Bachelorarbeit Rohfassung

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Abbreviations

VR Virtual Reality

VE Virtual environment

HMD Head-mounted device

1. Abstract
2. Introduction

In the past few years Virtual reality (VR) has become more and more present. Nowadays, it has found its way into several applications, like entertainment, training, education and even healthcare. Virtual environments (VE) that completely separate the user from their real surroundings increase the degree of immersion immensely and therefore changes the way people experience VR. It offers a distinct edge by delivering increasingly dynamic and emotionally heightened encounters. [3]

VR is considered to be a high-presence medium. The terms *presence* and *immersion* are oftentimes used interchangeably. The user’s engagement with a VR system leads to *immersion*, resulting in the user entering a flow state. Sensory immersion, which is defines as “the degree which the range of sensory channel is engaged by the virtual simulation”, is a significantly factor of immersion to VR systems [10].

The term presence is often used to express the sense of “being there” in the virtual environment.

There are several elements that significantly contribute to the immersion of a user in a VR game. To get a player feel completely present in a game, you have to prioritize usability, clarity, and visual appeal in the VE design. Besides the design aspects of the VE, user-friendly menus, intuitive interaction elements, and realistic interfaces that allows user to navigate through the VE are also a big part of the immersion [7].

However, there is also a downside to VR. Some users can suffer from symptoms of motion sickness during VR experiences. Other terminologies of motion sickness are VR sickness or cybersickness. The major symptoms are eye fatigue, disorientation, and nausea. This unpleasant experience can influence the way a user feels immerged into a VE and therefore minimize the presence. [16]

todo

für Sophia {habs noch nicht umgeschrieben}

1. VR Games

When talking about virtual reality, it is important to understand the three most important features, the so called three I’s of virtual reality. The first two I’s are interactive and immersive. These two features go hand in hand. However, most of the people forget about the last feature of virtual reality. Virtual reality is not only accessible for the medium or high-end user interface. It can also provide solutions to real problems in engineering, medicine, military and so on. It depends on the user’s imagination, if an application can solve a particular problem.

Therefore, virtual reality is an intertwined concept with the so called three ‘I’s of VR - immersion, interaction and imagination. [2]

* 1. Use of immersive VR

As virtual reality is emerging as a new area of multidisciplinary research, it has increased its scope into many different fields of study [18]. It provides a better opportunity for 3D visualization during teaching purpose.

Immersive VR is widely used for entertainment purposes, like gaming and sports.

VR has also found its use in the medical field, as it allows the students and doctor to interact with the human body and gain experience [19].

The military industry is always on the lookout for new ideas, therefore it is slowly emerging as one of the major investors into VR [18].

* + 1. Healthcare and medical field

**Medical field**

The medical industry is adopting VR technology to improved treatment of patients, as it allows doctors to learn new skills in a safe environment. Applications of this technology in the healthcare industry are psychological therapy, medical rehabilitation, medical research, and teaching.

It helps a surgeon to operate without causing any harm to the real patient and strengthen their confidence in making decision. Practicing in the virtual environment, can reduce the error rate in surgery and helps doctors to make less mistakes.

Intensive care unit staff can practice a procedure in limited time, during emergency cases. It is extremely useful for building trust and to make informed decisions. It helps in addressing and trying out various neuropsychological issues during the patient's treatment.  
Besides the learning experience, VR is also immensely helpful for pain management, as it reduces the pain during treatments. In addition, this technology can be used for treating phobias.

Other applications of VR in the medical field are diagnosis, planning a performing of surgery, reducing depression, and many more.

The wide range of applications of this technology in the medical field provides an essential role to improve performance of the medical profession. [19]

* + 1. Digital marketing

**Product and service advertisement**

As the world is frequently evolving and getting more digitalized, some enterprises need to adjust their methods to promote products and services to customers. To establish and maintain the relationships with clients and other individuals, one of the most important elements is marketing communication. Companies that use modern marketing communication methods and tools can quickly and effectively interact with customers and other entities. One of the latest marketing communication methods is the use of VR. Clients can experience products and service presentations in 3D with 360-degree rotation option and with very realistic content presentation, so that the user has the impression that they are watching it in real life. In addition, they can also interact with the product to get an overview of the product.  
VR has also been used to promote a business and present themselves in industry fairs. These types of promotions are usually more exited for users, since the businesses use advances equipment that not everyone has at home.   
According to [23] VR campaigns have a positive impact on the attitude and general perception of promotional messages towards the products and services that were being promoted, increasing its recognition in the process. [23]

* + 1. Education and learning

**Military field**

Technology is extremely important for military effectiveness. Therefore, military technologies are also found using multiple virtual reality simulations to demonstrate effects of operations in real time. One area where the armed forces take advantage of VR is training. They use it to reduce the risk of being exposed to hazards and to increase secretness. However, it is also used for the reason that “on job training” can be impossible, as far as warfare is concerned. As stated in [18] the key to effectiveness of VR in the military field is the man-machine interface or also known as human-computer interaction. They also state that, VR devices need to display an IVE that includes the relevant information and responses that is needed to learn and perform military tasks. [18]

One of the early employments of VR technology is simulators used for flight training. Many pilots were trained before and during World War ΙΙ with flight trainers that were build by the Link Company (Binghamton, New York) in late 1920’s and 1930’s. To maximize the learning experience it is essential that every instrument in the simulation is functioning identically to their real-world matching components and the quality of the main feature in VR – the immersion. [18]

Education field

VR has many uses of applications in the field of education. For example, students can visit museums, far-away cultural sites or travel back in time. It could also help chemistry or biology students to conduct experiments in a safe environment or allow art students to visit art galleries or experience their creations in 3D. As the cost of VR equipment decreases it also revolutionize both the way students learn and educators teach.   
Other advantages are for example engineering students can design and model their prototypes at no cost, while physic students can experience the effects of gravity on the moon or other planets.  
VR can also benefit students while learