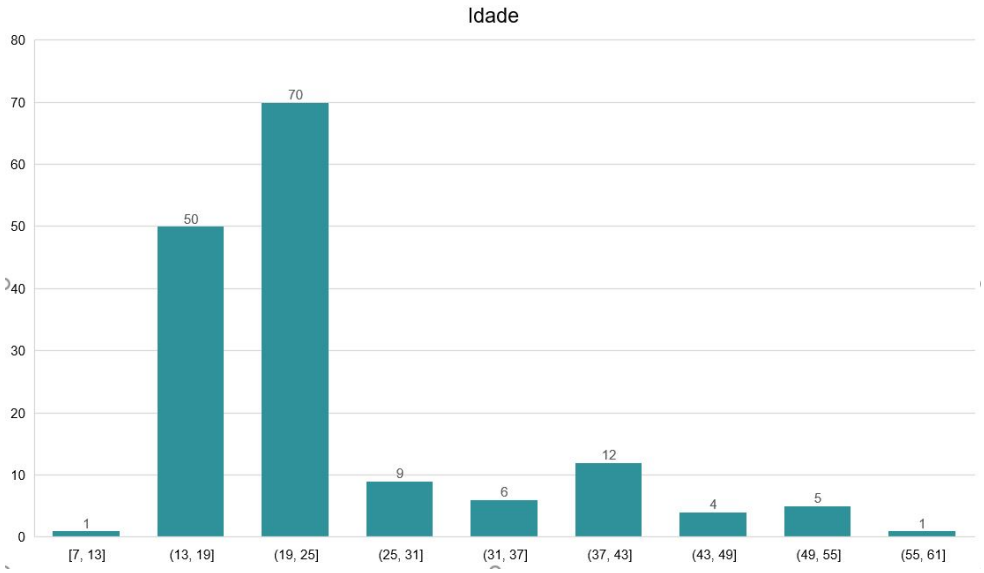


Figure 5.2: Participants' ages

Figure 5.3 shows the participants' highest completed level of education. As can be seen, approximately half (48.1%) of those have an high school diploma while 32.9% have a degree and 16.5% have a masters.

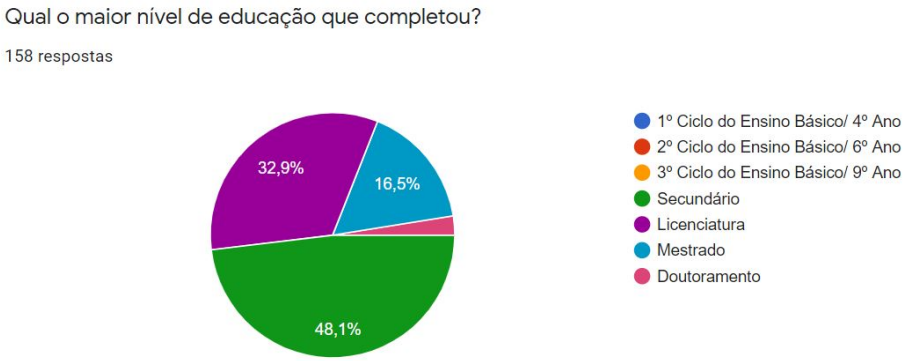


Figure 5.3: Participants' level of education

Like previously mentioned, most participants are **college students** and so, most of the answers to the question *"Main professional occupation"*, 86.1% to be exact, are **students**. For this question, the occupations presented to the respondents were taken out of the ***"Classificação Portuguesa das Profissões"*** official document. The options "student" and "unemployed" were added to encompass a larger range of people. Besides college students, the second biggest slice of the pie chart belongs to **specialists in intellectual and scientific activities** - 8.2% - which includes jobs such as **teachers** and **health professionals**. Additionally, 6.3% of participants claimed they were **intermediate level technicians and professions**, meaning they occupy positions like **health technicians**, **engineering technicians**.

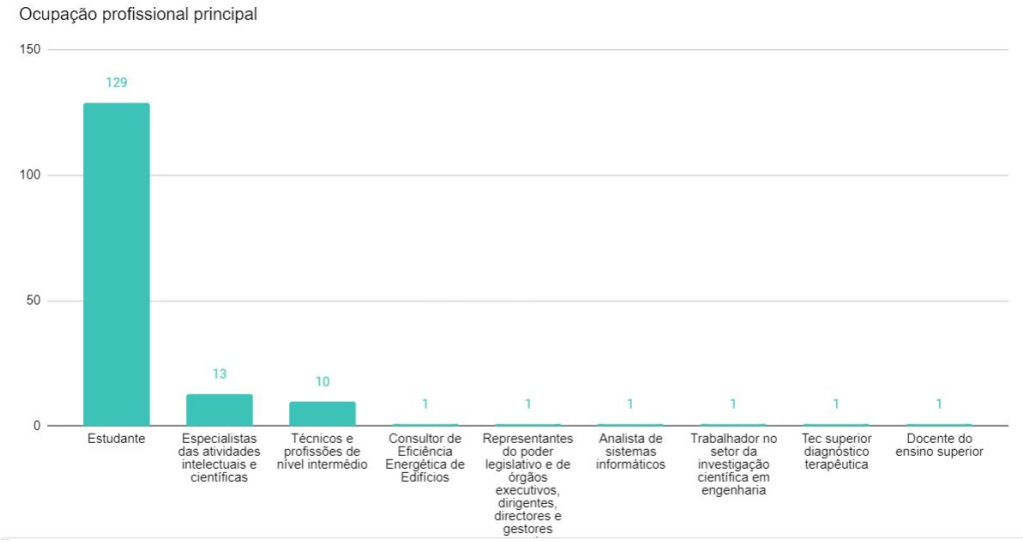


Figure 5.4: Participants' main professional occupation

Observing figure 5.5, it can be concluded that most participants (62%) don't have technology proficiency, meaning, they have never been formally or informally instructed in technology and informatics. This is an important data because it allows to assess how well they know technology related concepts and their amount of contact with platforms of this kind and overall knowledge.

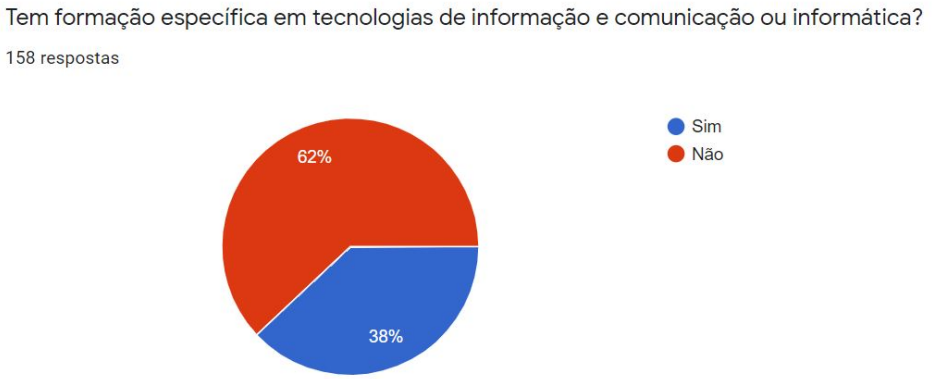


Figure 5.5: Participants' technology proficiency

The graph 5.6 relates to the participants' level of technology expertise. There are four levels, ranging from the most **Basic**, which represent individuals that are capable of identifying and using collaborative work tools, **Intermediate**, when a person can choose and use the most appropriate collaborative work tools to develop their work, **Advanced**, when an individual is capable of evaluating and proposing the most suitable collaborative work tools as well as supervising others usage of them and finally, **Extremely Specialized**, which describes someone capable of conceiving and developing said collaborative work tools. Just like the preview figure 5.5, these stats show the participants general technological awareness and proficiency and validates the answers that were given. Approximately half - **50.6%** - of the participants place themselves at an **intermediate** level

of knowledge. A quarter - **25.9%** - claim they have an **Advanced** level, while 13.9% affirm they have only a **Basic** knowledge of this area. A smaller percentage - **9.5%** - consider they have an **Extremely Specialized** level of knowledge.

Figure 5.6: Participants' technology expertise level

5.1.2 Diagnosed health conditions

This section, **Diagnosed health conditions**, is important because the user's experience with video-conferencing platforms and online meetings in general can and most likely is influenced by their present health state. Some health conditions like epilepsy, color blindness, ADHD and other types of sensory disturbances or mental illnesses, most likely affect the user's interaction online and specially with VR equipment and environments as well as their perceptions of the dynamics that take place during meetings. Observing the graph below 5.7, it can be infer that most of our sample of users does not suffer from any ailments or illnesses - 85.4% of participants answered "No" when asked if they were diagnosed with any kind of health condition that would impair their experience.

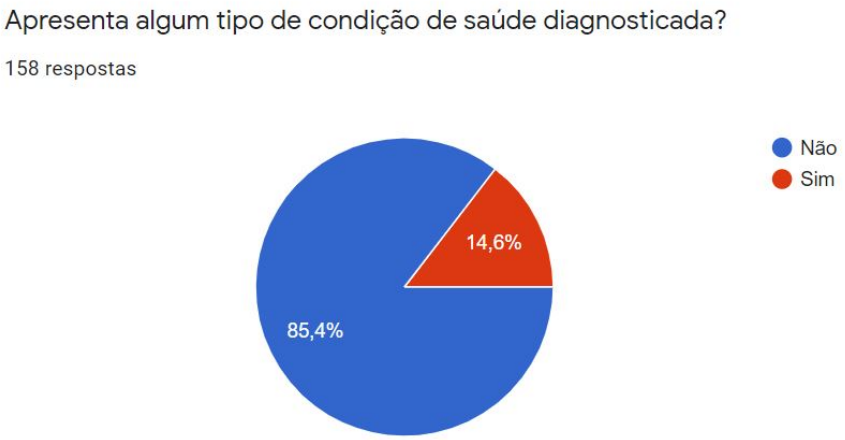


Figure 5.7: Participants' health conditions

For the small percentage of respondents - 14.6% - that answered positively the previous question, they were asked to specify exactly what kind of illnesses or ailments they suffer from. While some health conditions **don't impact or affect directly** their user experience with virtual reality environments and equipment, like **asthma** or **diabetes**, others very much influence the user's interaction with the technology and platform. Conditions like **epilepsy**, **color blindness**, **dyslexia** directly shape the user's experience. Even ailments like **rheumatism** and **anxiety** can have not so obvious effects on the user and how they interact with VR technology. These statistics allow to have a general idea of how many people would be impacted while using virtual reality immersive environments. In case these numbers are considered substantial and impactful (or even for future works, regardless of the numbers), measures to ease and allow all users to have a efficient experience would be taken.

Figure 5.8: Participants' health conditions - specified

5.1.3 General experience using videoconferencing platforms

This particular section pertains to the general experience when using videoconferencing platforms and focuses on the broader aspects of online meeting such as most used platforms, meeting context, meeting frequency, etc.

The Figure 5.9 shows the reasons most participants have videoconferences. The most common context is **Educational** with 93% claiming they use these online meetings and platforms to attend online classes, webinars and workshops. The second most chosen answer was for **Social** reasons (66.5%) such as family or friends reunions and lastly, in the **Professional** context (39.2%), for business meetings.

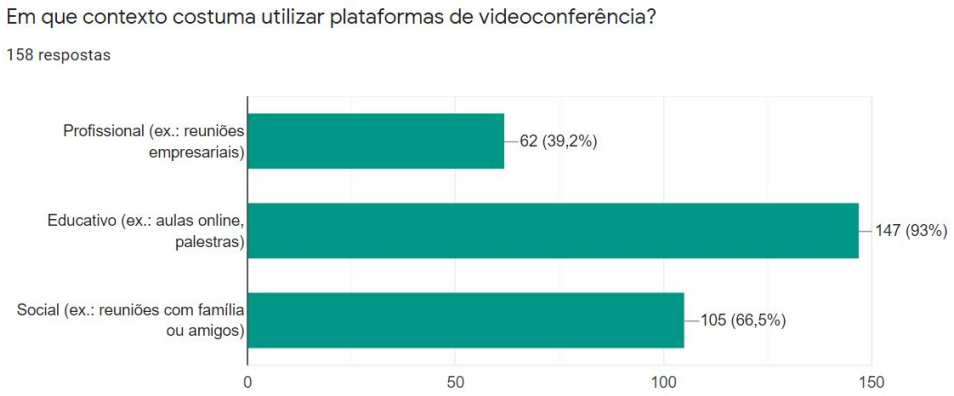


Figure 5.9: Participants' meeting context

In the next graph 5.32, it can be seen that the most used videoconferencing platform is **Zoom** (98.1%), in second place comes **Microsoft Teams** (52.3%), followed by **Google Meet** (44.9%) and **Discord** (44.9%) tied in third place and **Skype** in fourth (22.4%) . A small percentage of participants (7%) also uses **WeBex**. The other platforms mentioned: **Mozilla Hubs**, **Facebook**, **Whatsapp**, **Aimeet**, **jitsi meet**, etc, have a really small amount of votes, so they can be dismissed.

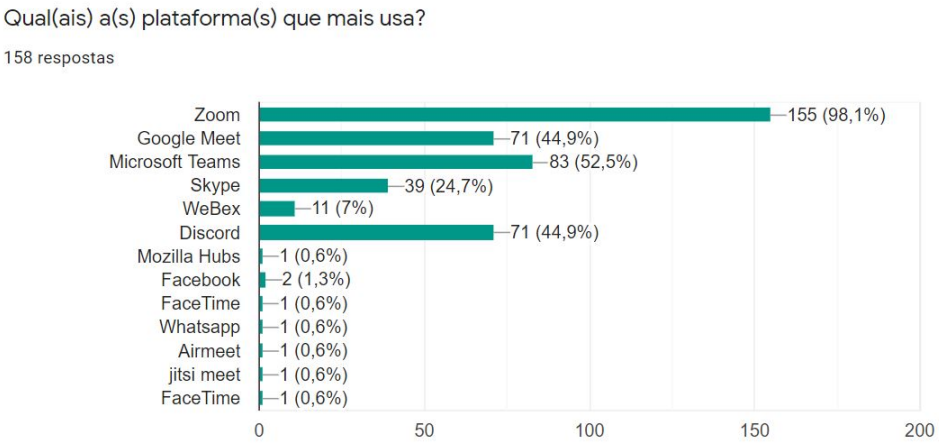


Figure 5.10: Participants' most used platforms

The graph chart below 5.33 represents the participants' meeting frequency. The meeting frequency is important because it has an impact on an individual's mental health and exhaustion: the more meetings, the more likely that person is to be fatigued and overwhelmed. Analysing the figure, most people, 40.5% to be exact, have meetings every day or nearly every day (5 to 6 times per week), 31% in this case. Less frequent are participants with online meetings 3 or 4 times a week - 13.3% - and once or twice per week - 12%.

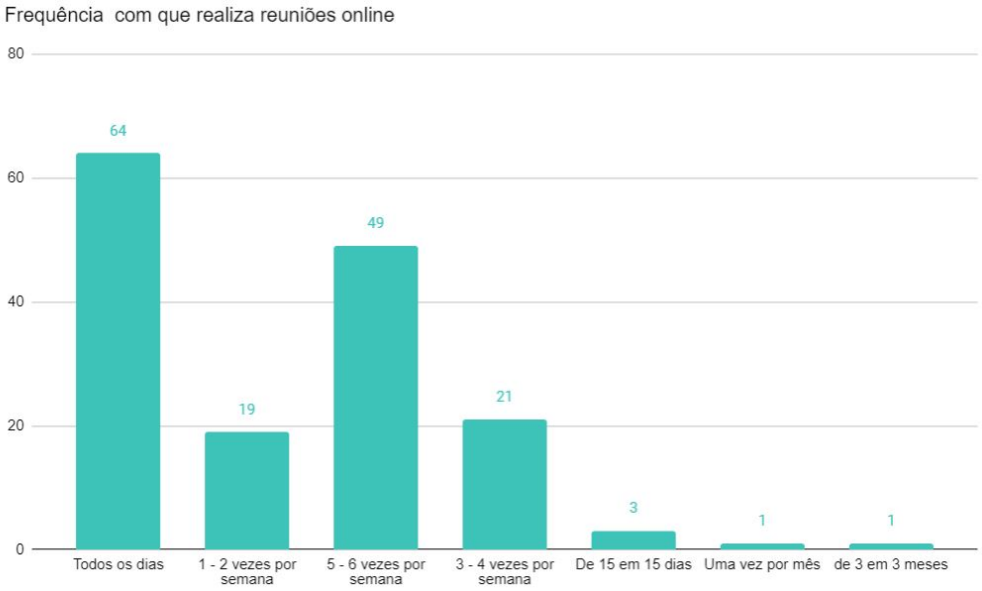


Figure 5.11: Participants' meeting frequency

A participant's usual role in a meeting is an essential piece of information because different roles (host, co-host, participant) equate to different experiences during a videoconference and different responsibilities. A host has to have more in-depth knowledge of that platform's functionalities and general functioning. And so, due to the aforementioned reasons, the question *"What is your usual role in an online meeting?"* is a key one. The below figure 5.12 shows that most people's usual role is that of the **participant** - 93.7% -, followed by **host** - 17.1% - and lastly **co-host** - 7%, which is consistent with that fact that most of the participants are still students.

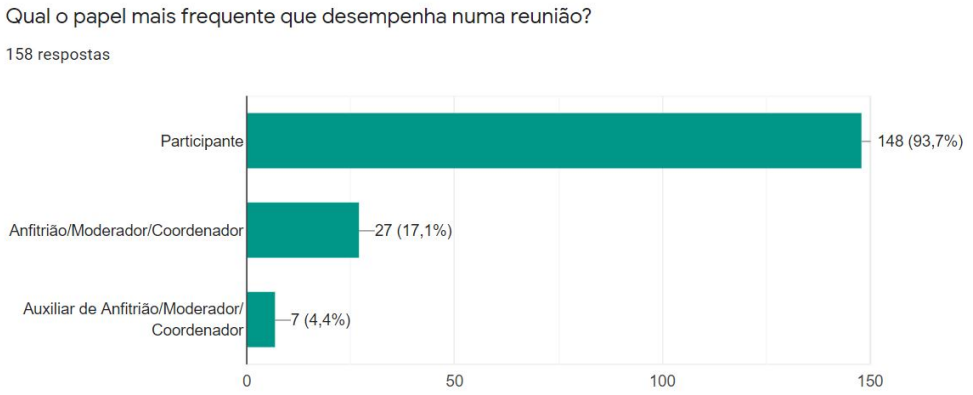


Figure 5.12: Participants' usual meeting role

5.1.4 Virtual meetings & Mental health

With the current global pandemic state, most people have to work remotely at home. As such, and because this is an unprecedented situation, the impact on mental health and the long-term effects of

this imposed self-isolation are still unknown but very much present in our day-to-day life, even if people don't consciously notice it. It is important to study how this new reality impacts everyone and search solutions for minimizing the impacts of the unexpected problems that arrive with it. The topic of mental health is a particularly important subject seeing as it impacts every aspect of an individual's life and is often overlooked and not talked about.

The graph chart below 5.13 represents an individual's exhaustion level directly after one meeting. As can be seen, approximately half of the participants - 48.7% - feel moderately exhausted after a meeting, 20.9% claim they feel very exhausted, 19.6% feel little exhaustion and 8.2% experience extreme exhaustion.

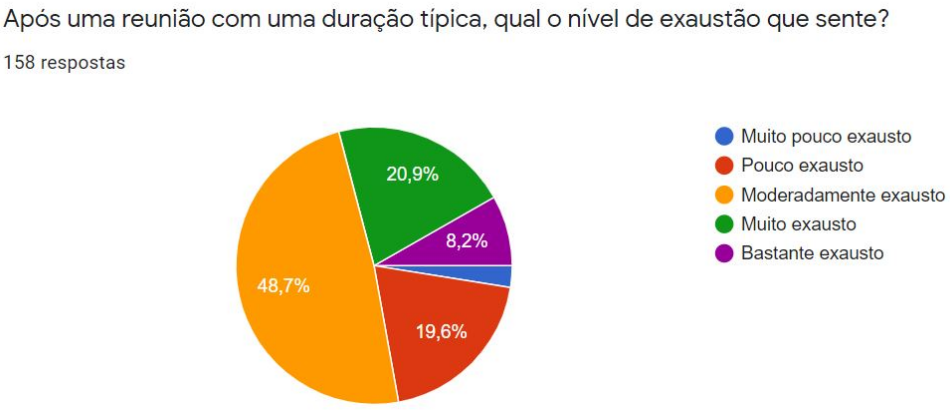


Figure 5.13: Participants' exhaustion after a meeting

The following graph chart 5.14 shows one's exhaustion level after a week of meetings, basically measuring how the accumulation of online meetings and remote work affects a participant's weariness at the end of the week. Approximately 42.4% of the participants state they feel moderately exhausted while 32.2% affirm they feel very exhausted. A smaller percentage of the participants claim they experience extreme exhaustion and 8.2% very little.

Figure 5.14: Participants' exhaustion after a week of meetings

Currently, a hot topic in conversations regarding mental health and the pandemic's effect on it

is ***"zoom fatigue"***, meaning, the weariness and fatigue one feels after now over a year of online meetings. These meetings leave the individual feeling emotionally and physically exhausted and even, after a while, unmotivated and depressed. With that in mind, the question *"How often do you feel too tired to do other things after videoconferencing?"* seemed like a very important one and, as can be seen in the below chart 5.15, most participants - **43%** - answered **"a lot of times"** and **20.3%** even claimed **"always"**. Approximately a quarter - **26.6%** - only feel tired **"sometimes"** and a smaller percentage - **10.1%** - say they **"rarely"** feel exhausted. It is important to note that **no one claimed they "never" felt tired** after a virtual meeting.

Figure 5.15: Participants' willingness to work after a meeting

The pie chart 5.16 focuses on how much of an impact on the participants' their appearance and others perceptions of them have during a videoconference. Mostly, it seems it is not a major preoccupation and source of stress for most people. Mainly, people claim they are just slightly worried over their appearance - 38.6% - or moderately conscious of it - 30.4%, while 18.4% claim they are not worried at all and, conversely, 9.5% affirm they are very self-conscious and worried about what others think of their looks.

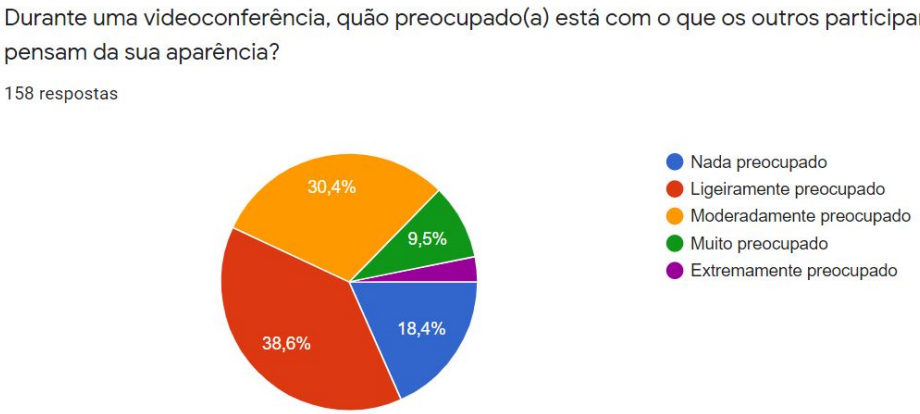


Figure 5.16: Participants' self-consciousness about their appearance

In case appearance was not a stress factor for the participant, the following question asked

them to specify what they thought was the major issue that caused anxiety and strain during a videoconference from a list of options:

- Seeing your own face - **20.3%**
- Difficulties using the platform - **6.3%**
- Technical problems during meetings - **31.6%**
- Difficulties with interpersonal communication - **34.2%**
- Difficulties relating to other participants - **36.7%**
- Fears of unauthorized monitoring - **11.4%**
- Difficulty understanding your role in the meeting - **8.9%**
- Unfamiliarity with the social norms and cues in this digital context - **8.9%**
- Ease to multitask, which facilitates distractions - **62%**
- The physical distance from the other participants - **42.4%**
- Understanding the agenda - **5.1%**
- Understanding the evolution of the agenda - **13.3%**

Seeing as nonverbal communication is a big part of communication and others' nonverbal cues give insight into how they are feeling and what they think, it's essential to analyse how much online meetings takes a toll on one's ability to read nonverbal cues such as body language and tone of voice. Looking at the figure 5.17, it's easy to deduce that most participants struggle with reading others' body language and interpreting what they are saying: 31.6% of participants struggle a lot when it comes to reading others nonverbal communication, 34.8% claim that it is only slightly easy to do so while 28.5% claim it is a moderately easy task.

Figure 5.17: Participants' ease reading body language

5.1.5 Features and functionalities

This section of the questionnaire focuses on the user's experience and specific problems with videoconferencing platforms and its **current functionalities** - whether it is their problems or suggestions for new features that could help with remote meetings. These questions help target the

areas where the platforms fall short and users have the most difficulties with, so that they can be improved and boost work conditions.

Below 5.18 is a graph of the most used features. In first place is **share screen** functionality, most people - **91.8%** - use this feature regularly, as well as the **chat** - **76.6%** -, the **breakout rooms** - **48.1%** and the **file sharing** functionality - **47.5%**.

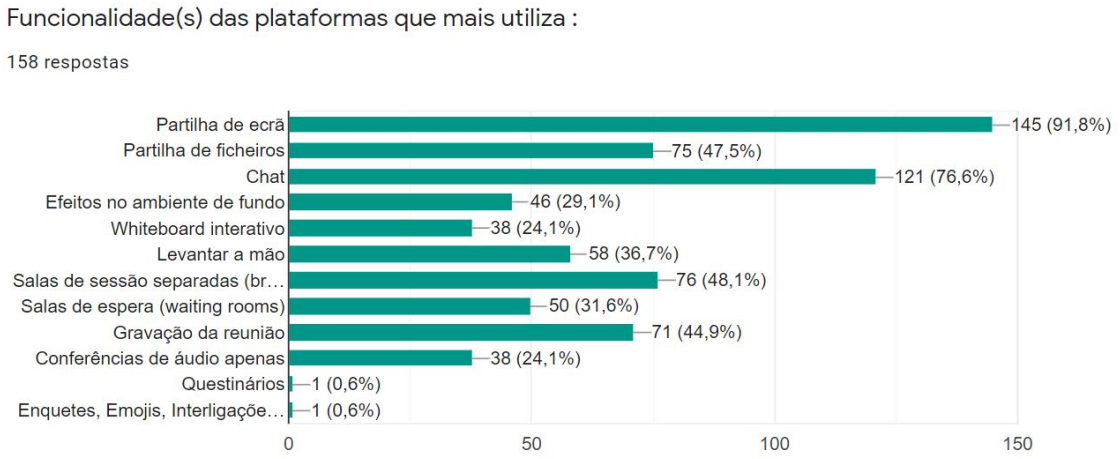


Figure 5.18: Participants' most used features in the current platforms

To understand people's dissatisfaction with the current state of the videoconferencing platforms, the question ***"Which of the available features of the videoconferencing platforms do you like the least?"*** seemed like an important one, seeing as it would give an idea of where these technologies lacked. While this open question was only answered by 20 of the 158 participants and so most of these answers could be mentioned and discussed here, other open questions had more adherence and so a lot more answers. Due to this, a list of all the answers given to the open questions can be found in the C *Full answers to all the open questions in the first questionnaire* section of the **Appendix**.

In regards to this specific question, most of the 20 answers referred they did not have an opinion regarding this matter. Despite these, a few participants mentioned functionalities such as the **screen sharing**, the **chat** not being appealing enough, the **background effects** being too distracting, the **hand raising**, the inability to **record the meeting** - if you are not the meeting's host - and the **file sharing** feature. To see all of the answers to this question, please go to C.1.

Additionally, the participants were asked ***"What features do you think would be useful to implement in these platforms?"*** in order to scope what the general population thought would be good additions to the already available functionalities. This question had 24 answers so, just like the previous one, not a huge amount considering there were 158 participants. Some people answered simply "I don't know" but a few participants gave the following suggestions: the ability to pose questions anonymously, the possibility to regulate the volume of each participant - which is already possible on Discord -, the addition of ambient music, noise suppression - again, a feature

available on Discord -, the addition of an indicator that would let the participants know how long it has been since the participants have spoken, the implementation of a *status* feature, so that other people could see when that user was available to meet and lastly, more diverse questionnaires that would be able to be answered in real-time. For all the suggestions given, please go to C.1.

Figure 5.19 shows how easily the participants' use these videoconferencing platforms - the big majority thinks they very easily - 31.6% - or easily - 50.6% - use these technologies. Conversely, some claim their experience is neutral: it is neither easy or hard to utilise them - 16.5%.

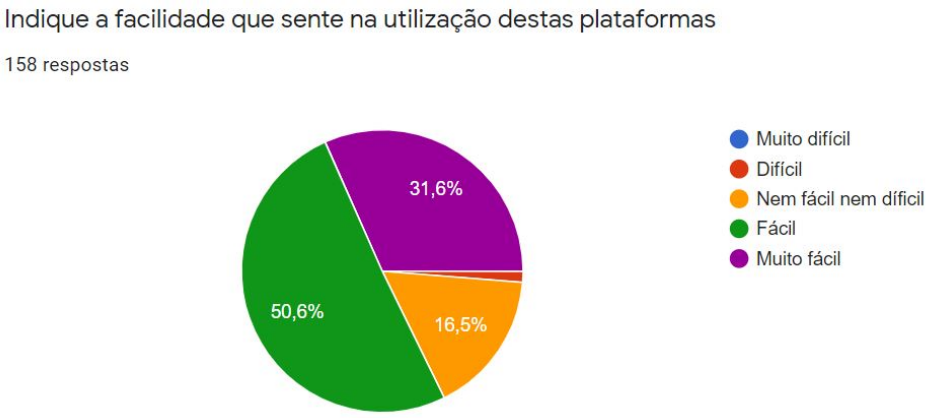


Figure 5.19: Participants' ease of use

In light of the fact that seeing one's face can be a stress factor, it was interesting to conclude that most people - though not by a large margin, 55.7% - would prefer a video and audio meeting, meaning seeing their own face as well as others' was preferable over the contrary, which means it is not such a big concern for most users.

Figure 5.20: Participants' preference: video and audio vs video meetings

The last question of this section focuses on **which platform characteristics posed the most difficulty when using said platform** regarding the platform's look and interface, the participants

had a list of possible aspects to choose from:

- Confusing interface - **38.6%**
- Buttons and/or text too small - **13.3%**
- Features available unclear, vague and/or hard to find - **72.2%**

5.1.6 Remote work productivity

This section focuses on the user's **sense of accomplishment and productivity** when working remotely. The participants' **feeling of closeness** to others and their **perceived involvement** in their project has a significant effect on their mental well-being and also the company's results.

In the following graph 5.22, the participants were asked if they felt their videoconferences were productive and its' objectives were reached. The **overwhelming majority** - 69% - **answered positively**, while 31% felt their meetings were lacking and unproductive.

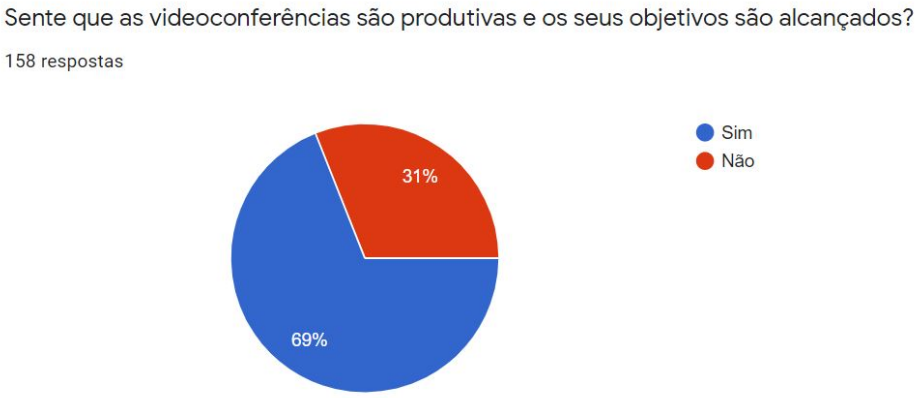


Figure 5.21: Participants' meeting productivity

For the participants that answered with ***"No"*** to the previous question, the following open question **Which were the reasons that lead you to that answer?** invited them to elaborate on that stance, giving reasons as to why they thought virtual meetings were unproductive and/or their goals not accomplished. Twenty eight of the 31 participants that answered negatively to the previous question, answered this one. Mainly, they cite reasons such as **difficulty focusing and concentrating**, **exhaustion**, **the meetings' long duration**, **the environment** and **technical difficulties** that end up taking a long time to fix or are never fixed and complicate communication. It is important to note though, that most participants thought online meetings were productive. For all the answers to this question, please head to Appendix C.2.

Additionally to being asked why they thought videoconferencing was unproductive, the respondents were asked to give suggestions so that this aspect could be improved. Only 15 of the original 31 participants gave an answer and most of them claimed that **"It was not possible to be improved"** as it was something that could only be solved by meeting physically. A few, however,

suggested **shortening** the meetings' **duration**, **better planning** or even, **having the same attitude** that used to exist in face-to-face meetings (more and better communication and willingness to help others). The full list of answers to this question is present in Appendix C.2.

Despite the answers to the meetings' productivity being mostly positive, when asked **how close they felt to other teammates/participants in comparison with face-to-face interactions**, 32.9% of the respondents claimed they felt very distant to the others, 46.8% stated they felt distant and 19% affirmed they felt close. These results show that **while the meetings are seen as productive**, the **team's dynamic and sense of togetherness has suffered a lot** with the switch to remote online work (Figure 5.22).

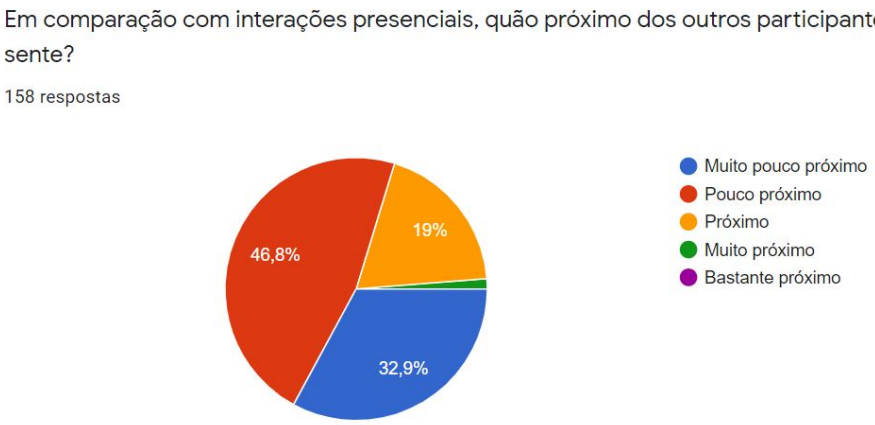


Figure 5.22: Participants' sense of closeness

Furthermore, when comparing with face-to-face interactions, the participants' sense of engagement in their work and meeting is a bit polarizing: 18.4% of the respondents claimed they felt very little involvement, 39.2% felt little involvement. Conversely, 31% of participants affirmed they felt involved, 9.5% felt like they were very involved and a small percentage claimed they felt extremely involved (Figure 5.23).

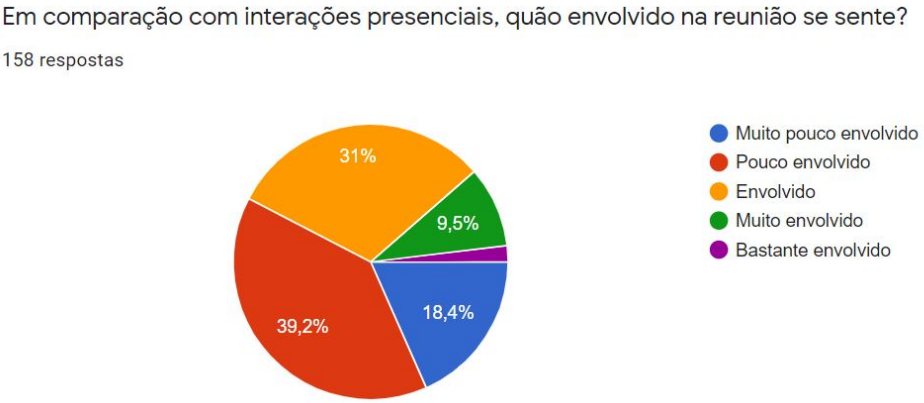


Figure 5.23: Participants' feeling of involvement

Another important factor when talking about productivity is the **individual's ability to pay attention and focus during the meetings**. The participants were asked if they felt less attentive and focused on their online meetings in contrast to face-to-face meetings and 83.5% claimed they frequently lost focus while 16.5% affirmed otherwise (Figure 6.35).

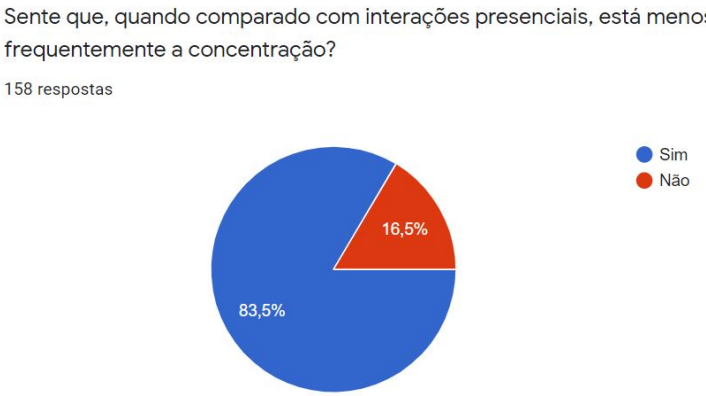


Figure 5.24: Participants' attention and focus during meetings

5.1.7 Immersive virtual work environments

This subsection's focal point is the virtual environment and the users' experience with immersive 3D spaces. Its' importance to this project is crucial seeing as it is here that conclusions can be drawn in regards to the population's general view of this technology and the depth of their knowledge towards said technology.

When asked ***"If videoconferences were conducted in a common virtual room, more interactive and 3D, do you think that new medium and environment would be a distraction factor or would it encourage your participation?"*** the participants gave very polarising answers.

For this question, a video of a demo room in *Mozilla Hubs* and a link to said room were made available to the participants so they could have a grasp of the technology in question, in case they had never tried it themselves. Of the 158 participants, **86** answered this question. While some mentioned they could not make a case for either option because they had never used such technology, most of the respondents appeared very divided: approximately half of the answers thought it was a very bad idea and would contribute to the distraction they already felt dealing with the normal platforms, the other half claimed it would be very interesting and would encourage them to participate more.

As downsides, the participants mentioned things like the fact that a 3d artificial environment and a higher level of interactivity would be very overwhelming and distracting. Additionally, using a VR headset would not allow to write notes and could potentially make the user sick - sometimes, when using a VR headset symptoms like those of motion sickness can be felt by the individual-, as one participant mentioned.

A few respondents also thought that while it would be very distracting at first, it would eventually make the meetings either better because the team would feel more involved or it would become mundane and the same problems had currently with platforms like *Zoom* would appear or become even worse.

As upsides, aspects like the new environment would make the meeting more engaging to all participants and the feeling of being closer to others, even if digitally, would improve the present feeling of isolation and loneliness as well as make one feel more at-ease and comfortable.

Finally, something that seemed to be common in both people that did not like the idea and those that were for it is that the virtual environment would have to be simple and neutral, as well as the avatars and that an adjustment time would be necessary seeing as it is a concept not explored by many. For the full list of answers to this question, look up subsection C.3 in the Appendix.

The pie chart 5.25 below represents the percentage of the participants that own any type of headset or VR equipment. Unsurprisingly, most people - 92.4% - do not own any kind of virtual reality equipment, which is unfortunate for this project and any other VR-related works.

Figure 5.25: Percentage of participants that own Virtual Reality equipment

The following graph 5.26 focuses only on the percentage of respondents who answered positively to the previous question - 7.6%. Here, they were asked to specify which VR technology they own. The most voted VR equipment was **Google Cardboard** - 54.5% -, followed by **PlayStation VR** - 36.4% - and **Oculus Rift** - 18.2% - and lastly, all tied for last place, is **HTC Vive**, **Go Quest**, **Hyper X** - 9.1%.

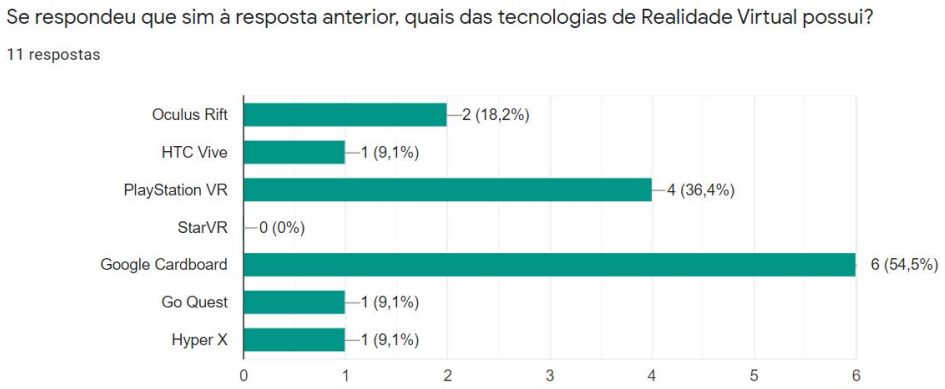


Figure 5.26: Participants most common Virtual Reality equipment

5.1.8 Final Feedback

This final section serves as a place for anyone to include any other thoughts, feelings and suggestions that they did not express on the previous questions. Anything they experienced and felt was important and relevant to this study as well as their overall satisfaction with the current way of working remotely and the available platforms.

This question had **59** answers and a varied range of opinions and thoughts. Mostly, people are unsatisfied - with a few exceptions, that prefer this way of working - but understand this is the only way to continue being productive and social with others. A few highlight some advantages that are gained by working remotely like the time gained now that travelling is unnecessary or the fact that because no one can have side-conversations, it is much easier to follow what is being said. Others, however, shared that the monotony of working like this leads to lack of motivation and the ease that people have scheduling meetings makes it so that one can have multiple meetings per day which adds to the exhaustion felt.

For the full answers to this question, go to the C.4 subsection in the C section of the Appendix.

5.1.9 Summary

To finish this vast questionnaire, a few conclusions can be taken from the analysis of the answers the participants gave.

Firstly that a user's experience with remote work and isolation in general may depend greatly on their personality - more introverted people who prefer to spend their time alone find this approach to be simpler and more straight to the point, extroverts miss the social aspect of meetings and work and find themselves losing focus, motivation and concentration rather easily .

Furthermore, although most people consider that their virtual meetings are productive and a necessary option given the global pandemic context, they feel disconnected from others and exhausted at the end of a week full of meetings and social distancing.

Regarding platforms like *Zoom*, *Google Meets*, *Microsoft Teams*, etc., and the users experience with them is mostly, if not positive, at least neutral: not a lot of flaws were pointed out nor suggestions for improvement were given. The platforms themselves are adequate, it's the continuous cycle of virtual meetings, regardless of the technology used, that seem to cause the most fatigue.

In terms of virtual environments, the general population's experience with them is very reduced and most people do not have the proper equipment to experience it fully - even though *Mozilla Hubs* works on a regular computer as well. In terms of virtual meetings in these 3d immersive and interactive spaces, the opinions are very mixed, it was not possible to determine whether this was seen as a mostly positive change and new direction or a complete waste of time that would only result in more distractions and feelings of exhaustion. However, a few stylistic aspects for a possible 3D immersive virtual room can be taken from all these answers: the environment needs to be as neutral as possible, not very distracting in terms of furnishing and decoration, it should be as open and small as possible so that the user can clearly see the whole room and there is no need to explore hallways and lots of rooms. It should be a comforting place so that the user feels at ease, closer to the other participants and more encouraged to participate. The avatars should also be as neutral as possible, if everyone has a different and flashy visual it can become a distraction.

5.2 Meeting Hosts' Perspective

As it was mentioned in previous chapters, one of the aspects of this thesis is to make an outline for a tool for managers, teachers, *CEOs*, supervisors and any other jobs that require team management. This tool would allow them to best manage their teams and improve the performance of remote online work as well as keep an eye on team member's well-being. For this purpose, a few user metrics would have to be extracted. In chapter 2 **State-of-the-art**, the metrics extracted by the most used platforms were listed and described.

With this in mind, a questionnaire directed towards *CEOs*, team leaders, supervisors, managers was developed. Its' goal was to assess what the best user metrics to extract were based on what the people in charge of teams and companies thought was most useful and wanted to know about their employees.

As this questionnaire was directed towards a very specific group of people, unlike the first one, the number of participants was, predictably, lower. It was originally sent to 70 people, but only answered by 8 people. Nonetheless, below is an analysis of their answers and what can be concluded from them and transposed to this thesis.

5.2.1 Demographics

Just like the previous survey, this one has a section dedicated to the participant's personal information, to give a general idea of who the participants are. Most of the sample was composed by CEO's and Informatic Technicians, but there were also managers, directors, product owners and team leaders (Figure 5.27).

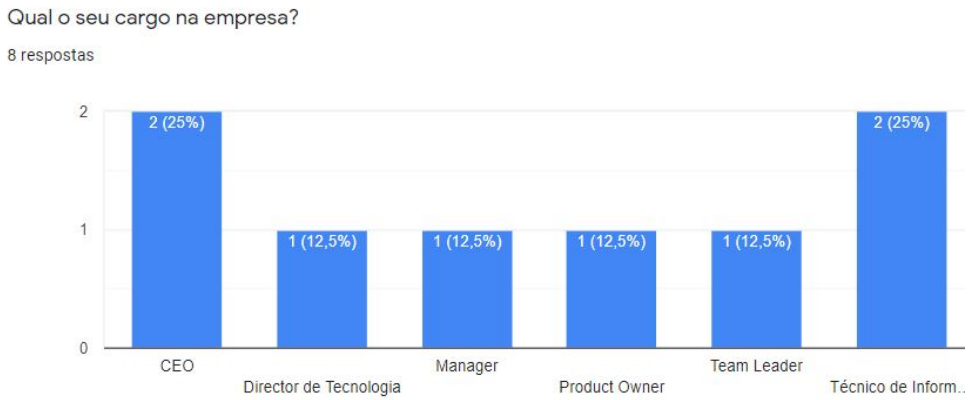


Figure 5.27: Participants' role in their company

The majority of participants had more than twenty years of professional experience (Figure 5.28). These numbers refer to their total number of years working in their profession, not how long they have been in their current company. Analysing the graph below, the most popular answers were: twenty years of experience - **37.5%** - and twelve - **25%**.

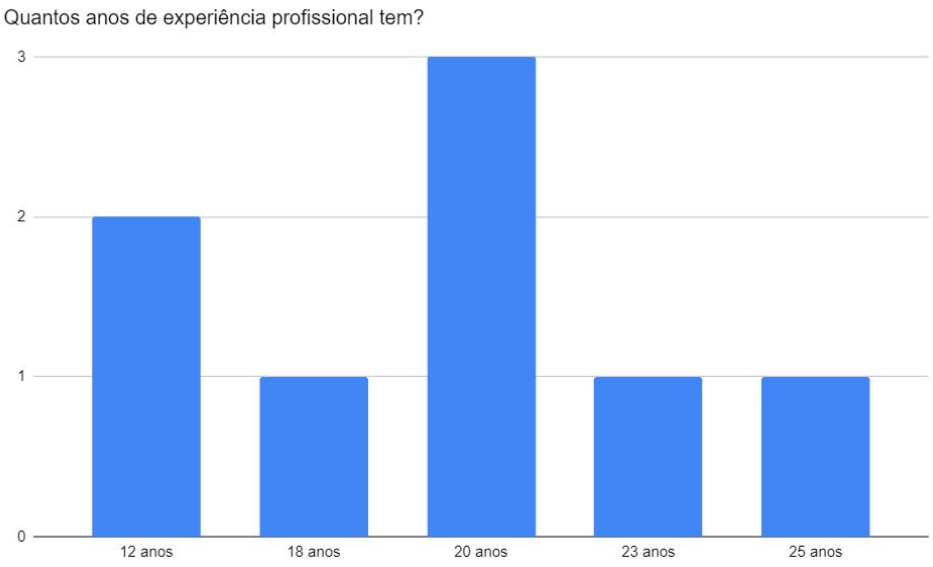
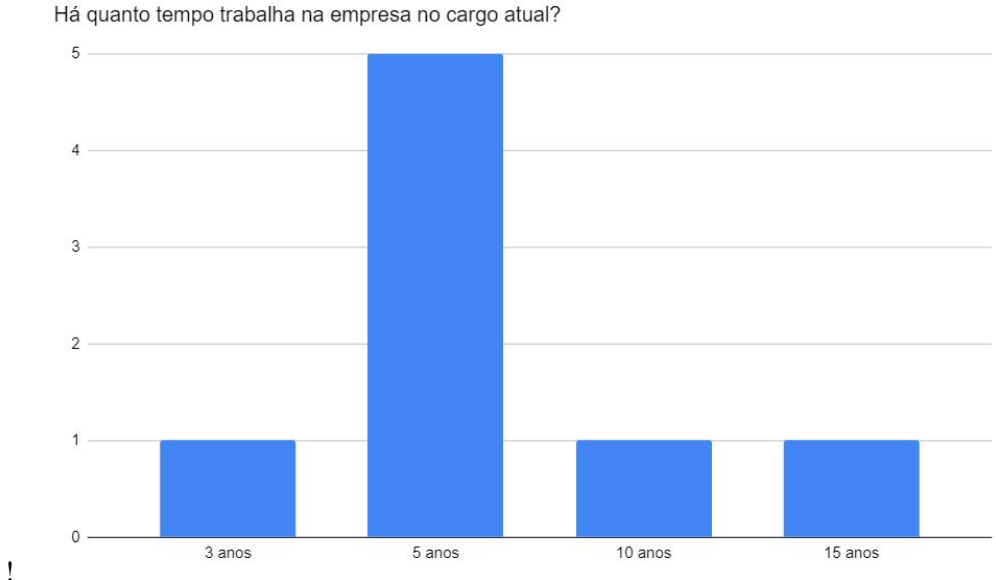


Figure 5.28: Participants' years of experience

Most of the individuals worked for more than five years on the current role on the company (Figure 5.29) - **625%**. Only one had worked for only three years on their current place of work.



!

Figure 5.29: Participants' number of years in current position

5.2.2 General characterization of the videoconferencing context

The graph below (Figure 5.30), refers to the company's sector, meaning, which business area they cater to. If the **Informática**, **Software** and **Tecnologia** are all considered the same area and grouped under the same sector, such as IT, then the overwhelming majority of the participants worked in a company whose sector is technology. Only one participant belonged to a company that works in the health sector.

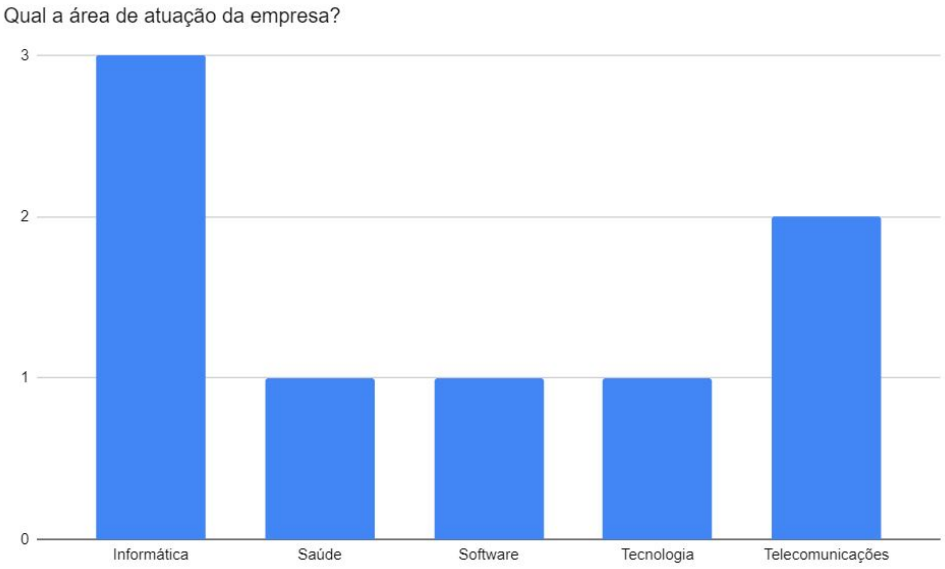


Figure 5.30: Participants' company sector

The size or dimension of a company is decided by the number of workers, balance sheet total and annual balance, according to EU legislation.[54]. To be considered either a small, micro, medium or large sized company, a business has to meet the staff headcount and one (or both) of the financial limits.

With this financial knowledge in mind, and observing the graph below that represents the participants' company size it can be concluded that half of the individuals worked on a large company and the remainders on a small or micro one (5.31).

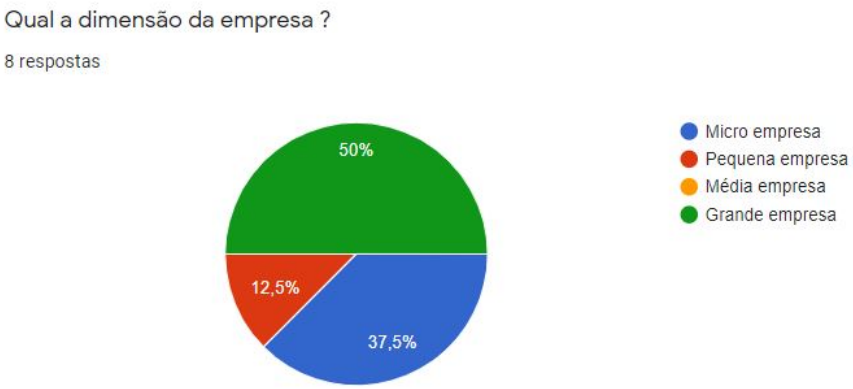


Figure 5.31: Participants' company size

Most of the companies used Microsoft teams (62%), Skype (50%), Google Meet (25%) and Zoom (25%) to perform the meetings (Figure 5.31). This is important to note, seeing as Microsoft Teams extracts a lot of metrics from the user and allows for managers to have a detailed analysis of each member's work during and off meetings - a support that the rest of the platforms do not offer.

Figure 5.32: Participants' most used platforms

The majority of the participants had more than 3 meetings per day on a typical meeting (Figure 5.33).

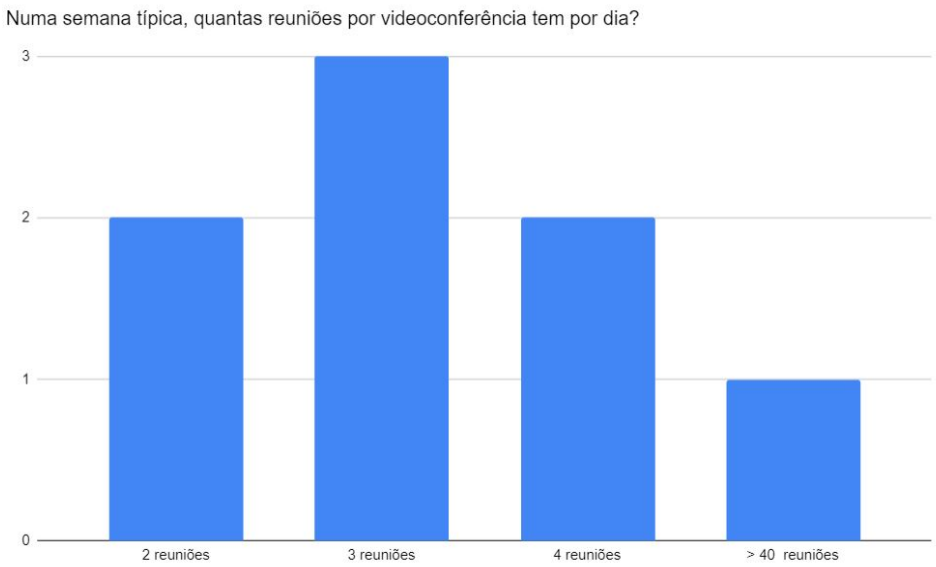


Figure 5.33: Participants' meeting frequency

As shown in the figure below, (Figure 5.34), each meeting lasted, on average, 60 minutes - **62.5%**, with **25%** of participants claiming theirs lasted for about 45 minutes and one - **12.5%** - affirming theirs lasted on average 35 minutes.

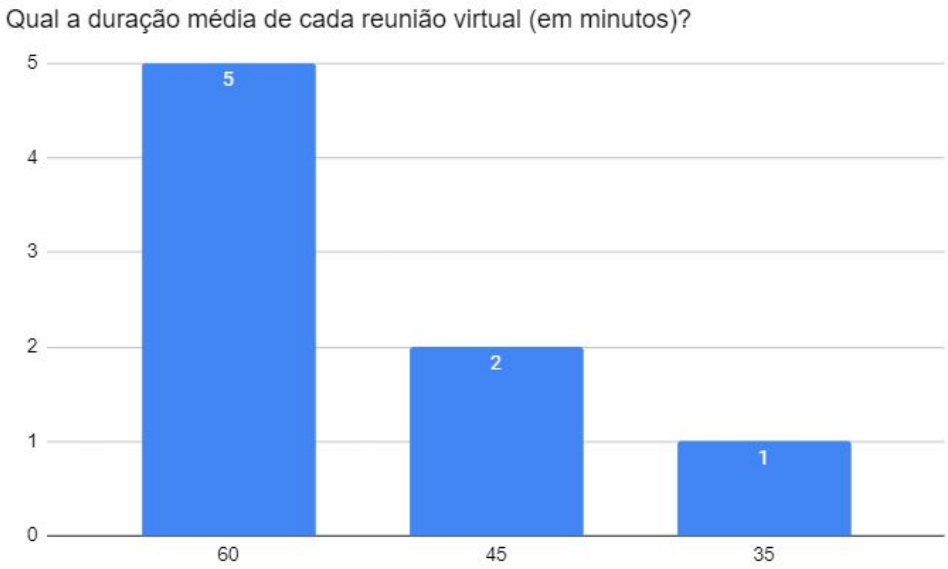


Figure 5.34: Participants' average meeting duration

In most meetings, participated at least and on average four individuals (Figure 5.35), claimed 37.5% of respondents. Followed by an average of five people or three per meeting - **25%** - and six - **12.5%**.

Figure 5.35: Participants' average number of people attending the meetings

5.2.3 Characterization of the constraints of videoconferences

Looking at the graph below 5.36 that represents the participants' meeting productivity, half of the respondents felt that it was *"easy"* to maintain productivity and reach the meetings' goals. On the other hand, a quarter claimed that it was *"hard"* and the other quarter remained neutral, *"neither easy nor difficult"*.

Figure 5.36: Participants' meeting productivity

The participants pointed that sharing screens, their surrounding environment, the environment noise, scheduling management, keeping focus and attention, losses on quality and technical challenges as the main difficulties of managing meetings throughout video conferences (Figure 5.37).

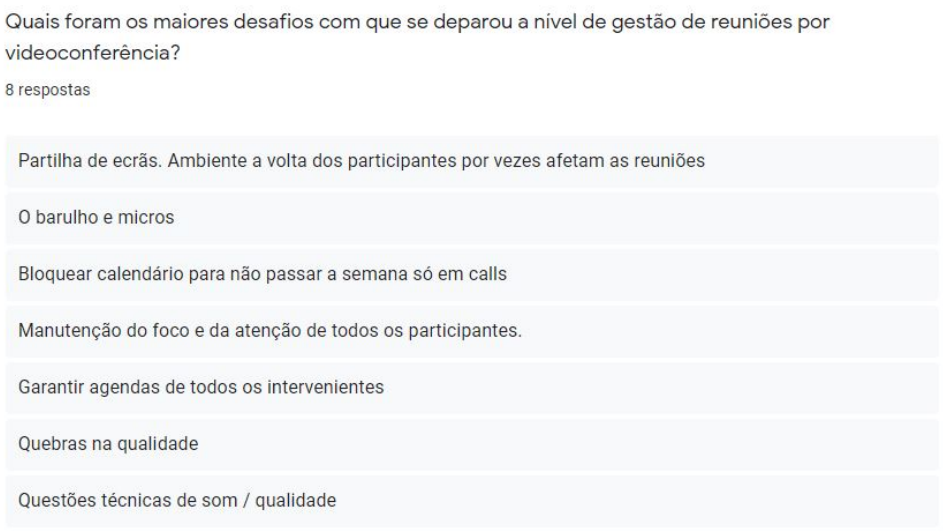


Figure 5.37: Participants' challenges during meetings

The final question was regarding user metrics and what they would like to know about the participants in their meetings. However, it was not possible to conclude anything as the overwhelming majority of participants did not answer this question.

5.2.4 Summary

To conclude, the low number of participants on this questionnaire makes it so that there is not a lot of conclusions that could be drawn from it. Additionally, the demographic seemed a little homogeneous: most participants had worked for a long time in a large IT company and had similar routines when it came to online meetings.

Regarding online meetings and the remote work context, this survey was very much in line with the first one when it comes to the host's ideas and feelings on productivity, concentration factors and challenges faced. Notably, regardless of role in the meeting, it seems that the experience remains the same across all users: no challenges and difficulties specific to hosts were raised, most mentioned problems that had already been pointed out by the participants of the first questionnaire.

In regards to the final question that involved user metrics and that was distinct from the previous survey, it was not answered by most of the participants and so there can be no conclusions in regards to that aspect.

Chapter 6

Intelligent Virtual Immersive Work Environment

This chapter focuses on explaining the work process, the challenges faced, lessons learned as well as the results produced, meaning the virtual immersive environment and its functionalities, and how to replicate them. This virtual environment created in collaboration with 3Decide integrated several concepts extracted from the questionnaires mentioned in the previous chapter, 5 Perspectives on videoconferencing in the current global context.

6.1 Deployment

In order to implement these new features, it was necessary to have a **local development environment** where the custom client code could be altered and tested.

Additionally, most of the proposed functionalities required access to the backend services' code because the client side of Hubs is responsible mostly for the graphics interface and so the **users' actions are dealt by the reticulum and janus servers** .

Having a running local development environment proved far harder then initially predicted, which resulted in some time lost spent on trying to have a Hubs client running locally on a computer. This is due to several reasons: the documentation available was not up-to date nor was it very extensive and in-depth, it was mostly a guide for users trying to use Hubs for the first time and not suited for developers trying to implement new features. The support on the Mozilla Hubs Discord also proved not very helpful and lastly, the software architecture and all the different services were very complex and used specific technology that was not familiar.

Despite these challenges, after thorough examination of how the code works, what servers are running, what different services are responsible for what is appearing on a user's page, it was possible to have a running hubs client setup functioning. Nonetheless, there was still no way to access and alter the code responsible for messages, videos or other user actions'.

To have a running local development setup, one has to follow these steps:

```
1. git clone https://github.com/mozilla/hubs.git
2. cd hubs
3. npm ci
4. npm run dev
```

After running these commands on a command prompt or console, go to *"https://localhost:8080"*.

Once there, an initial page is shown in Figure 6.1. This page allows the user to **create a room**, **access a public room** or **visit the Hubs Cloud, Scene Editor, Docs, Source and Community pages**.The user should also create an account.

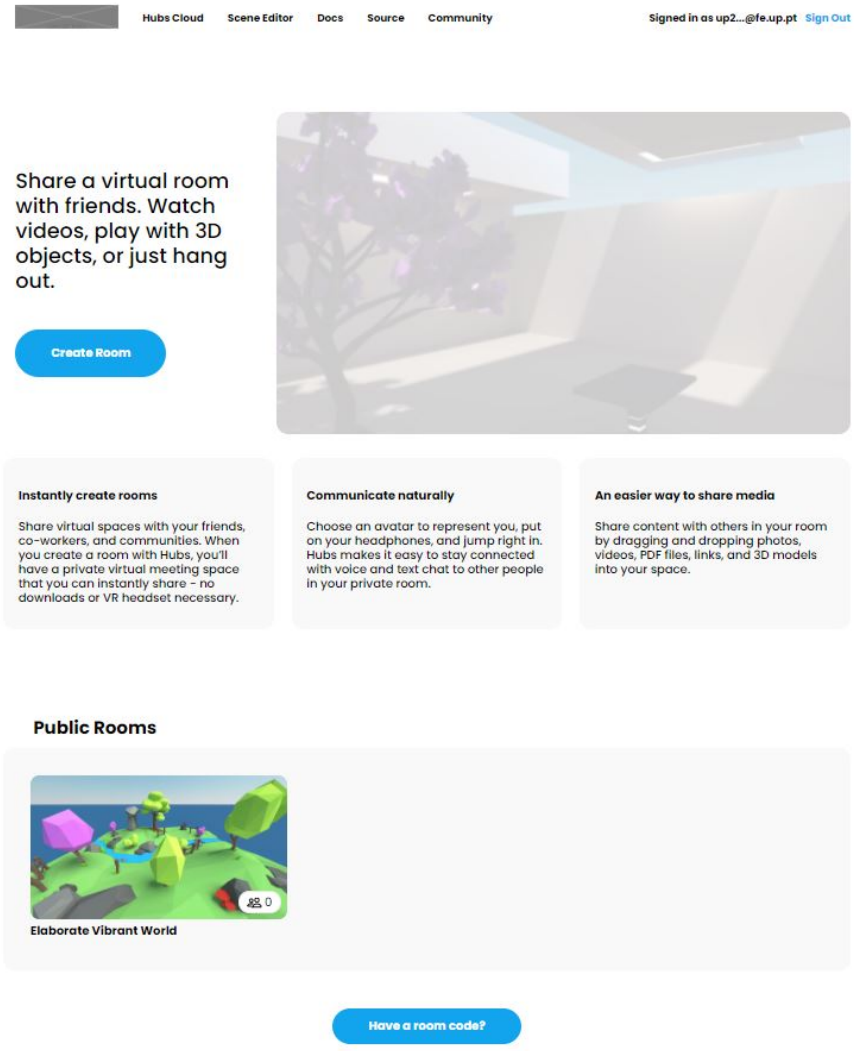


Figure 6.1: Hubs Client initial page

While in the first attempt the create room option or the public room seemed like the most likely to produce results in terms of having a local Hubs client and a virtual environment that allowed for the changes to the code to be reflected, the second time, a different approach was chosen.

Going to the **Scene Editor** page, a virtual environment was created. After publishing this room to Hubs and making it public, the scene ID was saved.

Next, in the hubs code, the file `scene.js` in the `src` folder was changed to accept the room with the specific sceneID of the virtual room previously created. This was done by changing line *67* on the `onReady` async function.

```
1  const sceneId = "qZiqtsJ" || qs.get("scene_id") || document.location.pathname.
    substring(1).split("/")[1];
2
```

The first string *"qZiqtsJ"* is the scene ID of the room. It is a manual and static implementation but it was the solution reached and it works.

After this change, the URL needs to be replaced with **https://localhost:8080/scene.html**. And now a page as shown in Figure 6.2 will appear with the name of the scene created on the bottom left (eg.*3DecideTest2.0*). This page has three buttons: **Create a room with this scene**, **Remix on Scene Editor** and **Share on Twitter**. The first button, as the name suggests, allows the user to create a room with that scene. Once the room is created, the user has a working local environment and is ready to implement and test changes to the Hubs client code.

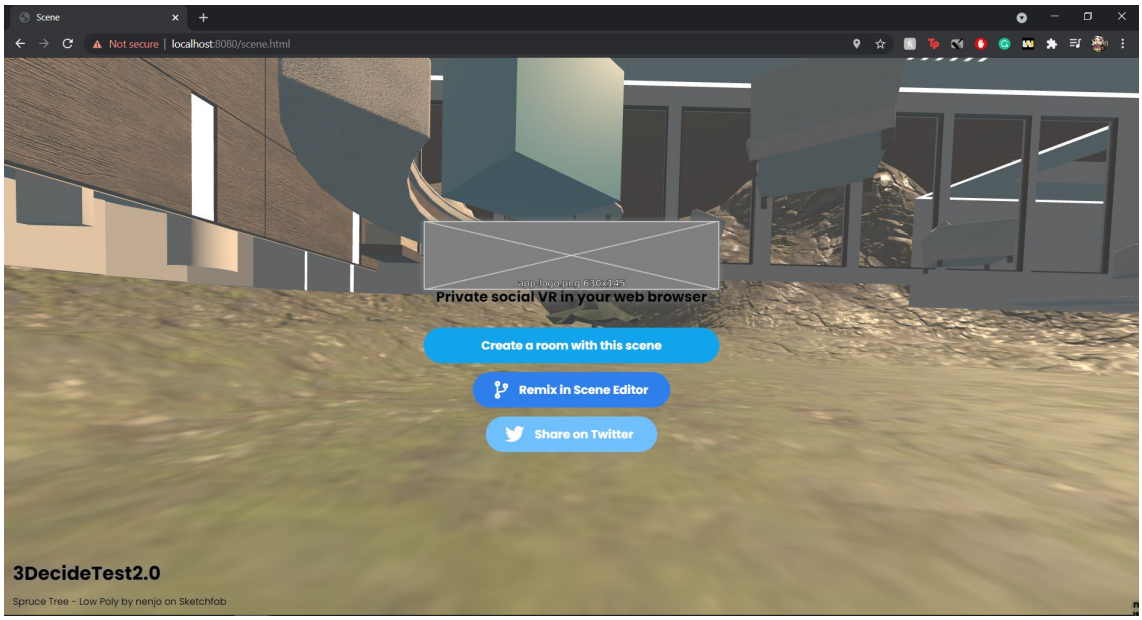


Figure 6.2: Hubs Client create scene page

6.2 Functionalities

6.2.1 3Decide Virtual Environment

A very important part of this project was the virtual environment in itself. The visual presentation is one of the key aspects of this thesis, so the look and feel of this room was a very thought out decision.

The questionnaire directed towards the general population played a huge role in the choices made for this part of the work. An important characteristic for this space that was mentioned by many of the participants was the lack of possible distractions: it should be a calm, simple, neutral room that does not offer a lot of visual stimulus while being immersive and giving the user the idea that they are in a physical space with others.

This meant making a virtual environment that was not very complex nor had a lot of rooms and divisions, with more of an open-space concept - the user can see most rooms immediately. The color palette is neutral, consisting of mostly warm browns, whites and greys. The decor is minimalist, with touches of green in the form of plants and the room is spacious with a lot of natural light coming through the big windows and skylight.

The space is divided into five areas : the **main lobby** - figure 6.6 -, the **theater** - figure 6.7 -, the **meeting room** and the two **galleries** - figures 6.3 and 6.4 represent Gallery 1 and figure 6.5 represents Gallery 2. It is important to note that the main lobby has a space designed for the **dressing room**.

The galleries were designed for the eventual exhibitions that 3Decide might be interested in making, to show clients the work developed in a visual manner. The theater is a good space for presentations, either for clients or for the workers and the main lobby is a great hangout spot.

This virtual space was developed by 3Decide's multimedia team using Spoke and a third-party 3D computer graphics program for the custom models. The following images show the final product.

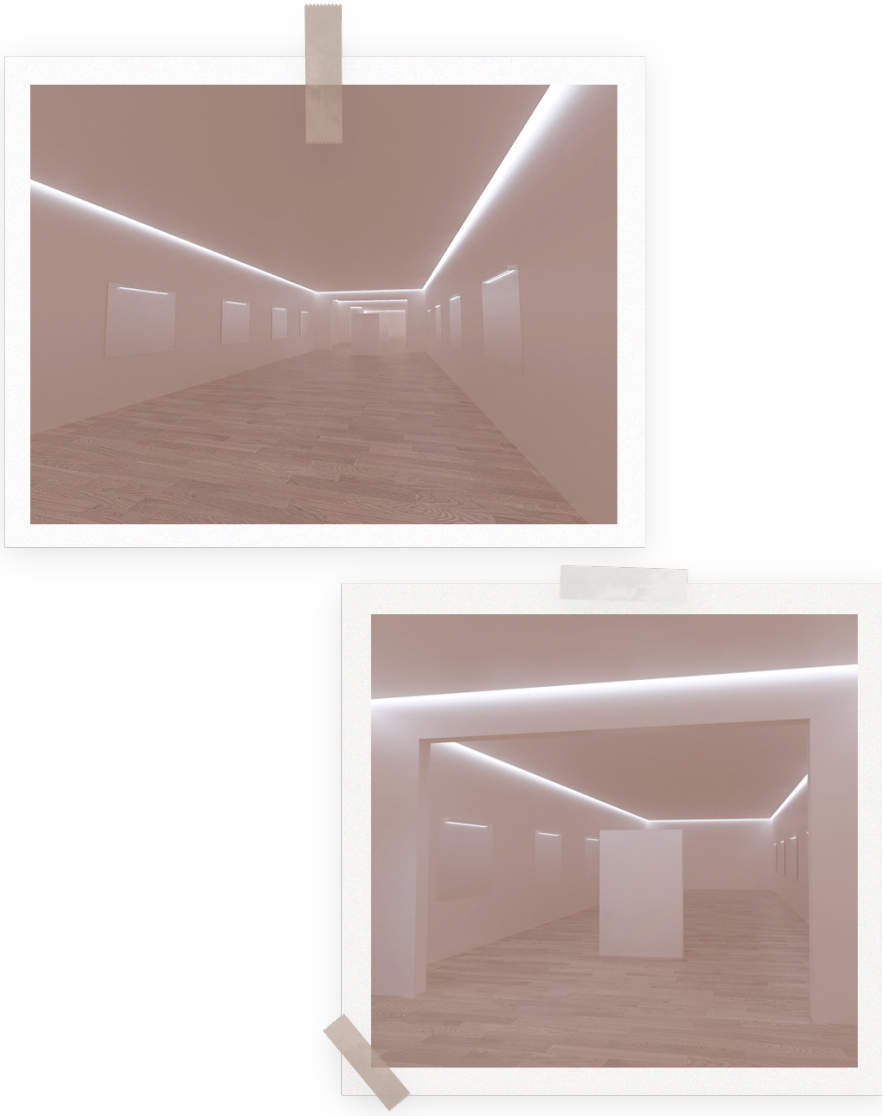


Figure 6.3: 3Decide Gallery

Figure 6.4: 3Decide Gallery

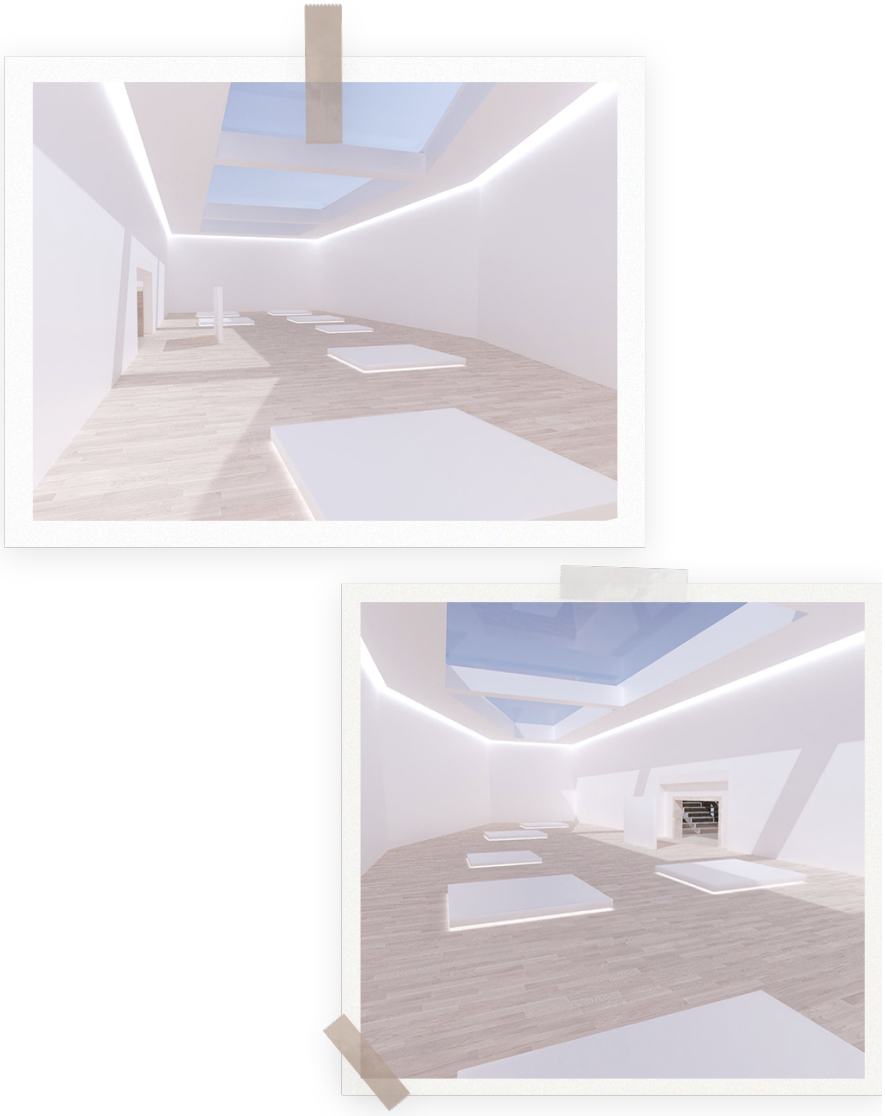


Figure 6.5: 3Decide Gallery

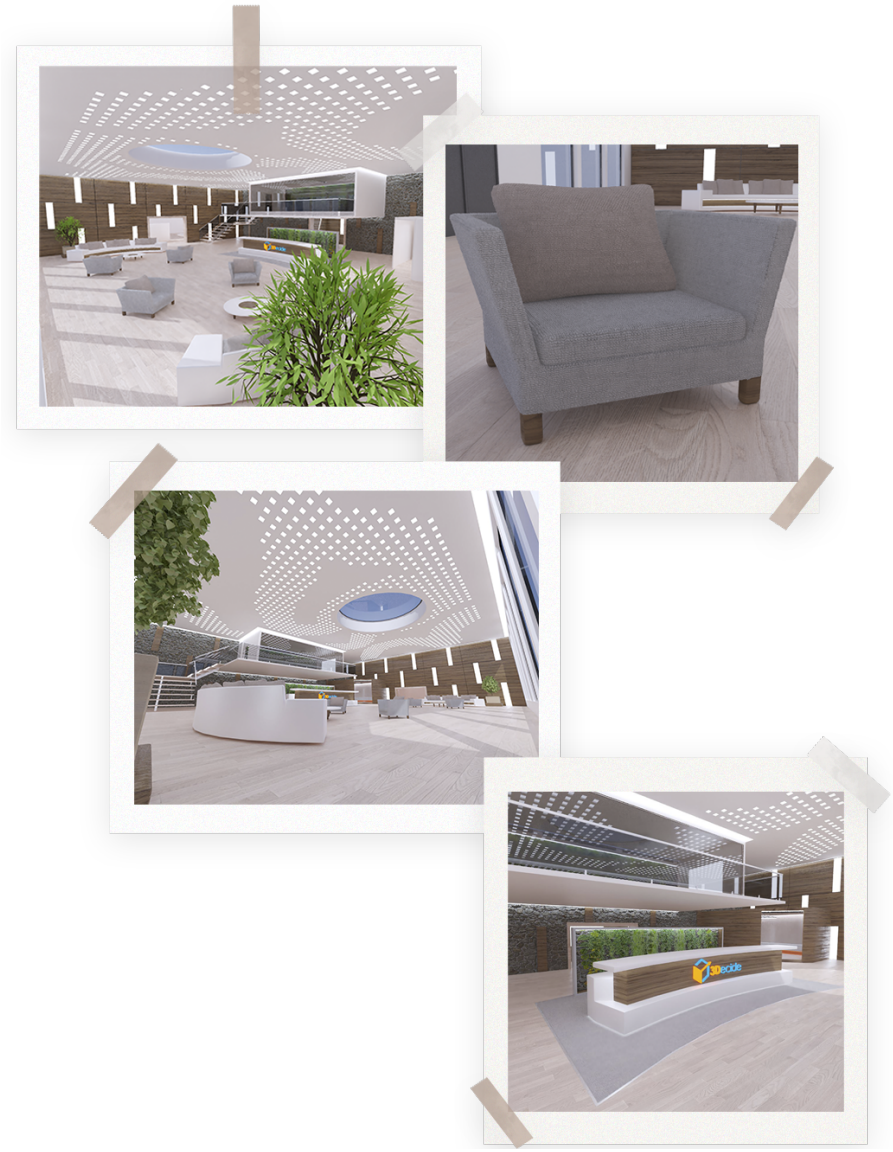


Figure 6.6: 3Decide Lobby

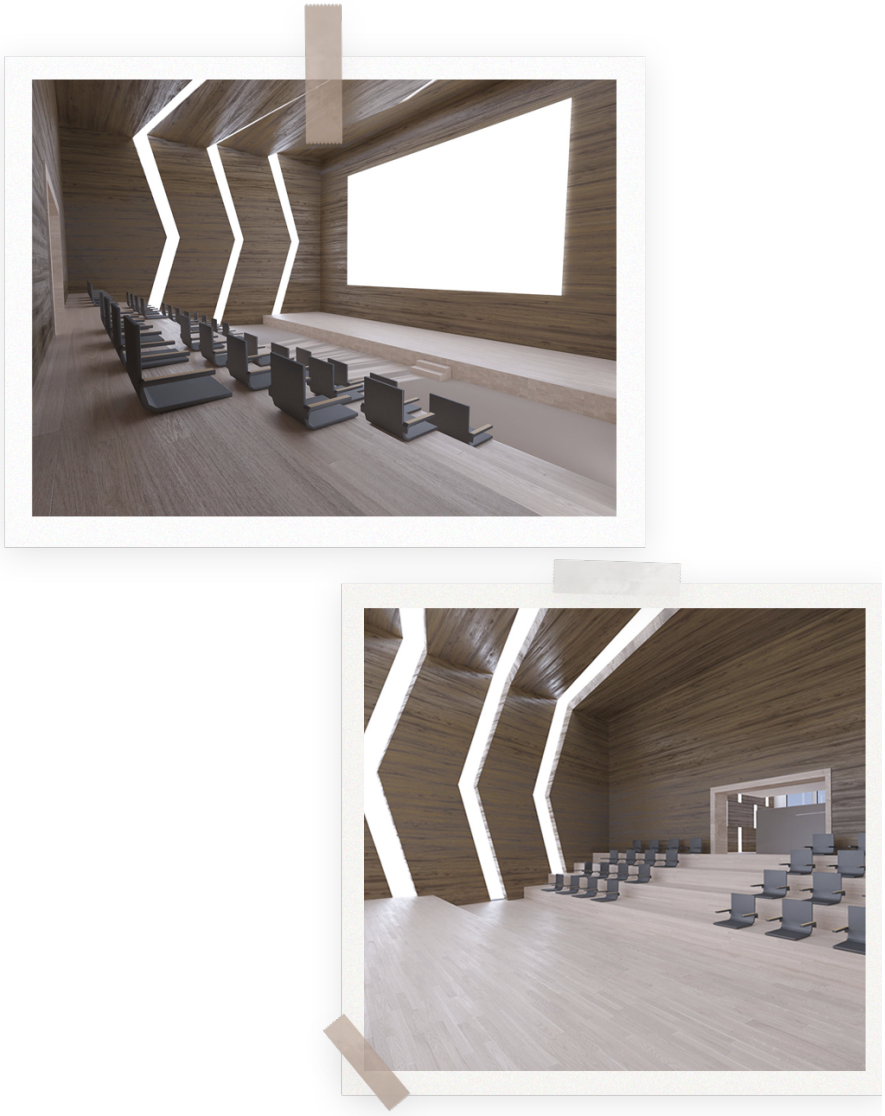


Figure 6.7: 3Decide Theater

6.2.2 Dressing Room Feature

The dressing room feature is a part of the functionalities suggested in order to **improve team identity** and **connection between members**. It would, in theory, help **strengthen team identity** and **establish a team structure** and an individual's role in it, consequentially **bettering team dynamics**.

To this end, a room in the virtual environment had to be made so that there the user could choose their avatar according to their role on the team: multimedia, developer, team leader, etc. This was done by copying various avatars and linking them in the dressing room, so that the user just has to click on the avatar image and choose that as their avatar. Here, the questionnaire directed towards the general population was also useful seeing as it was mentioned that the avatars could be very distracting and so, just like the virtual environment, they had to be simple, sleek and

uniform across the board, so that everyone looked like they belonged to the same team while also being slightly set apart depending on their role on the team.

Figures 6.20, 6.9 and 6.10 were draft versions of a possible dressing room. This virtual space was made with the intention of fully understanding how Spoke works, the full extent of its features and what was possible to be made. Like mentioned in previous chapters, Spoke is an online scene editor used to create rooms in Hubs so it was important to explore this platform. Although it was not used in the final product, it was part of the process.

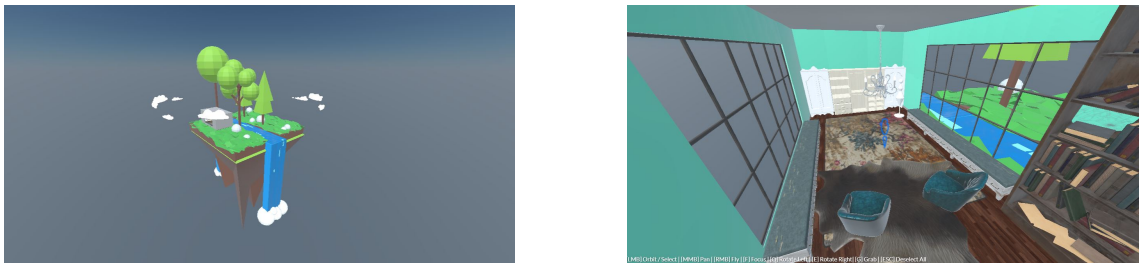


Figure 6.8: Dressing Room attempt

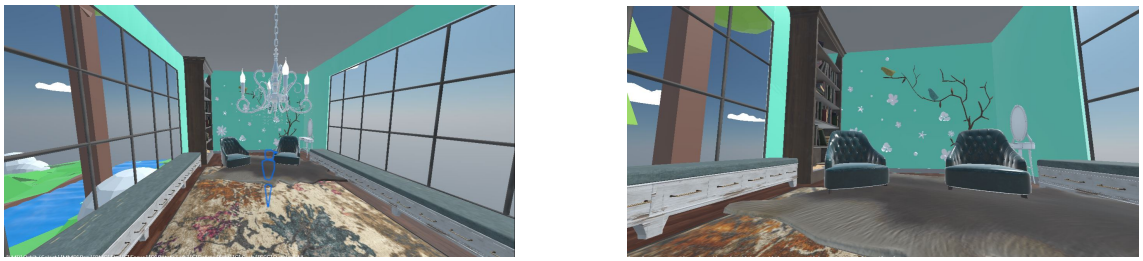


Figure 6.9: Dressing Room attempt

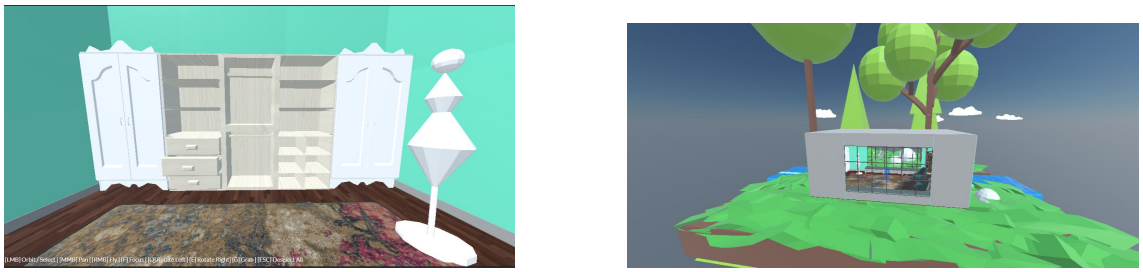


Figure 6.10: Dressing Room attempt

The inspiration for the dressing room was the picture below, 6.12. It is a neutral room, very illuminated with minimal decoration and spacious.

Figure 6.11: Dressing Room inspiration

The following images 6.12 are the finished result. This dressing room is located in the main lobby division and, just like the inspiration image 6.11 and the rest of the 3Decide's virtual room, it is simple, with a lot of light - natural and otherwise.

Figure 6.12: 3Decide Dressing Room

6.2.3 Dynamic Sky Feature

This feature is a part of the enhancements to the environment mentioned in chapter 3. This functionality was proposed so as to **add realism to the experience**, which can sometimes feel disengaging, the **environment reflects the user's circadian rhythm and location by mirroring the time zone outside**.

To implement this dynamic sky feature, it was necessary to change the file `skybox.js` in the `components` folder, which in turn is in the `src` folder.

A skybox is used to create the illusion of far off three-dimensional backgrounds, they are essentially cubes with textures on each side of the cube. Usually both the player and camera are then placed within this cube so that all six textures surrounding them give the illusion that they're within a much larger environment.

The skybox present in Hubs rooms is customizable on Spoke, meaning, there the user can change the sky's appearance according to the hour they define on that object's setting, like shown in figure 6.13. However, the goal for this feature is for the sky to change dynamically throughout the day.

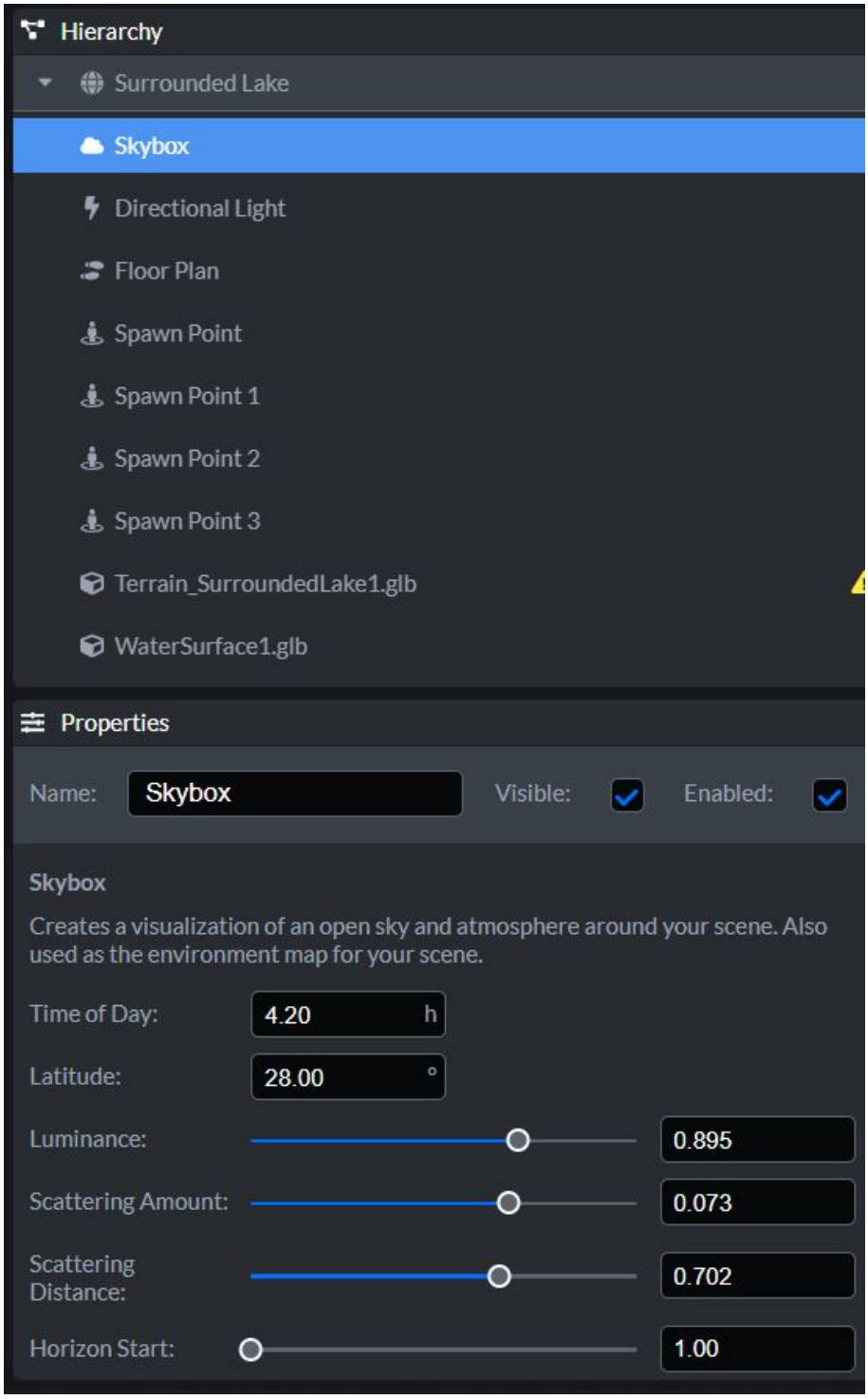


Figure 6.13: Skybox settings on Spoke

This means that the skybox object created on the `skybox.js` file allows for the manipulation of the different parameters that constitute it.

The first step is to **get the user's location and date**. The location is given by the **HTML Geolocation API**. Since this can compromise privacy, the user's position is not available unless the user approves it, which means when entering the room, the user is asked to allow the website to track them. The `getCurrentPosition` function returns a coordinates object with **latitude** and **longitude**. The code below shows the application of this API in the `skybox.js` file.

```
1
2  setUserLocation(latitude, longitude) {
3     this.latitude = latitude;
4     this.longitude = longitude;
5   }
6
7     updateSunPosition() {
8     //sun position is given by angle from zenith and azimuth angle
9     //they depend on time of day, date, latitude, longitude
10
11    navigator.geolocation.getCurrentPosition(position => {
12      this.setUserLocation(position.coords.latitude, position.coords.longitude);
13    });
14
15    console.log("LATITUDE: ", this.latitude, "\nLONGITUDE: ", this.longitude);
16    ...
17    }
```

The time is given by the JavaScript `Date` object, as shown in the code below, present in the `skybox.js` file. The function shown, `getUserDate` is called on the skybox constructor.

```
1
2   getUserDate() {
3     this.now = Date();
4
5     this.time = this.now.substring(16, 24);
6     this.date = this.now.substring(4, 15);
7     this.gmt = this.now.substring(25, 34);
8
9     //date - mm/dd/yyyy
10    this.month = this.date.substring(0, 3);
11    this.day = this.date.substring(4, 6);
12    this.year = this.date.substring(7, 11);
13
14    //time - hour & minutes
15    this.hour = this.time.substring(0, 2);
```

```
16      this.minutes = this.time.substring(3, 5);
17
18      console.log(this.now);
19    }
```

Looking at the skybox's Sky shader components, we can see it is composed of the following parameters: **luminance**, **rayleigh**, **turbidity**, **mieCoefficient**, **mieDirectionalG** and lastly **sunPosition**, which is a vector. The vertexShader and fragmentShader are defined by threejs' sun sky shader.

```
1
2   export default class Sky extends Object3D {
3     static shader = {
4       uniforms: UniformsUtils.merge([
5         UniformsLib.fog,
6         {
7           luminance: { value: 1 },
8           turbidity: { value: 20 },
9           rayleigh: { value: 2 },
10          mieCoefficient: { value: 0.005 },
11          mieDirectionalG: { value: 0.8 },
12          sunPosition: { value: new Vector3() }
13        }
14      ]),
15      vertexShader,
16      fragmentShader
17    };
18
19    constructor() {
20      super();
21
22      const material = new ShaderMaterial({
23        fragmentShader: Sky.shader.fragmentShader,
24        vertexShader: Sky.shader.vertexShader,
25        uniforms: UniformsUtils.clone(Sky.shader.uniforms),
26        side: BackSide,
27        fog: true
28      });
29
30  ...
31    }
```

In order to implement a sky that changes throughout the day it is important to understand what all these components mean and how they influence the sky's appearance and how they change

according to the time. To that end, the paper **A Practical Analytic Model for Daylight** also known as **The Preetham Model**, the standard analytic skydome model, was used as a base.[5]

Before exploring the different parameters, it is essential to calculate the **sun's position** seeing as most of these variables require it for their calculations.

The sun's position is given by the angle from zenith (θ_s) and azimuth angle (ϕ_s) and they depend on the **time of the day**, **latitude** and **longitude**, as shown in figure 6.14.

Solar Azimuth is an horizontal coordinate that defines the Sun's relative direction along the local horizon. There are several conventions for the solar azimuth; however, it is traditionally defined as the angle between a line due south and the shadow cast by a vertical rod on Earth. This convention states the angle is positive if the shadow is east of south and negative if it is west of south. For example, due east would be 90° and due west would be -90°. [55, 56, 57]

Solar Zenith is the angle between the sun's rays and the vertical direction. [58, 59]

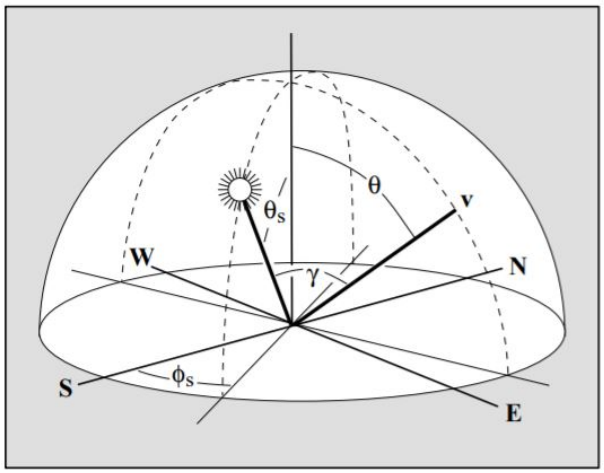


Figure 6.14: Coordinates for specifying the sun position and the direction **v** on the sky dome Source:[5]

Solar position can be calculated from the solar declination angle, latitude and longitude. The **solar declination angle** (δ) in radians is given by the following formula [5]:

$$\delta = 0.4093 \sin(\frac{2\pi(J-81)}{368})$$

Where J stands for the Julian date (the day of the year as an integer in the range 1 to 365). After calculating the solar declination angle, one can calculate the azimuth (ϕ_s) and zenith (θ_s).

$$\theta_s = \frac{\pi}{2} - \arcsin(\sin l \sin\delta - \cos l \cos\delta \cos\frac{\pi t}{12})$$

$$\phi_s = \arctan(\frac{-\cos\delta \sin\frac{\pi t}{12}}{\cos l \sin\delta - \sin l \cos\delta \cos\frac{\pi t}{12}})$$

Where l is latitude in radians and t is solar time in decimal hours. Solar angles from zenith are between 0 and $\frac{\pi}{2}$ and angles above $\frac{\pi}{2}$ indicate sun below the horizon. Positive solar azimuthal angles represent direction west of south.

Fortunately, there is a BSD-licensed JavaScript library named **SunCalc**[60, 61] for calculating sun position, sunlight phases (times for sunrise, sunset, dusk, etc), moon position and lunar phase for the given location and time. It was added to the hubs client code by running the command `npm install suncalc` on the console in the project folder. It was also added to the skybox constructor in the `skybox.js` file.

```
export default class Sky extends Object3D {
 ...

  constructor() {
    super();

    this.SunCalc = require("suncalc");

   ...
   }
```

SunCalc has a few useful functions, but the only relevant one used in this context was the `getPosition` one.

```
SunCalc.getPosition(/*Date*/ timeAndDate, /*Number*/ latitude, /*Number*/ longitude
    )
```

This returns an object with the following properties:

- **altitude** (α_s): sun altitude above the horizon in radians, e.g. 0 at the horizon and $\frac{\pi}{2}$ at the zenith (straight over the user's head), can also be called inclination. This solar altitude angle is the complementary angle to the solar zenith angle, so $\theta_s = \frac{\pi}{2} - \alpha_s$.
- **azimuth** (ϕ_s): sun azimuth in radians (direction along the horizon, measured from south to west), e.g. 0 is south and $\frac{3\pi}{4}$ is northwest.

The code below shows how the sun's position is calculated and how the variables **inclination** and **azimuth** are determined. The distance parameter is not changed, it does not influence the visual aspect that much, the sun's distance to the observer is almost always the same and does not vary a lot from location to location. The `updateSunPosition` function is where all the calculations of these parameters are done.

```
```

```
export default class Sky extends Object3D {
  static shader = {
    uniforms: UniformsUtils.merge([
      UniformsLib.fog,
      {
        luminance: { value: 1 },
        turbidity: { value: 20 },
        rayleigh: { value: 2 },
        mieCoefficient: { value: 0.005 },
        mieDirectionalG: { value: 0.8 },
        sunPosition: { value: new Vector3() }
      }
    ]),
    vertexShader,
    fragmentShader
  };

  constructor() {
    super();

    const material = new ShaderMaterial({
      fragmentShader: Sky.shader.fragmentShader,
      vertexShader: Sky.shader.vertexShader,
      uniforms: UniformsUtils.clone(Sky.shader.uniforms),
      side: BackSide,
      fog: true
    });
    ...
    //default values when user location isn't given
    this._inclination = 0;
    this._azimuth = 0.15;
    this._distance = 8000;
  }

 updateSunPosition() {

    navigator.geolocation.getCurrentPosition(position => {
      this.setUserLocation(position.coords.latitude, position.coords.longitude);
    });

    if (this.latitude != undefined && this.longitude != undefined) {
      var sunPos = this.SunCalc.getPosition(new Date(), this.latitude, this.
    longitude);

      this._inclination = sunPos.altitude;
      this._azimuth = sunPos.azimuth;

    }

```

```
50      const theta = Math.PI/2 - this._inclination; //y-axis
51      const phi = this._azimuth; //x-axis
52
53      ...
54      const distance = Math.min(1000, this._distance);
55
56      const x = distance * Math.cos(phi);
57      const y = distance * Math.sin(phi) * Math.sin(theta);
58      const z = distance * Math.sin(phi) * Math.cos(theta);
59
60      this.sky.material.uniforms.sunPosition.value.set(x, y, z).normalize();
61      this.sky.scale.set(distance, distance, distance);
62    }
```

Moving on to the next parameter, the **turbidity**, is a **measure of the fraction of scattering due to haze**. More formally, turbidity T is the ratio of the optical thickness of the haze atmosphere (haze particles and molecules) to the optical thickness of the atmosphere with molecules alone. [5] It can be calculated using the following formula:

$$T = (t_m + t_h)/t_m$$

Where t_m is the vertical optical thickness of the molecular atmosphere and t_h is the vertical optical thickness of the haze atmosphere. Besides this definition, several others are used in various fields. Turbidity can also be estimated using meteorologic range, as shown in figure 6.15. Meteorological range R_m is the distance under daylight conditions at which the apparent contrast between a black target and its background (horizon sky) becomes equal to the threshold contrast of an observer, and it roughly corresponds to the distance to the most distant discernible geographic feature.

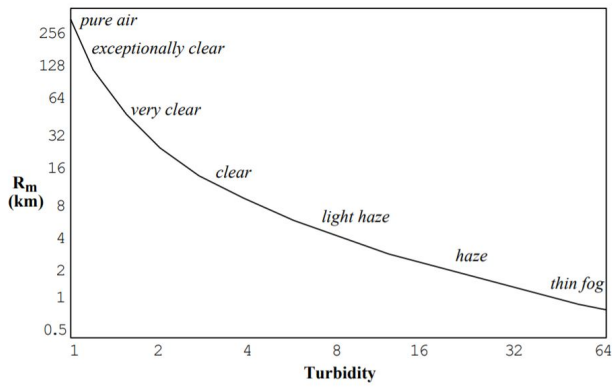


Figure 6.15: Meteorological range R_m for various turbidity values Source:[5]

The following figure 6.16 shows the difference in the sky with different turbidity values applied.

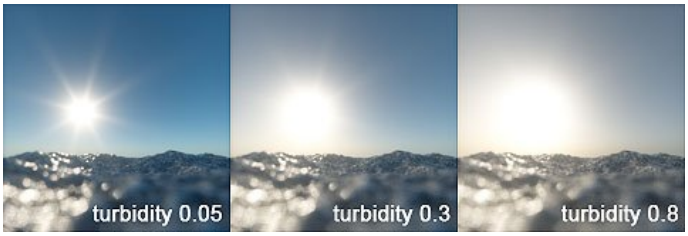


Figure 6.16: The difference in the sky with different turbidity values

So, as it was explained, the turbidity value varies from place to place, hour to hour and depends on the haziness of the sky at that moment and place. After researching, there were no calculators, APIs or javascript functions that calculated the turbidity value on a specific location at a specific time or that gave any values that could be used to calculate it.

Subsequent analysis of the turbidity parameter of the skybox object in hubs allowed to conclude that it ranged in value from 0 to 20.

The solution ended up not being ideal seeing as it is not completely accurate to that user's location and time: usually turbidity values are lower in the morning - it is normal to be foggier at dawn-, highest at midday and during the early afternoon, and again lower late afternoon and at night, although not as low as in the morning.

```
1
2  updateSunPosition() {
3  ...
4
5      //turbidity
6      // varies from 0 - 20 - cannot be calculated automatically
7      // need meteorological range
8      // mostly -> morning - lower turbidity - 2
9      // midday - 4 pm -  high turbidity - 15
10     // 4pm - night - lower turbidity - 7
11
12     if (this.hour < 12) {
13       this.sky.material.uniforms.turbidity.value = 2;
14     } else if (this.hour >= 12 && this.hour < 17) {
15       this.sky.material.uniforms.turbidity.value = 15;
16     } else if (this.hour > 17) {
17       this.sky.material.uniforms.turbidity.value = 7;
18     } else this.sky.material.uniforms.turbidity.value = 10;
19 ...
20 }
```

Rayleigh scattering is the elastic scattering of light or other electromagnetic radiation by particles much smaller than the wavelength of the radiation. It is used for gas molecules. Rayleigh scattering of sunlight in Earth's atmosphere causes diffuse sky radiation, which is the reason for the blue color of the daytime and twilight sky, as well as the yellowish to reddish hue of the low Sun, as shown in figure 6.17. Rayleigh, in simpler terms, represents the sky appearance globally.[62, 5]

Figure 6.17: Rayleigh scattering causes clouds to appear colored, like this picture, due to the scattering of light on cloud particles

The **Rayleigh sky model** describes the observed polarization pattern of the daytime sky. It is important to note that because the polarization pattern is dependent on the sun, it changes not only throughout the day but throughout the year. During a single day, the pattern rotates with the changing position of the sun. [63, 64, 5]

The model predicts the degree of sky polarization as:

$$\delta = \frac{\delta_{max} \sin^2 \gamma}{1 + \cos^2 \gamma}$$

Where γ represents the angular distance between the observer and the sun and δ_{max} is the maximum degree of polarization . The maximum degree of polarization, δ_{max}, at any time is 80%. [63, 64], which is a realistic maximum for a clear sky during day time. The angular distance value, γ, however could not be calculated, and so the rayleigh value remains the default one.

Luminance is a photometric measure of the luminous intensity per unit area of light travelling in a given direction. [65] It basically describes the amount of light that passes through, is emitted from, or is reflected from a particular area, and falls within a given solid angle. **Brightness** is the term for the subjective impression of the objective luminance measurement standard. It is often used to characterize emission or reflection from flat, diffuse surfaces. Luminance levels indicate how much luminous power could be detected by the human eye looking at a particular surface

from a particular angle of view.[65] Luminance is thus an indicator of how bright a surface will appear.

Luminance values depend on the luminance at the zenith - Y_z - at that time and place, which can be calculated from :

$$Y_z = (4.0453T - 4.9710)\tan\chi - 0.2155T + 2.4192$$

Where T is the turbidity and χ is calculated from $\chi = (\frac{4}{9} - \frac{T}{120})(\pi - 2\theta_s)$.

So, after calculating the luminance at the zenith at that time and place, the formula for the luminance distribution is:

$$Y = Y_z \frac{1 + 2\cos\theta_s}{3}$$

The following code shows how the luminance value was determined according to the calculations referred previously.

```
updateSunPosition() {
...
 //luminance
    //chi
    const chi = (4 / 9 - this.sky.material.uniforms.turbidity.value / 120) * (Math.
    PI - 2 * theta);
    //luminance at the zenith
    const y_z =
      (4.0453 * this.sky.material.uniforms.turbidity.value - 4.971) * Math.tan(chi)
     -
      0.2155 * this.sky.material.uniforms.turbidity.value +
      2.4192;

    //formula y_z*(1 + 2 * cos theta)/ 3
    var luminance = (y_z * (1 + 2 * Math.cos(theta))) / 3;
    this.sky.material.uniforms.luminance.value = luminance;
...
}
```

Lastly, there is the **mieCoefficient** and **mieDirectionalG**. The **Mie solution** describes the scattering of an electromagnetic plane wave by a homogeneous sphere. The **Mie scattering**, which is sometimes referred to as a non-molecular scattering takes place in the lower 4.500 meters of the atmosphere, is related to the haze particles in atmosphere. [5] [66, **?**] The mieCoefficient is in the interval between [0, 0.1] and affects the property mieDirectionalG. This property in turn, represents the amount of haze particles present in the atmosphere, following the Mie scattering theory. It is important to note that there are two types of scattering coefficient: the angular scattering coefficient and the total scattering coefficient. Both of these determine how the light is scattered

by particles, and the total scattering coefficient is the integral of the angular scattering coefficient in all directions. The formulas to calculate the angular and total scattering coefficients for Mie scattering are, in order :

$$\beta_p(\theta) = 0.434c(\frac{2\pi}{\lambda})^{v-2}\frac{1}{2}\eta(\theta)$$

$$\beta_p = 0.434c\pi(\frac{2\pi}{\lambda})^{v-2}K$$

Where c is the concentration factor that varies with turbidity T and is calculated with the formula (0.6544T - 0.6510)x10^{-16} and v is named Junge's exponent and is a constant, with a value of 4 for the sky model. The λ represents the electromagnetic waves of the atmosphere. While these formulas are very complex, the way these values change throughout the day is not mentioned in the Preetham Model and, after extensive research, it was not possible to find any studies that analised these changes. And so, just like the rayleigh parameter, these two remained the default ones, set when the skybox is called.

After calculating the different parameters that define the skybox's appearance throughout the day on the `updateSunPosition` function, it is necessary to continuously call it so that the sky's look is always being updated.

For that, it is important to understand how an **A-Frame component** works. A component is a reusable and modular chunk of that, which is plugged into an entity, in this case, the skybox, to add appearance, behaviour and/or functionality. Components modify entities which are 3D objects in the scene. Components can be compared to CSS in the sense that CSS modifies the appearance of elements, and component properties modify the appearance, behaviour and functionality of entities.

```
1
2  AFRAME.registerComponent("skybox", {
3    schema: {
4      turbidity: { type: "number", default: 10 },
5      rayleigh: { type: "number", default: 2 },
6      luminance: { type: "number", default: 1 },
7      mieCoefficient: { type: "number", default: 0.005 },
8      mieDirectionalG: { type: "number", default: 0.8 },
9      inclination: { type: "number", default: 0 },
10     azimuth: { type: "number", default: 0.15 },
11     distance: { type: "number", default: 8000 }
12   },
13 ...}
```

Furthermore, a component has an `.init()` function that is called once at the **beginning of its lifecycle** and is often used to **set up initial state and variables**, **bind methods** and/or **attach event listeners**. The code below shows the skybox's init() function, which calls upon the Sky class defined previously.

```
init() {
  this.sky = new Sky();
  this.el.setObject3D("mesh", this.sky);

  this.updateEnvironmentMap = this.updateEnvironmentMap.bind(this);
  // HACK: Render environment map on next frame to avoid bug where the render
  target texture is black.
  // This is likely due to the custom elements attached callback being
  synchronous on Chrome but not Firefox.
  // Added timeout due to additional case where texture is black in Firefox.
  requestAnimationFrame(() => setTimeout(this.updateEnvironmentMap));

  this.tick = AFRAME.utils.throttleTick(this.tick, 500, this);
},
```

The `.update(oldData)` function is called whenever the component's properties change, including at the beginning of the component's lifecycle. A-Frame calls `.update()` every time a component's data changes, as a result of the .setAttribute function.

Although this seems like the most appropriate function to use in order to update the skybox's appearance, the `.tick()` function is a more suitable option seeing as it is called on each tick or frame of the scene's render loop. The scene will call a component's tick handler:

- On each frame of the render loop
- On the order of 60 to 10 times per second
- If the entity or scene is not paused
- If the entity is still attached to the scene

The tick handler is often used to continuously modify the entity on each frame or on an interval. This, however, can be too much for the scene's performance seeing as this method is called so many times. In order to limit this number, it is best to use utilities such as `AFRAME.utils.throttleTick`.

As such, the `updateSunPosition` is called on the `.tick()` method, like shown in the code below.

```
tick() {
    //update sun position according to time + location
    this.sky.updateSunPosition();

    //for inclination + azimuth matrix needs to be updated
    this.el.object3D.matrixNeedsUpdate = true;
```

```
7
8       //requestAnimationFrame repaints the frame according to updateEnvironmentMap,
        because it is constantly being called
9       //should always be repainting the scene
10      requestAnimationFrame(() => setTimeout(this.updateEnvironmentMap));
11  },
```

So, after all these calculations and changes to the skybox file, the final results shown in the next figures. These were taken at different times throughout the day.

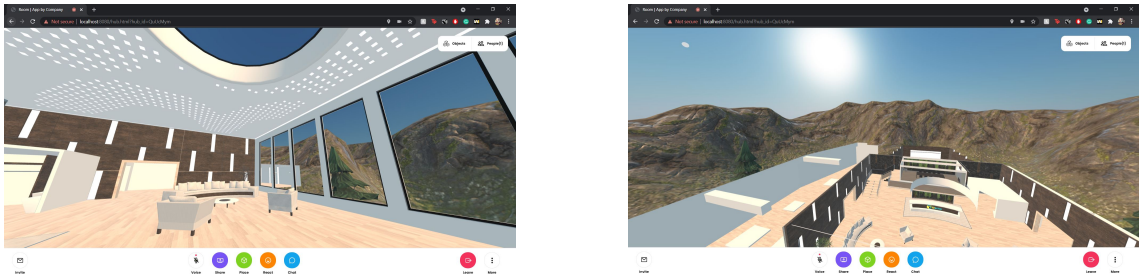


Figure 6.18: 3Decide Room at 3pm

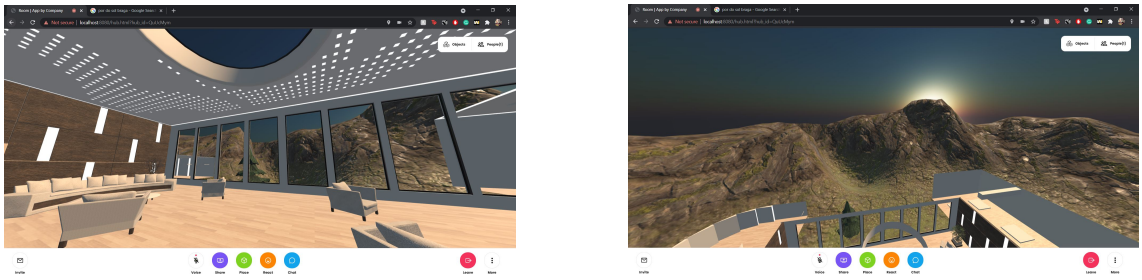


Figure 6.19: 3Decide Room at dawn - approximately 7.45am

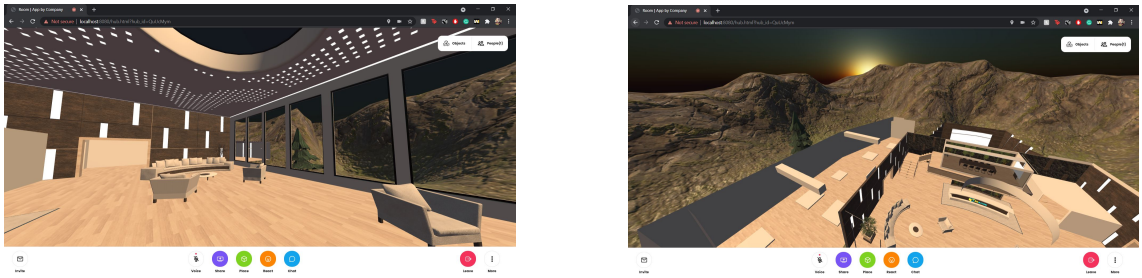


Figure 6.20: 3Decide Room at sunset - approximately 21.30pm

6.3 Evaluation

Lastly, in order to validate the virtual environment created as well as the functionalities implemented, a small number of participants were chosen to experience the customized hubs room. Because these changes are only local, the final solution is not available online so the only way to test this scene is using the machine in which it was implemented. As such, each participant entered the scene individually, which means they could not unfortunately interact with anyone else in that room.

Additionally, and as a consequence, the number of participants is small due to the government's health department constraints and guidelines. The participants used a VR headset - **pico G2** to allow for a more immersive and realistic experience. They filled out a Google form based on the SUS questionnaire and some questions from the first questionnaire devised for the general population. The full survey is available in section E of the Appendix. Below are the results of said form.

6.3.1 System Usability Scale

The SUS - **System Usability Scale** - is a reliable tool for measuring usability and it consists of 10 questions with 5 response options for participants. It was used because it has become an industry standard and it is a very easy scale to administer, can be used on a small sample, such as this one, with reliable results and is valid, meaning it can effectively differentiate between usable and unusable systems [67].

The 5 response options range from : **1 -** Strongly disagree, **2 -** Disagree, **3 -** Neither agree nor disagree (neutral), **4 -** Agree and **5 -** Strong agree. And a question is presented to the participants like shown in the figure below, 6.21.

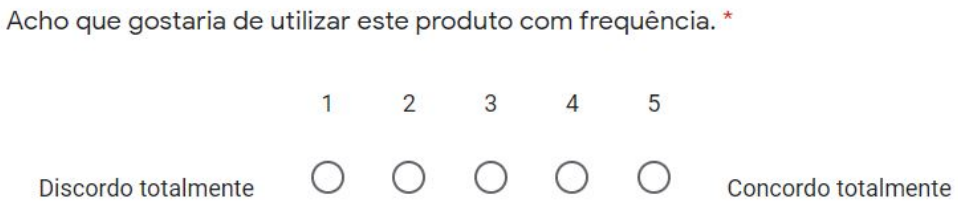


Figure 6.21: SUS question's presentation

Experimental Setup

The participants were chosen from the immediate surroundings, they were given a brief explanation of what the Hubs by Mozilla is, its purpose and what this thesis is based on and the general purpose of the room. The implemented features were also explained as well as what was immediately appearing on their visor screen. Each participant had a minimum of 10 minutes to walk around.

Participant	Age	Profession	Level of technological experience
P1	53	High School Biology Teacher	Basic
P2	52	Dermatologist	Basic
P3	48	Urologist	Basic
P4	51	College Physics Teacher	Medium
P5	30	Translator	Medium
P6	21	Computer Engineering Student	Advanced
P7	23	Engineering and Industrial Management Student	Advanced

Table 6.1: Participants' information

Result Analysis

As shown in figure 6.22, most participants showed an interest in using this product regularly. This interest in this product can be a result of several factors including a participant's job and how much they depend on meetings to work as well as their openness to different technologies and experiences such as VR equipment and virtual immersive spaces.

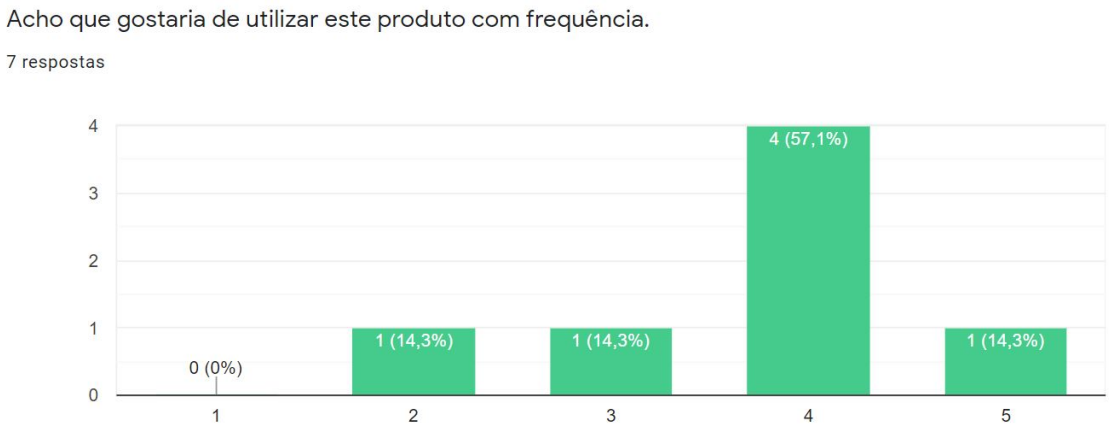


Figure 6.22: Product's frequency of use

By analysing figure 6.23, the opinions in regards to the product's complexity are divided, half the participants considered the product complex, the other half did not. It is important to note that none of the participants had any experience dealing with VR equipment or technology and some had vision problems that did not combine well with this medium, which contributed for a poorer overall experience.

Figure 6.23: Product's complexity

Looking at figure 6.24, most respondents considered the product easy to use - positive answers include the options 4 and 5 which represent *"agree"* and *"strongly agree"*.

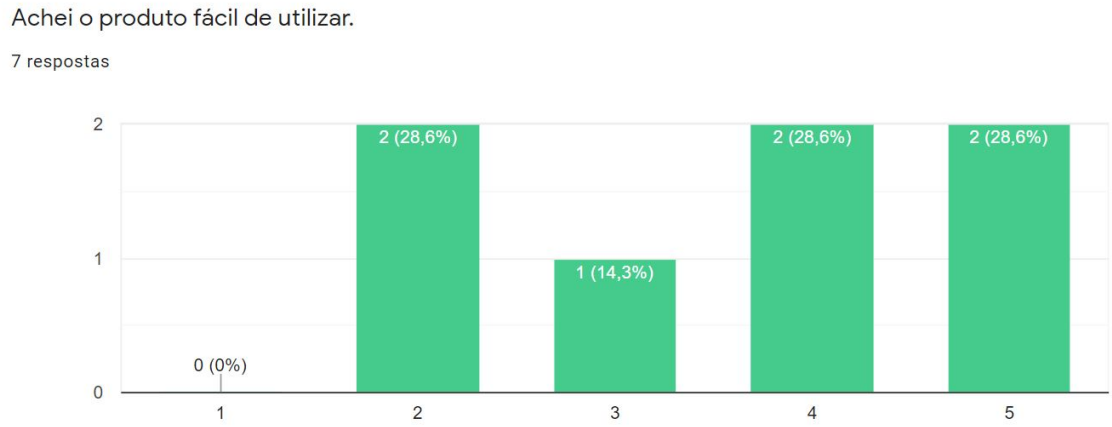


Figure 6.24: Product's ease of use

Figure 6.25 shows the participant's thoughts regarding their need for a technician's help utilizing this product. Most participants answered that it would not be necessary - options 1 and 2, which represent *"strongly disagree* and *"disagree"* make up **57.2%** of answers.

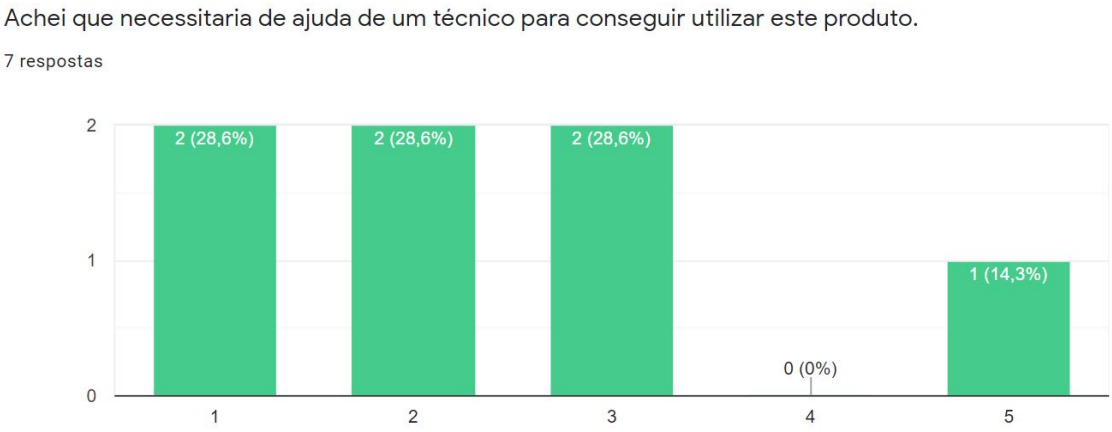


Figure 6.25: Participant's need for help

Observing figure 6.26 that refers to how well the participant thought all features were well integrated, it can be seen that the majority, **57.1%** thought they were.

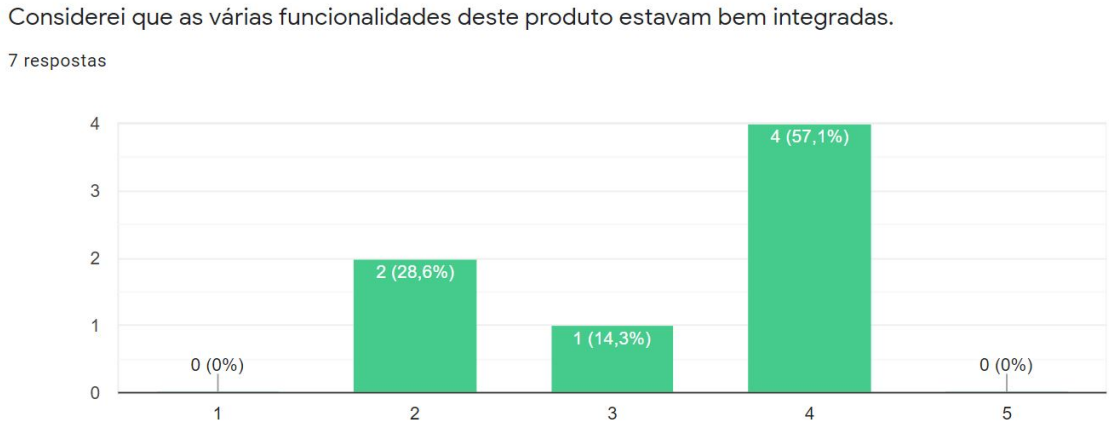


Figure 6.26: Well integrated functionalities.

When asked if they thought the product had a lot of inconsistencies, the results shown in figure 6.27 show a division, **42.9%** of participants disagreed strongly and **57.1%** neither agreed or disagreed.

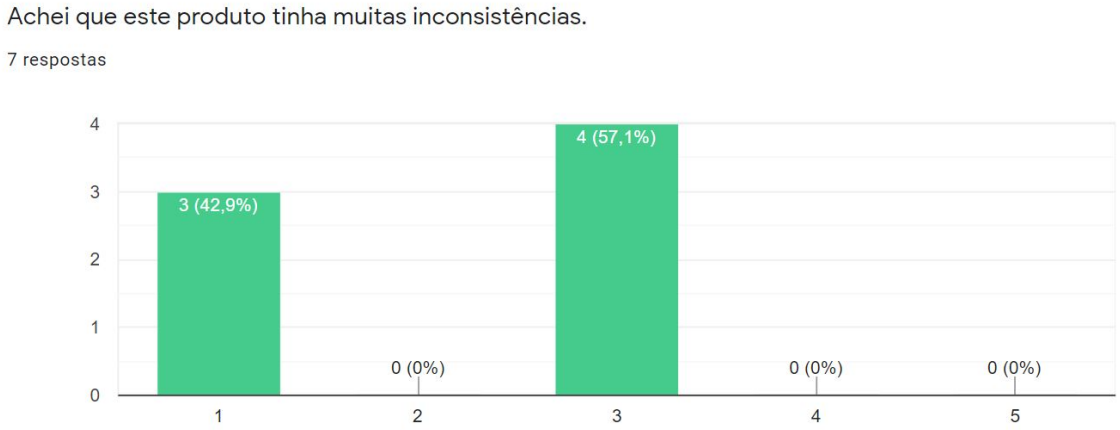


Figure 6.27: Product's inconsistencies

Figure 6.28 shows that most participants thought that the majority of people would rapidly learn how to use this product - **85.7%**.

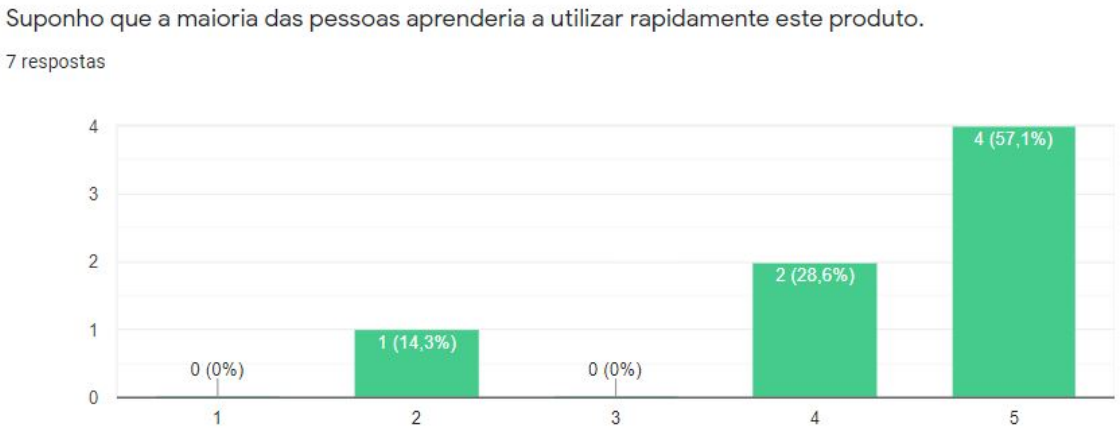


Figure 6.28: Other people's ease of use regarding the product

Analysing figure 6.29, it can be concluded that the majority of respondents - **71.4%** - strongly disagreed with the statement "I found the product very cumbersome to use".

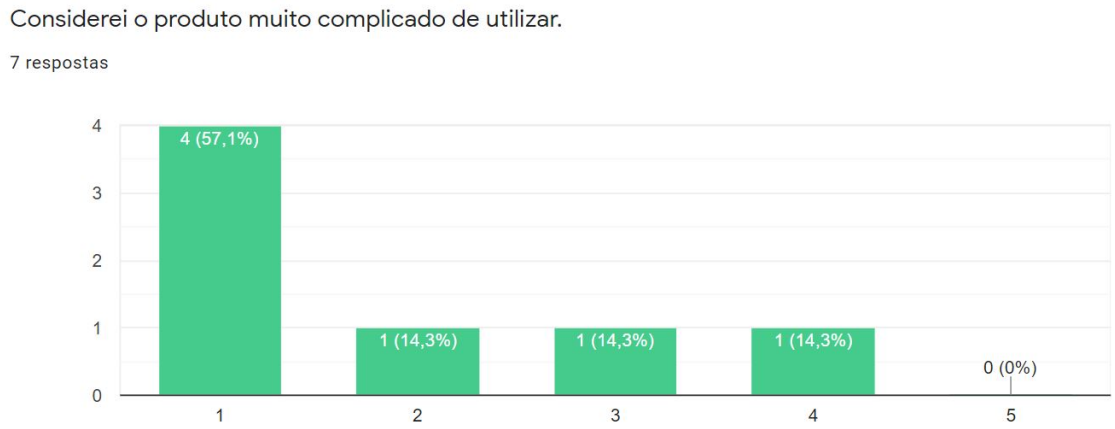


Figure 6.29: Degree of difficulty when using the product

As shown in figure 6.30, the participants felt very confident with their handling of the product -**71.5%**.

Figure 6.30: Participant's level of confidence handling the product

Looking at figure 6.31, that represents the respondents thoughts on the affirmation *"I needed to learn a lot of things before I could get going with this system"*, it can be concluded that the overwhelming majority strongly disagrees with the aforementioned phrase.

Figure 6.31: Participant's adjustment time to the product

System Usability Scale Score

The method to calculating SUS Scores is as follows:

- **For odd items:** subtract one from the user response
- **For even numbered items:** subtract the user response from 5
- This scales all values from 0 to 4, with four being the most positive response
- Add up the converted responses for each user and multiply that total by 2.5. This converts the range of possible values from 0 to 100 instead of 0 to 40.

It is important to note that the average SUS Score is 68. The best way to interpret one's score is to convert it to a percentile rank through a process called normalizing. This process gives grades according to the percentile value of the SUS Score. The figure 6.32 below shows how this association between percentile ranks and letter grades is made.

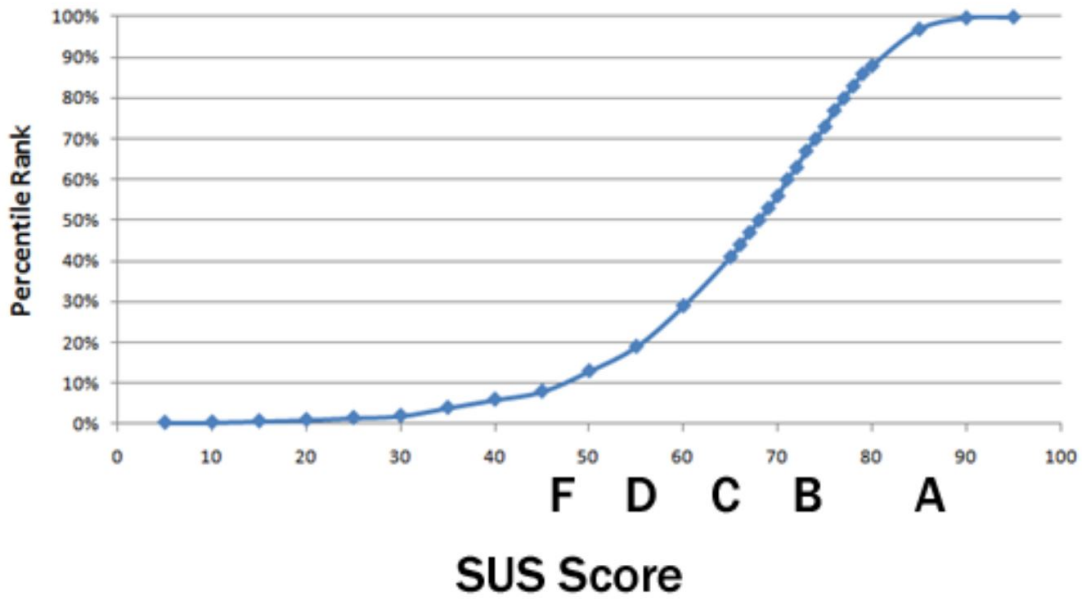


Figure 6.32: SUS Score and respective letter grades

After calculating each participants score, the results are shown in the table below 6.2.

Participant	SUS Score
P1	95
P2	37.5
P3	80
P4	90
P5	90
P6	60
P7	52.5
Final Score	**73**

Table 6.2: Participants' SUS Score and Final SUS Score

The participants were encouraged to give their honest opinions, with the least amount of bias as possible. Most of the lowest scores can be justified: Participant 2 felt nauseated and had never experienced VR technology and so was not used to it and possible side-effects. Participant 7 did not understand how the command worked seeing as it was their first contact with VR technology as well.

The final score was calculated by doing an average of the sum of all the participant's scores. It resulted in a B grade seeing as its value was 73 and a B grade is given to scores between the 70 and 80 range.

6.3.2 3Decide virtual immersive environment

The following questions are centered on the user's experience on the virtual meeting room developed with 3Decide and are taken or based off of the first questionnaire sent to the general public.

In comparison with face-to-face meetings, most people, as shown in figure 6.33, do not feel as involved, which is to be expected since nothing can compare to an in-person interaction. However, these results are better when compared to the level of involvement when compared to virtual meetings - figure 6.34, so it can be concluded that while nothing replaces physical meetings, this method of videoconferencing is preferred over the traditional platforms like *Zoom*, at least, involvement-wise.

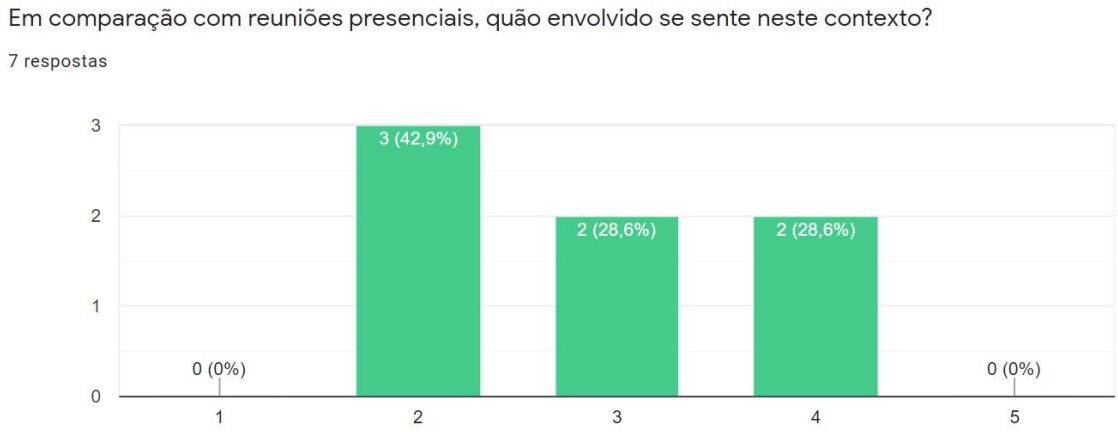


Figure 6.33: Participant's sense of involvement in the immersive meeting when compared to in-person reunions

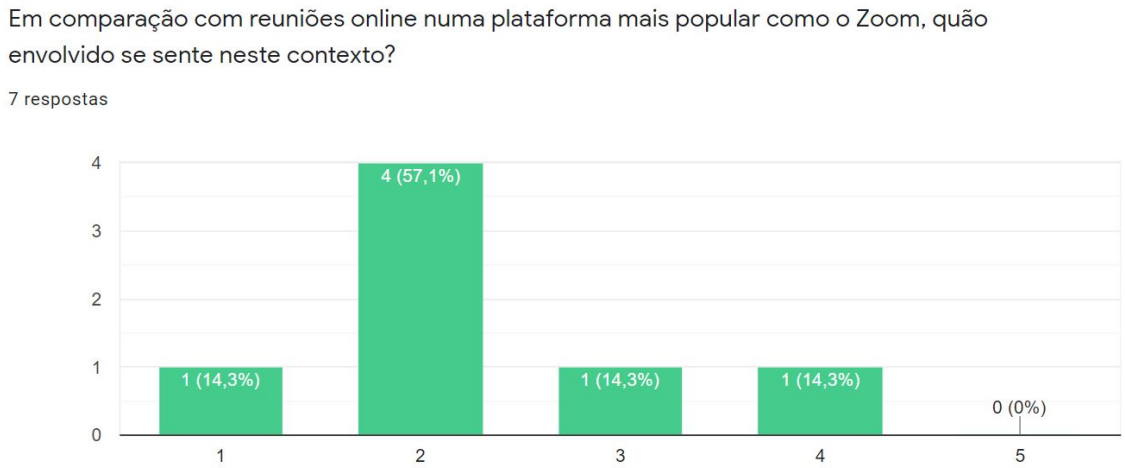


Figure 6.34: Participant's sense of involvement in the immersive meeting when compared to the usual videoconferencing platforms

The first open question, had the same objective as a previous one from the first questionnaire. It asked of the participants the following: "If videoconferences were conducted in a common

virtual room, more interactive and 3D, do you think that new medium and environment would be a distraction factor or would it encourage your participation?"

The answers can be seen in figure 6.35 and are slightly better than the first time, they were mostly positive - the participants thought it was something that would make them feel more comfortable and allow them to focus and participate more, with only one mentioning that it would be something not adequate for a meeting context and another stating that this new technology would not make an impact on their experience in a virtual meeting (neither make a better impression nor worsen the ability to focus).

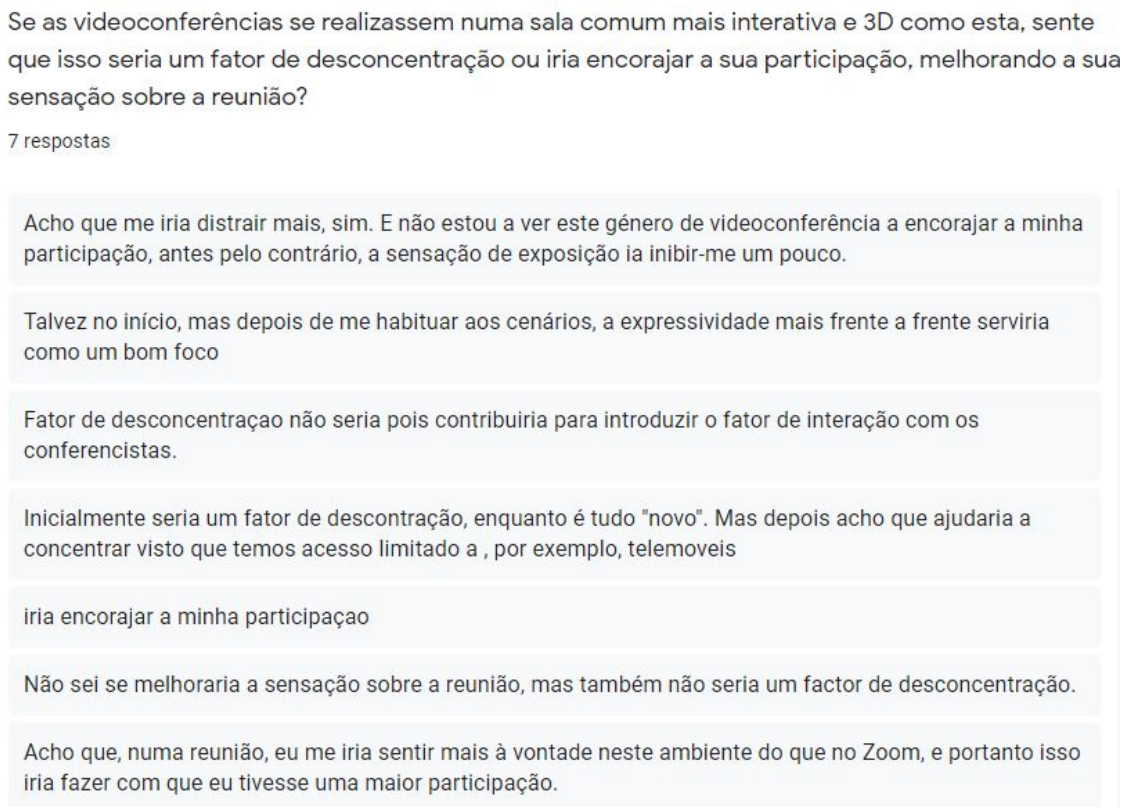


Figure 6.35: Participant's thought on how this context would influence their concentration and participation in the meeting

Regarding the aspects that they most enjoyed about the experience, they are shown in figure 6.36 and the space was one of the aspects highlighted. The dynamic nature of this technology as well as the "newness" of the experience. On the other hand, regarding the aspects that they disliked, there are some mentions of motion sickness. Additionally, some claimed that the features are not clearly understood in the beginning.

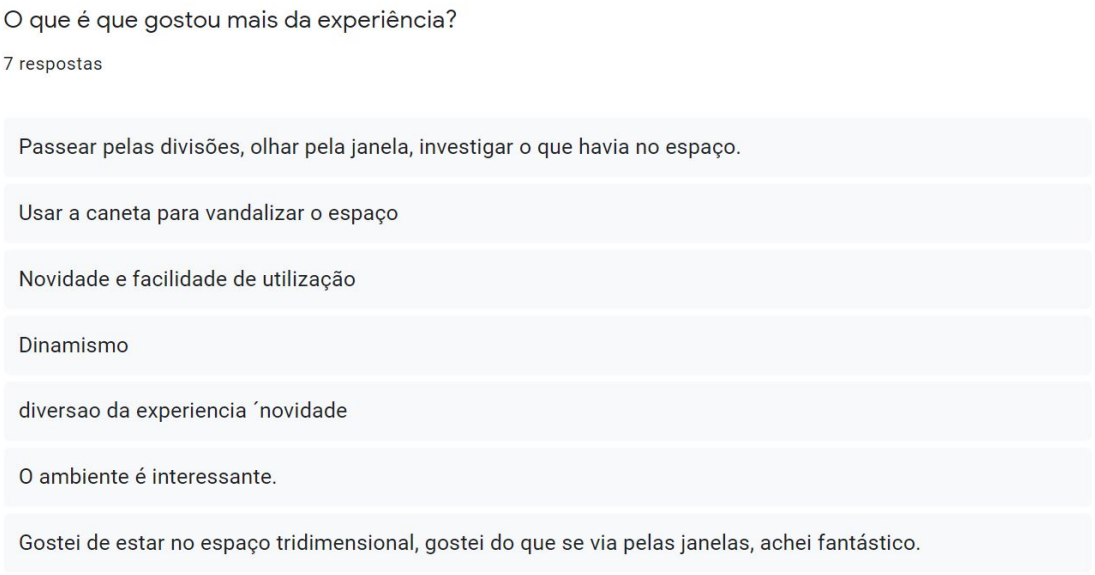


Figure 6.36: Participant's most liked aspects of the experience

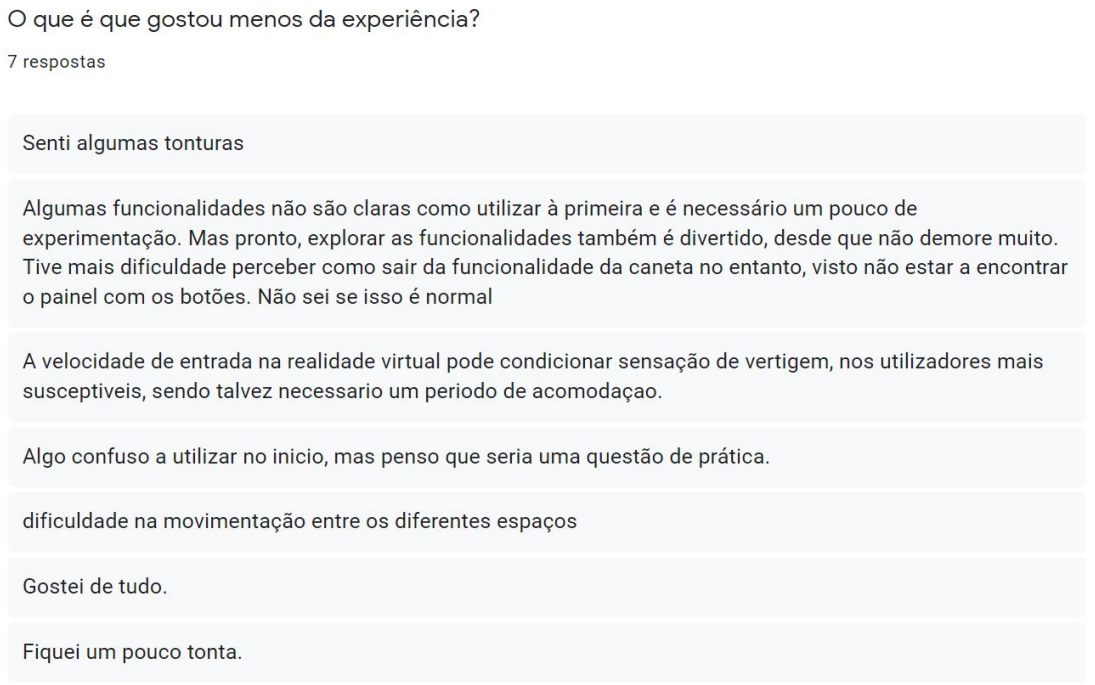


Figure 6.37: Participant's least liked aspects of the experience

Figure 6.38 shows the participants final thoughts of the experience. These range from: desinterest - *"Não estou a ver isto a ser muito útil para reuniões de trabalho, uma vez que iria distrair bastante os participantes (...)"*-, to curiosity - *"No geral, um produto interessante, quer como plataforma de comunicação, quer como salão de mini-jogos virtual para ajudar a passar o tempo.(...)"*, *"Pode ser uma alternativa para reuniões interativas com elevado número de*

participantes", "Fico intrigada para saber como seria ter reuniões num ambiente assim.".

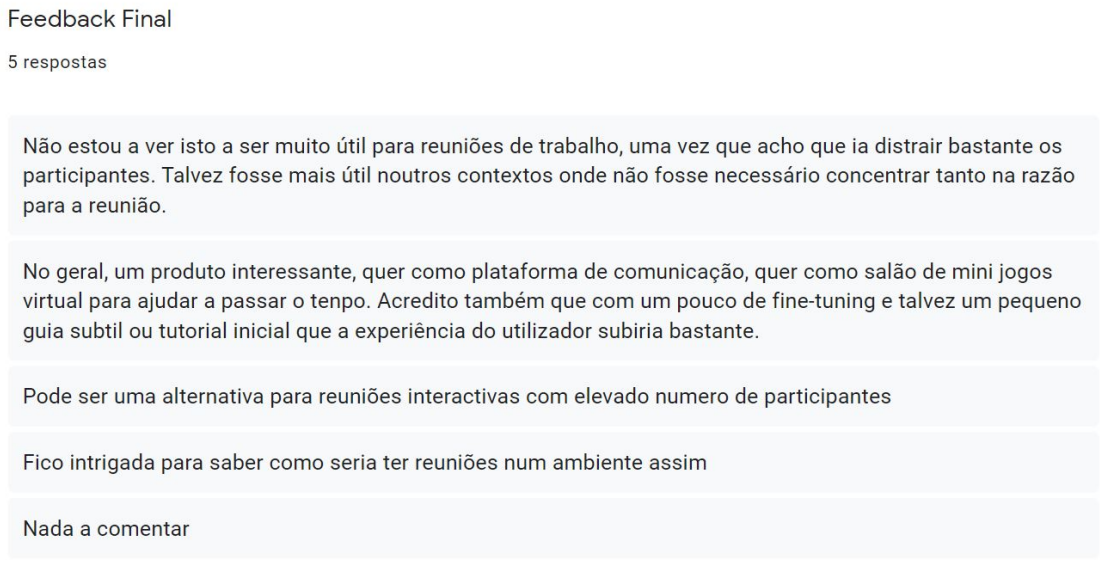


Figure 6.38: Participant's final feedback

6.4 Summary

To finalize, although there were some initial unexpected challenges faced when it came to the technology and platforms used (for reasons mentioned already), the implemented features add value to the original platform and the space created according to the analysis of the surveys done also work together to create a more immersive environment that was developed with the user's well-being in mind.

The dynamic sky feature in particular proved more complex than initially thought when it came to the scientific physics's knowledge and concepts required to develop it, more so than the understanding of the technology used and the code implemented.

Lastly, in regards to the final survey, the results are in line with what the project was striving for. All participants thoroughly enjoyed the experience, even with some experiencing motion sickness. It is a new technology and way of interacting with others, which sparks curiosity and interest regardless of the purposes of the experience. A lot of them mentioned the virtual space, commenting on the lobby and theater as their favorite rooms. Most liked the natural light, the windows and skylight a lot, as well as the outside scenery.

In terms of this method being superior over the more traditional platforms in regards to online videoconferencing, it is a question that polarizes most people. It can also prove as an hindrance to people that already struggle with using platforms like Zoom, Skype and even their telephone, as well as people with health conditions like vision impairment.

Additionally, it is important to note that when using the VR headset, its autonomy is not the most desirable, it allows for a maximum of 3 hours of use and requires almost half as much to fully charge.

Chapter 7

Conclusions

7.1 Overview

In conclusion, after analysing how groups work, their characteristics and identifying possible disadvantages to online teams, either due to the very nature of them or the present pandemic situation the world is experiencing, a few aspects are highlighted: team identity and connection, group structure and hierarchy, conflict resolution, non-verbal communication, perceived reward versus effort, goal orientation and social engagement. These specific characteristics are very weak when meeting exclusively online and weaker still in this COVID context.

Looking at the current state of the technologies that allow workers to conduct meetings remotely (*Zoom*, *Microsoft Teams*, *Skype*, *Google Meet*, *WeBex*) and identifying and comparing some of their key features, it can be concluded that none adequately and successfully deal with the issues enumerated, which results in a very detached experience for each team member. Additionally, the metrics extracted by each platform do not give much insight into a team's quality of meetings or a user's well-being.

Moreover, the conclusions taken from the questionnaires, show that the general population feels exhausted of online meetings and isolated, which is not mitigated by these videoconferences. Some highlight the advantages of online work: less time spent travelling and less work distractions. Furthermore, the need for this social distancing is understandable and many realize that these shortcomings are to be expected. However, the toll it takes on a team's productivity and someone's connections with coworkers, friends and families is very much felt by everyone. Not a lot of suggestions for improvements to a videoconferecing platform were given, most participants did not feel satisfied with the current technology, but did not know what could be done in order to improve it. Additionally, the CEOs and team leaders questioned did not show a lot of interest in user metrics, which made it hard to draw conclusions from regarding that aspect of the thesis.

In regards to the study of the Hubs by Mozilla platform, its architecture and all the related services, turned out to be much more complex that originally anticipated. Even though Mozilla provides an extensive documentation, this documentation is more useful and directed towards a regular user who wishes to know how to use the platforms and services, not a developer. It

was not very specific nor provided information or guidelines for people trying to implement new functionalities to the already existing platform and some of the information available was not up-to-date or was just missing.

This project was based on a theme/area that is not very known or worked on and so there were no tutorials, it required a lot of investigation and search for different articles and different implementations of similar concepts. A lot of time was spent analysing how the different services were pieced together and which were responsible for the various elements that the regular user interacts with.

Besides this, the actual process of implementing a testable local development environment took much longer that predicted. This was due to firstly, the unfamiliarity with the platform and the technologies used (A-Frame, threeJS, Elixir, Phoenix Framework, etc) which required learning from the beginning how each of these worked. Another mishap was the misinformation present in some parts of the github documentation available, which lead, sometimes, to dead ends (for example, despite reticulum's github documentation giving a tutorial on how to setup a local reticulum instance, after conversations with a Mozilla developer, it turned out to not be possible to implement). Despite this, the Mozilla Development team on Discord was helpful, and answered questions relatively quickly and always with helpful advices and tips. It is also important to note that 3Decide's developer team's help was fundamental and very reliable as well as crucial for this practical part of the thesis.

The virtual immersive room developed by 3Decide's team is very functional and they took into consideration the conclusions drawn from the surveys and improved upon them, creating a model that fits exactly the needs shown by the participants.

Regarding the implemented features, the dressing room functionality was implemented using tools that Hubs had available to create such a room on the scene. The dynamic sky functionality however required much more research. The scientific model in which it was based greatly helped even if it was, at times, difficult to understand due to the specific nature of it - the concepts and formulas used were unfamiliar and required a degree of expertise that was not there. Nevertheless, these challenges made the project exciting and the knowledge obtained from all these different aspects is priceless, as well as the lessons learned, especially from working with the 3Decide team.

However, despite the struggles, the final product sought to fill the gaps left by the current platforms by implementing visual features that improve upon the aforementioned group aspects that lead teams to worse results and that goal was achieved and so, it can be said that the project successfully accomplished what initially set out to do. Furthermore, the study of user-specific metrics during meetings will work as an outline for a possible tool for managers and leaders to overview their team's work, productivity, interactions and well-being.

7.2 Future Work

7.2.1 Possible additional features and improvement of the existing ones

The other features suggested in the Methodology chapter are very useful and could add a lot to the platform and improve user experience, especially the sentiment analysis functionality.

Although this feature was not implemented, it is very innovative. It would not be very suitable for users that did not speak English seeing as implementing this functionality would require that all communication be processed in written format, meaning a speech recognition technique would be necessary and currently this type of technology does not work well for languages other than English, but it is a recent technology that would allow for communication with others users to be more clear and also visual, seeing as the non-verbal communication part of interactions is lost when meeting online. Additionally, it would require for the creation of custom avatars that had built-in animation that would allow them to act out the feelings processed by the user.

Regarding the features implemented, a few improvements could be done. Firstly, when it comes to the dressing room feature, a few custom avatars could be developed using either Blender or other 3D model program or even the online tool that it is mentioned in the Hubs documentation. This would make the user experience even more unique and adapted to them.

When it comes to the dynamic sky feature, the next step would be to have a weather API that retrieves the weather information in the user's location and is able to mimic it into the virtual environment. The first step to this improvement, would be to be able to create objects that represent clouds, which would probably need to be created from scratch.

7.2.2 User metrics and analysis

Regarding the extraction of metrics, when looking at the most popular platforms, most have started tracking user metrics in order to rate meeting quality and give the hosts an overview of user statistics.

However, while good for objectively tracking the activity on an account, these metrics do not give much information about how the users behave during a meeting, and so would not allow drawing any conclusions about that user's productivity and quality of interaction.

The most suitable user metrics for the purpose of monitoring a team and bettering their dynamic as well as alert a team leader in case of unusual behaviour are the ones extracted by Microsoft Teams and Google Meet. These two platforms unlike the others that focus on simple account statistics like number of meetings attended, type of equipment used for meetings, etc, focus on the user's behaviour *during* these meetings. Microsoft Teams goes even further and gives whole analysis on each individual's behaviour, even out of meetings, because they monitor the activity of their other services like Outlook and Office. Additionally, they give recommendations and suggestions to team managers to improve team dynamics, including highlighting the most active users in their group.

Despite this, an important concern when extracting user metrics though is the ethical and legal aspects of this process, due to its the invasive nature, a user's privacy should and must be protected and so it is very difficult to implement such a thing while simultaneously watching over someone's sensitive data. So, in the future, this is an aspect that should be further investigated as well as researching more in terms of psychology and the adequate user actions that allow to make conclusions regarding their mental well-being and how well they are working in the team. This, like the security issues, is a very sensitive topic and requires a lot of scientific knowledge of human behaviour and psychology.

Appendix A

Additional State of the Art information

Feature	Platforms				
	Skype	Zoom	Microsoft Teams	Google Meet	WebEx
Breakout Rooms		X	X	*	X
Scheduling		X	X		X
Personal Meeting Room		X			X
Waiting Rooms		X			
Teams & Channels			X		
Priority Notifications			X		

Table A.1: Organization Related Features

Feature	Platforms				
	Skype	Zoom	Microsoft Teams	Google Meet	WebEx
Password Protection		X			
Built-in meeting security	X	X	X	X	X
HD VoIP					X
HIPAA/BAA Compliance					X
End-to-end encryption option		X			X
TLS 1.2 Support					X
Controls for meeting hosts		X		X	X
Compatible Across Devices	X	X	X	X	X
Customer Online Support					X

Table A.2: Security and Control Related Features

Appendix B

Questionnaire for the general user

Experiência de utilização de plataformas de videoconferência

O seguinte questionário está a ser realizado no âmbito da tese "iVIWE - Intelligent Virtual Immersive Work Environment" do Mestrado Integrado de Engenharia Informática e de Computadores da Faculdade de Engenharia do Universidade do Porto. O tema desta centra-se no desenvolvimento de um ambiente virtual inteligente e imersivo numa plataforma que permite reuniões online.

Para tal, este questionário tem como objetivo compreender a utilização das plataformas de reunião online, a percepção dos utilizadores sobre o funcionamento deste tipo de tecnologia e os efeitos deste modo de interação na saúde mental e produtividade dos participantes no contexto de pandemia global em que estamos todos inseridos. Pretende-se ainda avaliar o grau de satisfação dos utilizadores com estas plataformas e as suas funcionalidades.

As respostas são anónimas e confidenciais. Apenas serão divulgados o resultado do tratamento estatístico.

O preenchimento deste questionário demora aproximadamente 5 minutos. Caso tenha alguma questão sobre este questionário, por favor, contactar up201604741@fe.up.pt .

*Obrigatório

1. A participação neste projeto é voluntária, por isso se aceitar preencher o formulário, está a aceitar que esta informação seja utilizada. Contudo, se por algum motivo deixar de consentir no uso da informação não haverá qualquer tipo de penalidade e esta será imediatamente retirada. Os resultados deste estudo irão ser publicados, mas a identidade dos participantes nunca será divulgada. *

   Marcar apenas uma oval.

   ◯ Aceito *Avançar para a pergunta 2*

   ◯ Não Aceito

Dados demográficos

2. Género *

   Marcar apenas uma oval.

   - ◯ Feminino
   - ◯ Masculino
   - ◯ Outro

3. Idade *

   _____

4. Qual o maior nível de educação que completou? *

Marcar apenas uma oval.

- 1º Ciclo do Ensino Básico/ 4º Ano
- 2º Ciclo do Ensino Básico/ 6º Ano
- 3º Ciclo do Ensino Básico/ 9º Ano
- Secundário
- Licenciatura
- Mestrado
- Doutoramento

5. Tem formação específica em tecnologias de informação e comunicação ou informática? *

Marcar apenas uma oval.

- Sim
- Não

6. Ocupação profissional principal *

Marcar apenas uma oval.

- ◯ Pensionista/Reformado
- ◯ Desempregado
- ◯ Estudante
- ◯ Profissões das Forças Armadas
- ◯ Representantes do poder legislativo e de órgãos executivos, dirigentes, directores e gestores executivos
- ◯ Especialistas das atividades intelectuais e científicas
- ◯ Técnicos e profissões de nível intermédio
- ◯ Pessoal administrativo
- ◯ Trabalhadores dos serviços pessoais, de proteção e segurança e vendedores
- ◯ Agricultores e trabalhadores classificados da agricultura, da pesca e da floresta
- ◯ Trabalhadores qualificados da indústria, construção e artífices
- ◯ Operadores de instalações e máquinas e trabalhadores de montagem
- ◯ Trabalhadores não qualificados
- ◯ Outra: _____

7. Quanto ao uso de sistemas informáticos e nível de competência em colaboração através de tecnologias digitais, qual o nível mais adequado à sua experiência? *

Marcar apenas uma oval.

- ◯ Básico - Capaz de identificar e usar ferramentas para desenvolver trabalho colaborativo
- ◯ Intermédio - Capaz de escolher e usar as tecnologias mais apropriadas para desenvolver trabalho colaborativo
- ◯ Avançado - Capaz de avaliar e propor ferramentas adequadas a processos colaborativos assim como supervisionar a utilizaçao destas por outros
- ◯ Extremamente especializado - Capaz de conceber soluções e desenvolver aplicações para trabalho colaborativo

8. Apresenta algum tipo de condição de saúde diagnosticada? *

Marcar apenas uma oval.

- ◯ Não *Avançar para a pergunta 10*
- ◯ Sim

Condição de saúde diagnosticada

9. Identifique a condição de saúde diagnosticada

Por exemplo,perturbações sensoriais, daltonismo, autismo, depressão, hiperactividade e défice de atenção, dislexia, etc

_____

Experiência geral com videoconferências

10. Em que contexto costuma utilizar plataformas de videoconferência? *

Marcar tudo o que for aplicável.

- [ ] Profissional (ex.: reuniões empresariais)
- [ ] Educativo (ex.: aulas online, palestras)
- [ ] Social (ex.: reuniões com família ou amigos)
- [ ] Outra: _____

11. Qual(ais) a(s) plataforma(s) que mais usa? *

Marcar tudo o que for aplicável.

- [ ] Zoom
- [ ] Google Meet
- [ ] Microsoft Teams
- [ ] Skype
- [ ] WeBex
- [ ] Discord
- [ ] Mozilla Hubs
- [ ] Outra: _____

12. Frequência com que realiza reuniões online *

Marcar apenas uma oval.

- ◯ Nunca
- ◯ Uma vez por mês
- ◯ De 15 em 15 dias
- ◯ 1 - 2 vezes por semana
- ◯ 3 - 4 vezes por semana
- ◯ 5 - 6 vezes por semana
- ◯ Todos os dias
- ◯ Outra: _____

13. Tempo médio de duração de uma videoconferência *

Marcar apenas uma oval.

- ◯ até 15 mins
- ◯ 15 - 30 mins
- ◯ 30 - 45 mins
- ◯ 45 - 60 mins
- ◯ 1h - 1h30
- ◯ 1h30 - 2h
- ◯ Outra: _____

14. Qual o papel mais frequente que desempenha numa reunião? *

Marcar tudo o que for aplicável.

- [ ] Participante
- [ ] Anfitrião/Moderador/Coordenador
- [ ] Auxiliar de Anfitrião/Moderador/Coordenador
- [ ] Outra: _____

Reuniões virtuais e saúde mental

15. Após uma reunião com uma duração típica, qual o nível de exaustão que sente? *

Marcar apenas uma oval.

- ◯ Muito pouco exausto
- ◯ Pouco exausto
- ◯ Moderadamente exausto
- ◯ Muito exausto
- ◯ Bastante exausto

16. No final da semana, qual o nível de exaustão que sente? *

Marcar apenas uma oval.

- ◯ Muito pouco exausto
- ◯ Pouco exausto
- ◯ Moderadamente exausto
- ◯ Muito exausto
- ◯ Bastante exausto

17. Com que frequência fica com vontade de não fazer nada depois de uma reunião? *

Marcar apenas uma oval.

- ◯ Nunca
- ◯ Raramente
- ◯ Às vezes
- ◯ Muitas vezes
- ◯ Sempre

18. O que é que lhe causa mais stress durante uma reunião (pode escolher mais do que uma opção). *

Marcar tudo o que for aplicável.

- [ ] Ver a própria cara
- [ ] Dificuldades no uso da plataforma
- [ ] Problemas técnicos de comunicação
- [ ] Dificuldade de comunicação interpessoal
- [ ] Dificuldade em relacionar com os outros participantes
- [ ] Receio de monitorização não-autorizada
- [ ] Dificuldade em perceber o papel a desempenhar na reunião
- [ ] Desconhecimento das regras sociais neste contexto
- [ ] Facilidade de multitasking, causando distrações
- [ ] Distanciamento físico dos outros participantes
- [ ] Perceber a ordem de trabalhos da reunião
- [ ] Perceber a evolução da ordem de trabalhos ao longo da reunião

Outra: ☐ _____

19. Durante uma videoconferência, quão preocupado(a) está com o que os outros participantes pensam da sua aparência? *

Marcar apenas uma oval.

- ◯ Nada preocupado
- ◯ Ligeiramente preocupado
- ◯ Moderadamente preocupado
- ◯ Muito preocupado
- ◯ Extremamente preocupado

20. Durante uma videoconferência, quão fácil é ler a linguagem corporal dos outros participantes e interpretar as suas respostas? *

Marcar apenas uma oval.

- ◯ Nada fácil
- ◯ Ligeiramente fácil
- ◯ Moderadamente fácil
- ◯ Muito fácil
- ◯ Extremamente fácil

Funcionalidades

21. Funcionalidade(s) das plataformas que mais utiliza : *

Marcar tudo o que for aplicável.

- [ ] Partilha de ecrã
- [ ] Partilha de ficheiros
- [ ] Chat
- [ ] Efeitos no ambiente de fundo
- [ ] Whiteboard interativo
- [ ] Levantar a mão
- [ ] Salas de sessão separadas (breakout rooms)
- [ ] Salas de espera (waiting rooms)
- [ ] Gravação da reunião
- [ ] Conferências de áudio apenas

Outra: ☐ _____

22. Quais as funcionalidades disponíveis atualmente que não gosta?

_____

_____

_____

_____

_____

23. Que funcionalidades acharia útil serem incluídas nestas plataformas?

24. Indique a facilidade que sente na utilização destas plataformas *

Marcar apenas uma oval.

- ◯ Muito difícil
- ◯ Difícil
- ◯ Nem fácil nem díficil
- ◯ Fácil
- ◯ Muito fácil

25. Nas plataformas que características considera que aumentam a dificuldade de uso? (Pode escolher mais do que uma opção) *

Marcar tudo o que for aplicável.

- [ ] Interface confusa
- [ ] Botões e/ou texto muito pequenos
- [ ] Funcionalidades disponíveis pouco claras ou difíceis de encontrar
- [ ] Outra: _____

26. Dada a escolha, preferia ter uma reunião em que todos os participantes têm a câmara ligada ou uma reunião de áudio apenas? *

Marcar apenas uma oval.

- ◯ Reunião de áudio
- ◯ Reunião de áudio e vídeo

Produtividade do trabalho remoto

27. Sente que as videoconferências são produtivas e os seus objetivos são alcançados? *

Marcar apenas uma oval.

- ◯ Sim
- ◯ Não

28. Se respondeu que não à pergunta anterior, quais as razões que levaram a essa resposta?

29. De que forma esses aspetos podem ser melhorados?

30. Em comparação com interações presenciais, quão próximo dos outros participantes se sente? *

Marcar apenas uma oval.

- ◯ Muito pouco próximo
- ◯ Pouco próximo
- ◯ Próximo
- ◯ Muito próximo
- ◯ Bastante próximo

31. Em comparação com interações presenciais, quão envolvido na reunião se sente? *

Marcar apenas uma oval.

- ◯ Muito pouco envolvido
- ◯ Pouco envolvido
- ◯ Envolvido
- ◯ Muito envolvido
- ◯ Bastante envolvido

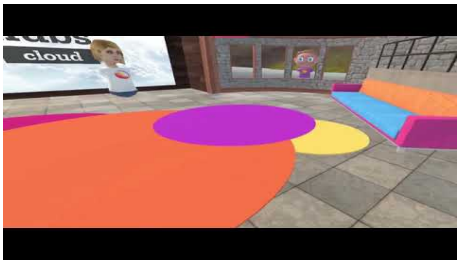
32. Sente que, quando comparado com interações presenciais, está menos atento e perde mais frequentemente a concentração? *

Marcar apenas uma oval.

- ◯ Sim
- ◯ Não

Ambientes virtuais de reunião

Mozilla Hubs Demo



http://youtube.com/watch?v=-VQj0qZ9Bto

33. Se as videoconferências se realizassem numa sala comum mais interativa e 3D como a do vídeo, sente que isso seria um fator de desconcentração ou iria encorajar a sua participação, melhorando a sua sensação sobre a reunião?

Se quiser experimentar por si mesmo, este link leva-o para uma sala de demonstração : https://hubs.mozilla.com/AxV22wu/hubs-demo-room

34. Possui algum tipo de headset ou equipamento de Realidade Virtual? *

Marcar apenas uma oval.

- ◯ Sim
- ◯ Não

35. Se respondeu que sim à resposta anterior, quais das tecnologias de Realidade Virtual possui?

Marcar tudo o que for aplicável.

- [ ] Oculus Rift
- [ ] HTC Vive
- [ ] PlayStation VR
- [ ] StarVR
- [ ] Google Cardboard

Outra: [ ] _____

Feedback final

36. Qual o nível de satisfação geral que sente com o modo de reuniões virtuais atual? Partilhe a sua experiência e tudo aquilo que ache relevante e importante que não tenha sido mencionado nas perguntas anteriores.

_____

_____

_____

_____

_____

Este conteúdo não foi criado nem aprovado pela Google.

Google Formulários

Appendix C

Full answers to all the open questions in the first questionnaire

C.1 Features and functionalities

Currently, what are the available features that you don't think work/don't like?

Out of 158 participants, only **20** answered this question.

- *"nenhuma"*
- *"Nenhuma"*
- *"Nada"*
- *"O chat não ser suficientemente apelativo"*
- *"Compartilhar tela e ficheiros"*
- *"Efeitos no ambiente de fundo"*
- *"Fundos com demasiada presença"*
- *"Quando a plataforma entra automaticamente em modo de tela cheia"*
- *"Levantar a mão"*
- *"não me ocorre nenhuma"*
- *"Desligar o microfone de todos os participantes no Teams. O Zoom gosta de receber o foco no computador com aquela barra no topo o que incomoda a redimensionar"*
- *"Não tenho nenhum em particular."*
- *"Não desgosto particularmente de nenhuma"*
- *"0"*
- *"Nada"*
- *"nada"*
- *"Nenhuma"*
- *"Incapacidade de impedir gravação por parte de participantes (não organizador/gestor da reunião)"*
- *"Possibilidade de desligar microfones de outras pessoas"*
- *"Partilha de ficheiros"*

What features do you think would be useful and should be implemented in these platforms?

Out of 158 participants, **24** answered this question.

- *"Nada"*
- *"Abertura de múltiplas janelas, para a partilha de diferentes conteúdos"*

- *"criação de salas separados por parte dos participantes"*
- *"Fazer perguntas de modo anónimo"*
- *"Joguinhos :)"*
- *"mute seletivo"*
- *"Possibilidade de silenciar participantes como participante."*
- *"O controlo individual do volume de cada participante (assim como o Discord permite)"*
- *"música ambiente, disponibilização de atividades interativas"*
- *"Alguma ferramenta de trabalho colaborativo"*
- *"Noise suppression como o discord"*
- *"Um método melhor do que "Levantar a mão""*
- *"não me ocorre nenhuma"*
- *"Algum indicador de há quanto tempo os alunos não falam ou o próprio utilizador. Sendo estudante, ocorre muito ficar à espera que os outros respondam aos professores, mas se me apercebesse rapidamente que ninguém ia falar, não me importava de ser eu a responder."*
- *"nenhuma"*
- *"Poder gerir o status em função de um horário à escolha assim como permitir que tipo de notificações e de quem posso receber essa notificações de acordo com o status e o horário predefinido. Uma espécie de out of office mas mais personalizável"*
- *"Penso que tenha tudo o que é necessário."*
- *"GIFs, bot de música"*
- *"Questionários mais diversificados para fazer em tempo real, quase um pulgin do mentimeters ou de outra aplicação equivalente."*
- *"0"*
- *"a acima referida"*
- *"Uma notificação ou algum indicador do número de pessoas na sala de espera para entrar na reunião."*
- *"Não sei"*

C.2 Remote work productivity

For context, in regards to the question ***"Do you feel videoconferences are productive and their goals accomplished?***, 69% of participants answered *"yes"* while 31% claimed otherwise. To those who answered negatively, the following question asked them to list and explain the reasons behind their previous choice. Below are all the answers given by the participants - **28** of the total, 158, answered.

If you answered "No" to the previous question, what were the reasons that lead you to that choice?

- *"Por vezes alongam-se demasiado o que as torna cansativas e pouco produtivas."*
- *"A produtividade é claramente inferior a uma reunião presencial"*
- *"Quando as reuniões são longas e há pouca interação por parte dos participantes (frequentemente), leva a uma maior distração."*
- *"Dificuldade de concentração e foco"*
- *"Muitas vezes acaba-se por não estar 100% focado e distrair-se com outras coisas"*
- *"Distraio-me muito facilmente nas videoconferências."*
- *"O limiar de atenção é excedido diariamente (aulas online)."*

- *"Perde-se muito tempo por vezes a resolver problemas técnicos (conexão ao áudio, dificuldade na partilha de ecrã, etc.) o que acaba por obrigar a uma abordagem mais rápida dos assuntos da reunião, perdendo-se um pouco do conteúdo nessas situações."*
- *"Distração"*
- *"Uma reunião online tira toda a pressão e regras sociais existentes numa reunião presencial. Logo a partir daí, as pessoas estão suscetíveis a distrações e é mais difícil manter uma participação equilibrada. De igual modo, não é comparável um contacto online com um presencial, cara a cara. Debates assim não são a mesma coisa."*
- *"Duração excessiva, organização pouco clara, objectivos incertos"*
- *"Sinto-me menos concentrada nas aulas online, por isso, penso que o estudo seria mais produtivo em modo presencial."*
- *"falhas na transmissão da mensagem, dificuldade em perceber o que dizem as pessoas quando: má ligação, pessoas falam em simultâneo"*
- *"Distração e cansaço"*
- *"É difícil concentrar-me durante manhãs de 5 aulas teóricas seguidas ou aulas práticas de 2h"*
- *"Não são produtivas pois existem muitas distrações e como não há tanta interação como nas aulas presenciais, mesmo a matéria mais interessante torna-se pesada e difícil"*
- *"É mais complicado de estar atento, uma vez que estamos em casa"*
- *"Apesar de ser, em contexto de aulas, uma maneira pouco eficiente de aprender, os professores esforçam-se bastante para possibilitar a melhor sessão, dentro dos possíveis."*
- *"A objetividade e pragmatismo de uma reunião por si só"*
- *"Facilidade de distração"*
- *"A entidade patronal apenas pretende controlar os seus seus funcionários."*
- *"Não aplicável"*
- *"É demasiado difícil manter a atenção e o foco ao longo de várias sessões online"*
- *"Existem muito mais distrações"*
- *"Muitas vezes para tornar a reunião mais produtiva as pessoas respondem sempre que "sim" quando na realidade têm duvidas"*
- *"Muitas vezes há falhas de internet; Em aulas, o/a docente não consegue saber se a maneira como explicou o conteúdo foi boa ou não, porque as pessoas não se chegam à frente para interromper e fazer perguntas (daí desejar que houvesse a opção de colocar questões de forma anónima)"*
- *"São cansativas, há problemas técnicos com frequência"*

In which ways can those aspects be improved?

- *"Não derivar do assunto principal da reunião."*
- *"melhor versatilidade e interacividade entre os vários feeds de informação (audio, video, apresentaçãoes, e outros)"*
- *"Redução do tempo de aulas ou intervalos maiores entre as mesmas."*
- *"Sem infringir na privacidade dos participantes não encontro nenhuma solução"*
- *"Impossível."*
- *"irl"*
- *"Tornar as aulas mais curtas ou com pausas a meio. Existência de uma pausa específica para jantar (no caso dos mestrados em pós-laboral)"*
- *"Não podem"*
- *"Planeando bem a reunião"*
- *"Ter a mesma atitude que existia no local de trabalho. Inter-ajuda, maior comunicação."*

- *"Penso que não podem"*
- *"Se existisse a opção de colocar questões de forma anónima"*
- *"É uma condição da Internet, não há grandes resoluções. Talvez pausas mais frequentes"*

C.3 Immersive virtual work environments

If videoconferences were conducted in a common virtual room, more interactive and 3D, do you think that that new medium and environment would be a distraction factor or would it encourage your participation?

- *"Não"*
- *"Sim"*
- *"Fator de desconcentração"*
- *"Desconcentração"*
- *"Seria um fator de desconcentração"*
- *"Desconcentração e mais confuso"*
- *"Penso que seria foco de muita desconcentração."*
- *"Penso que iria melhorar a minha concentração"*
- *"Seria mais uma desconcentração"*
- *"Seria uma distração e penso que não iria melhorar a qualidade da reunião."*
- *"Iria encorajar a participação desde que continue a haver a possibilidade de desligar o microfone para evitar ruídos de fundo. (Claro ligar quando necessário)"*
- *"O 3d e a interatividade iriam ajudar, mas julgo que o facto de ser um ambiente tão artificial como o da demo iria distrair mais. Julgo também que com óculos de realidade virtual, pelo menos os que conheço, seria difícil tirar notas em papel, o que também reduziria a concentração."*
- *"Iria encorajar a minha participação, melhorando a sensação sobre a reunião"*
- *"Em princípio não gostei desse tipo de experiência."*
- *"provavelmente o ambiente criado tornaria a reunião mais envolvente"*
- *"Melhorar bastante"*
- *"Desconcentração; para além disso, eu experimentei um headset de realidade virtual e senti-me com náuseas, o que não é nada bom neste contexto."*
- *"Acho que seria um fator de desconcentração, pelo menos nas primeiras vezes. Mas talvez ao fim de algum tempo já estaria habituada e então facilitaria a comunicação e atenção."*
- *"Muito provavelmente."*
- *"Seria diferente, talvez motivasse a concentração"*
- *"Acho que seria mais apelativo à participação"*
- *"Iria melhorar por haver uma "espécie" de proximidade física, mas tornar-se mais difícil/confuso de usar inicialmente. Já para não falar do equipamento necessário que não é barato."*
- *"Poderia melhor no ínicio, por ser uma sala nova"*
- *"Desconcentração, porque as pessoas iriam estar mais focadas nas animações do que propriamente no conteúdo da reunião"*
- *"No início melhoraria a sensação, mas rapidamente se tornaria banal."*
- *"podia facilitar a interacção, mas o ambiente gráfico apresentado também me parece excessivamente propicio a distracções, acredito que para resultar precisava de ser muito mais neutro."*
- *"desconcentração e fator pouco interessante de desgaste rápido"*

- *"Penso que seria um fator de desconcentração."*
- *"Desconcentração no início, até aprender a utilizar a plataforma"*
- *"desconcentração"*
- *"fator de desconcentração"*
- *"Não sei andtes de usar"*
- *"Não acho que fizesse uma diferença significativa em reuniões profissionais."*
- *"iria encorajar a minha participação"*
- *"Seria mais um fator de desconcentração. Seria mais uma ferramenta para explorar e levar a comportamentos não adequados numa reunião."*
- *"distração inicialmente mas depois de me habituar acho que seria interessante"*
- *"Acho que iria encorajar mais a minha participação."*
- *"Depende dos benefícios que isso possa trazer, mas imersivo é melhor"*
- *"Iria aumentar a concentração, mas possivelmente iria aumentar também o cansaço."*
- *"Poderia até melhorar a concentração"*
- *"Penso que teria o mesmo efeito"*
- *"Seria um fator de desconcentração e resultaria numa diminuição de produtividade"*
- *"Trazia melhor sentimento de presença e sentia-me mais confortável (os avatares não podiam ser demasiado fora do comum porque senão quebrava o sentido de imersão)"*
- *"Bem desenvolvida, poderia aumentar a concentração"*
- *"Não faço ideia"*
- *"seria um fator de desconcentração total. Demasiado detalhe à volta que é impossível passar despercebido. Reunião demoraria a arrancar mais e tempo é dinheiro. Vejo clara redução de produtividade neste cenário. Pois seria propicio a divergir da agenda de trabalhos."*
- *"sim, seria interessante"*
- *"Acho o conceito interessante, não consegui experimentar ver a partilha de outra pessoa, mas espero que ficasse em fullscreen. Por outro lado, o modelo online "atual" das aulas permite ao aluno estar mais descontraído, mais ou menos bem vestido, mais ou menos ensonado, etc. Se a interação for moderada e permitir manter este conforto, considero muito interessante."*
- *"Gosto menos. Parece as salas de chat da ONI nos finais dos anos 90...."*
- *"podia ser interessante, mas visto que há muitas pessoas que têm dificuldade em usar as plataformas "2D", penso que teriam ainda mais dificuldade na utilização destas; penso que levaria a mais distrações (principalmente no início da utilização visto que é uma novidade e as pessoas podem encarar como um "jogo" novo)."*
- *"Sinto que encorajaria a minha participação. É um formato muito mais envolvente e que elimina muitos dos fatores de distração. Por outro lado, provavelmente seria um formato mais cansativo e não sustentável durante reuniões muito longas."*
- *"Penso que iria piorar, mas principalmente por parecer estranho. Se me habituasse era possível que melhorasse."*
- *"iria encorajar a participação"*
- *"Iria encorajar a participação"*
- *"Seria idêntico. Já experimentei plataformas semelhantes (Laval, p.e.) e resultados não são interessantes, particularmente com grupos grandes."*
- *"Talvez inicialmente um fator de desconcentração, mas seria uma experiência interessante."*
- *"factor de desconcentração"*
- *"No início seria um fator de distração, mas ao fim de algumas sessões seria normal"*
- *"penso que sim"*

- *"no inicio iria distrair um bocado, mas seria mais interessante do que é normalmente"*
- *"Sim, olhando para a minha realidade profissional, penso que seria um fator de desconcentração e prejudicaria o objetivo da reunião."*
- *"Penso que seja mais distrativo. Talvez seja bom num ambiente que envolva crianças."*
- *"Encorajava, creio, mas seria pertinente preparar tudo antes da reunião"*
- *"distracção"*
- *"Iria ser um fator de desconcentração"*
- *"Iria encorajar a minha participação."*
- *"Provavelmente ia participar mais"*
- *"Seria mais um fator de desconcentração"*
- *"Encorajar a participação."*
- *"Sinto que iria melhorar a concentração e envolvimento."*
- *"confuso, fator de desconcentração"*
- *"Sim."*
- *"Provavelmente não...."*
- *"Acho que inicialmente seria mais uma distração. Mas com o tempo acabaria por me adaptar e possivelmente seria uma boa ferramenta para reuniões."*
- *"Iria melhorar e encorajar a participação, no entanto a tecnologia é cara e não seria justo a sua utilização visto que muitos participantes não teriam acesso a um equipamento de RV"*
- *"Não encoraja, é confusa. Faz tonturas. Não aprecio este tipo de ambientes virtuais"*

C.4 Final Feedback

What do you think is your overall satisfaction level with how virtual meetings operate currently? Share your experience and anything that you think might be relevant and/or important and that was not mentioned in all the previous questions.

Out of 158, **59** participants answered this question.

- *"Acho que é uma forma eficaz de colaborarmos com pessoas em lugares diferentes. Torna-se útil no meu trabalho. Uso todos os dias, quer com clientes, quer com colegas."*
- *"Sendo que eu sou o único membro da minha equipa no escritório, todas as reuniões com a restante equipa foram sempre virtuais. Desde que não se alonguem demasiado no tempo podem ser úteis, caso contrário são apenas perda de tempo e feitas como obrigação."*
- *"Satisfeito apesar de serem menos eficientes"*
- *"A experiência tem sido muito boa. Precisamente por ser fácil ficar distraído que tenho ganhado mais disciplina e participado mais nas aulas para tirar dúvidas. Assim obrigo-me a ficar atenta. Por isso dinamizar as aulas, por parte dos professores ao invés do tradicional método expositivo ajuda bastante. Aulas presenciais são sempre uma confusão, com muitas pessoas na mesma sala a conversar e a conviver, prejudicando o ambiente na sala. Aulas on-line é possível estar plenamente atento. Quanto ao conviver, os colegas têm conversado na mesma no discord, por exemplo. A diferença é que não o fazem com toda a gente a ouvir. Na verdade, só tenho coisas boas a dizer, da minha parte, sobre plataformas online."*
- *"Funcionam para o momento atual, mas ainda prefiro reuniões presenciais para assuntos de maior importância e decisões criticas. Existe uma dificuldade de entender os sinais visuais e outros comportamentos dos participantes, que por vezes são cruciais."*
- *"Pouco satisfeita, simplesmente não são produtivas quando comparadas com presenciais"*
- *"Insastifeita. Penso que não é um método útil para aprendizado e transmissão de conhecimento"*

- *"Não gosto, sinto-me mais cansada depois de uma aula online do que de uma aula presencial; sinto que há muitos inconvenientes na maneira como as aulas online estão estruturadas atualmente, mas também não sei muitas mais formas de as melhorar"*
- *"Médio"*
- *"De 1 a 10, 4"*
- *"Desejaria que não fossem a única maneira de interacção, mas não há efectivamente outra. Independentemente da implementação tecnológica nada substitui interação presencial seja em que contexto for."*
- *"Gosto do facto das reuniões serem muito mais produtivas. Também não implicam deslocações o que permite gerir muito bem a agenda"*
- *"Funcionam suficientemente bem, embora pudessem ser mais imersivas."*
- *"Acho que se conseguem evitar muitas doenças alem do covid... :)"*
- *"A monotonia leva à falta de motivação"*
- *"Pouco satisfeito, visto que aulas presenciais são, em tudo, melhores que online, mas, objetivamente, reuniões virtuais são uma ferramenta do meu dia a dia que me permitem continuar a aprender e falar com os meus colegas"*
- *"Estou pouco stiafeita"*
- *"Penso que tem corrido bem. A verdade é que ao ter as aulas online consigo estar mais atento e menos sonolento uma vez que não estou num auditório cheio de gente. Um professor que não seja muito entusiasmante a dar as aulas (como são a grande parte), numa aula online é mais fácil para mim de perceber tudo porque só se ouve o docente e não existem ruídos à volta. Além disso e para mim mais importante é o facto de podermos gravar as aulas. Isso faz com que a aula não se perca e podamos visualizar ao nosso ritmo posteriormente. Quando as aulas são presenciais (principalmente aulas teóricas) se tivermos disciplinas em atraso no estudo, as aulas dessas cadeiras vão passando e quando quisermos por em dia a matéria não temos essas aulas disponíveis para estudar. Quando a pandemia acabar, gostava que as aulas teóricas na faculdade fossem dadas via online. Ou pelo menos que se conseguisse aplicar as vantagens do ensino online no ensino presencial. Por fim e apesar de não ser relevante, gostava que existissem mais questionários em geral direcionados aos alunos (do ensino superior, no meu caso) para perceber as vantagens/desvantagens de "ensino online vs ensino presencial". Noto pela comunicação social que apenas professores e diretores falam do ensino online, sempre apontando problemas (principalmente sociais, que compreendo) e penso que era interessante ter estatísticas gerais sobre a opinião dos alunos do ensino superior."*
- *"No que toca às aulas, é muito fácil perder o foco na aula porque estão todas as notificações a aparecer no ecrã. Aliás, estou a responder ao questionário enquanto estou numa aula xD No que toca às "conferências" com os amigos, uso constantemente o discord e não tenho nada a apontar. É uma ferramenta versátil, fácil de usar e que continua a crescer com novas funcionalidades e melhorias de performance! A ideia de uma reunião em realidade virtual é interessante e, no que toca às pessoas mais dadas à tecnologia, iria funcionar bem. Agora, imaginando isso para uma aula do Secundário já parece um pouco menos prático. Ainda assim, só usa quem quer/pode/consegue portanto é uma ideia para avançar."*
- *"Acho que me encontro satisfeito no geral. No entanto, falta uma interação física entre os participantes e o cansaço que surge depois de uma reunião em frente a um ecrã impede que seja produtivo no restante dia."*
- *"zero. Não presta. Má retenção de action points, má comunicação, sentimento de desperdício de tempo. Reuniões online sem atas são tempo perdido."*
- *"É um bom substituto. Tem as suas vantagens, nomeadamente a nível de localização física,*

eliminando o tempo perdido nas deslocações entre reuniões/aulas (particularmente importante para trabalhadores/estudantes). No entanto ao final de um dia de 5-7h de reuniões/aulas o cansaço é consideravelmente maior."

- *"Satisfeito em geral."*
- *"8 de 10"*
- *"Em geral, sinto que as reuniões online, quando possível, têm que ser evitadas ao máximo. No contexto atual, é difícil, mas quando possível deve ser sempre o meio priveligiado, sendo apenas mantido quando a deslocação é impossível."*
- *"O que mais gosto nas videoconferências é o facto de poderem ser gravadas, o que permite que possa-se assistir depois com mais calma e pode-se acertar a velocidade para o que quisermos."*
- *"O tempo de atenção é muito reduzido, algo que facilitasse a troca de ideias e mind-maps colaborativamente já ajudava bastante. Vai Alexa!"*
- *"Eu sinto-me muito satisfeito com o modo atual"*
- *"7/10"*
- *"Relativamente elevado uma vez que me permite realizar todos os objetivos de uma reunião presencial. Não deixa contudo de ser um pouco menos pessoal e interactiva. De qualquer forma penso que se mantém extremamente relevante e eficaz."*
- *"Não muito satisfeito. Reparo num rendimento muito mais baixo, relativamente a reuniões presenciais."*
- *"Penso que as plataformas que tenho usado funcionam bem. A maior frustração é mesmo o facto de ser tudo on-line e do cansaço que isso traz."*
- *"O discord faz um bom trabalho. Tem basicamente tudo o que uma pessoa precisa, exceto um whiteboard."*
- *"Penso que está a funcionar bem."*
- *"Pouco satisfeito. Penso que presencialmente as reuniões são muito mais produtivas devido à interação existente."*
- *"Bastante satisfeita"*
- *"Dadas as circunstâncias, estou satisfeita."*
- *"Até me sinto satisfeito a nível de aulas online. É muito estranha a falta de interação em certas aulas mais práticas, mas para aulas teóricas com imensa gente em que ainda que haja lugar para dúvidas, não costuma haver perguntas individualizadas, considero funcionar bastante bem também pelo facto de poderem ser gravadas e facilmente revistas."*
- *"A nível social, para reunir com amigos, considero o Discord uma plataforma extremamente bem desenvolvida quer pelos bots (que dão para pôr música, criar memes, jogar minijogos, etc.) quer pela organização em vários canais de áudio ou texto."*
- *"Bastante satisfeito. Poupam muito tempo em deslocações desnecessárias. Reuniões mais produtivas e sem conversas laterais. Única contrariedade: dificulta o networking."*
- *"A maior vantagem das reuniões virtuais é diminuir as deslocações e dar a oportunidade de comunicação com pessoas que se encontram a longas distâncias (incluindo no estrangeiro)"*
- *"Bastante satisfeito"*
- *"Bastante baixa"*
- *"Baixo. Demasiado fatigante, pois a "facilidade" de se realizar reuniões consecutivas com grupos distintos de pessoas drenam energia e produtividade."*
- *"Razoável"*
- *"8/10"*
- *"Zero"*
- *"Baixo , bastante exaustivo"*

- *"Para a minha utilização penso que esteja bastante satisfeito com o modo das reuniões virtuais atual."*
- *"3/5"*
- *"Bastante satisfeito."*
- *"Julgo que foram uma óptima ferramenta para suprir as necessidades criadas pelas restrições da pandemia"*
- *"Pouco Satisfeito."*
- *"Constituem uma alternativa razoável a determinadas reuniões que seriam presenciais"*
- *"Um mal menor..."*
- *"Nível de satisfação suficiente para minimizar ligeiramente os danos causados pela suspensão de actividades presenciais."*
- *"A utilização de aplicações diferentes nas aulas não é pratico, tornando a informação segmentada. Existem tambem problemas de segurança em aplicações como Zoom e apesar disso continua a ser uma das mais utilizadas."*
- *"Gosto de interagir com pessoas, não com máquinas"*

Appendix D

Questionnaire for CEOS, team leaders and managers

iVIWE - Intelligent Virtual Immersive Work Environment

O seguinte questionário está a ser realizado no âmbito da tese "iVIWE - Intelligent Virtual Immersive Work Environment" do Mestrado Integrado de Engenharia Informática e de Computadores da Faculdade de Engenharia do Universidade do Porto. O tema desta centra-se no desenvolvimento de um ambiente virtual inteligente e imersivo numa plataforma que permite reuniões online.

Para tal, este questionário tem como objetivo compreender a utilização das plataformas de reunião online num enquadramento empresarial, a percepção dos funcionários com cargos de liderança deste tipo de tecnologia e os efeitos deste modo de interação na produtividade dos participantes no contexto de pandemia global em que estamos todos inseridos. Pretende-se também aferir quais as métricas extraídas dos utilizadores seriam mais úteis para a gestão de equipas e funcionários na empresa.

As respostas são anónimas e confidenciais. Apenas serão divulgados o resultado do tratamento estatístico.

O preenchimento deste questionário demora aproximadamente 3 minutos. Caso tenha alguma questão sobre este questionário, por favor, contactar up201604741@up.pt .

*Obrigatório

1. A participação neste projeto é voluntária, por isso se aceitar preencher o formulário, está a aceitar que esta informação seja utilizada. Contudo, se por algum motivo deixar de consentir no uso da informação não haverá qualquer tipo de penalidade e esta será imediatamente retirada. Os resultados deste estudo irão ser publicados, mas a identidade dos participantes nunca será divulgada. *

   Marcar apenas uma oval.

   - ◯ Aceito
   - ◯ Não Aceito

Dados demográficos

2. Qual o seu cargo na empresa? *
   Por exemplo: CEO, CTO, Gestor, etc

3. Há quanto tempo trabalha na empresa no cargo atual? *

4. Quantos anos de experiência profissional tem? *

Caracterização geral do contexto de videoconferências

5. Qual a área de atuação da empresa? *

6. Qual a dimensão da empresa ? *

Depende do número de funcionários, volume de negócios anual e balanço anual.

Marcar apenas uma oval.

- ◯ Micro empresa
- ◯ Pequena empresa
- ◯ Média empresa
- ◯ Grande empresa

7. Quais as plataformas mais usadas na empresa para as videoconferências? *

Marcar tudo o que for aplicável.

- ☐ Zoom
- ☐ Google Meet
- ☐ Microsoft Teams
- ☐ Skype
- ☐ WeBex
- ☐ Discord
- ☐ Mozilla Hubs

Outra: ☐ _____

8. Numa semana típica, quantas reuniões por videoconferência tem por dia? *

_____

9. Qual a duração média de cada reunião virtual (em minutos)? *

10. Qual o número médio de pessoas por reunião? *

Caracterização dos constrangimentos das videoconferências

11. Quão difícil é manter a produtividade numa videoconferência e alcançar os objetivos propostos para esta? *

Marcar apenas uma oval.

- ◯ Muito difícil
- ◯ Difícil
- ◯ Nem fácil nem difícil
- ◯ Fácil
- ◯ Muito fácil

12. Quais foram os maiores desafios com que se deparou a nível de gestão de reuniões por videoconferência? *

13. Se fosse possível incluir indicadores de atividade dos recursos humanos durante as reuniões por videoconferência, quais acharia úteis serem incluídos? *

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Appendix E

Final questionnaire to assess user satisfaction with final product

iVIWE - Avaliação

O seguinte questionário está a ser realizado no âmbito da tese "iVIWE - Intelligent Virtual Immersive Work Environment" do Mestrado Integrado de Engenharia Informática e de Computadores da Faculdade de Engenharia do Universidade do Porto. O tema desta centra-se no desenvolvimento de um ambiente virtual inteligente e imersivo numa plataforma que permite reuniões online.

Para tal, este questionário tem como objetivo compreender a utilização das plataformas de reunião online, a percepção dos utilizadores sobre o funcionamento deste tipo de tecnologia e os efeitos deste modo de interação na saúde mental e produtividade dos participantes no contexto de pandemia global em que estamos todos inseridos. Pretende-se ainda avaliar o grau de satisfação dos utilizadores com estas plataformas e as suas funcionalidades.

As respostas são anónimas e confidenciais. Apenas serão divulgados o resultado do tratamento estatístico.

O preenchimento deste questionário demora aproximadamente 5 minutos. Caso tenha alguma questão sobre este questionário, por favor, contactar up201604741@fe.up.pt .

*Obrigatório

1. A participação neste projeto é voluntária, por isso se aceitar preencher o formulário, está a aceitar que esta informação seja utilizada. Contudo, se por algum motivo deixar de consentir no uso da informação não haverá qualquer tipo de penalidade e esta será imediatamente retirada. Os resultados deste estudo irão ser publicados, mas a identidade dos participantes nunca será divulgada. *

   Marcar apenas uma oval.

   - ◯ Aceito
   - ◯ Não aceito

Escala de usabilidade do Sistema

Mede a usabilidade da plataforma sentida pelos utilizadores.
Para cada uma das seguintes afirmações indique o quanto concorda com elas.

2. Acho que gostaria de utilizar este produto com frequência. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

3. Considerei o produto mais complexo do que necessário. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

4. Achei o produto fácil de utilizar. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

5. Achei que necessitaria de ajuda de um técnico para conseguir utilizar este produto. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

6. Considerei que as várias funcionalidades deste produto estavam bem integradas. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

7. Achei que este produto tinha muitas inconsistências. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

8. Suponho que a maioria das pessoas aprenderia a utilizar rapidamente este produto. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

9. Considerei o produto muito complicado de utilizar. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

10. Senti-me muito confiante a utilizar este produto. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

11. Tive que aprender muito antes de conseguir lidar com este produto. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

Ambiente virtual 3Decide

Questões direcionadas ao ambiente imersivo criado com a 3Decide.

12. Em comparação com reuniões presenciais, quão envolvido se sente neste contexto? *

Marcar apenas uma oval.

	1	2	3	4	5	
Bastante envolvido	◯	◯	◯	◯	◯	Nada envolvido

13. Em comparação com reuniões online numa plataforma mais popular como o Zoom, quão envolvido se sente neste contexto? *

Marcar apenas uma oval.

	1	2	3	4	5	
Bastante envolvido	◯	◯	◯	◯	◯	Nada envolvido

14. Se as videoconferências se realizassem numa sala comum mais interativa e 3D como esta, sente que isso seria um fator de desconcentração ou iria encorajar a sua participação, melhorando a sua sensação sobre a reunião? *

15. O que é que gostou mais da experiência?

16. O que é que gostou menos da experiência?

17. Feedback Final

Qualquer opinião ou sugestão que ache relevante partilhar.

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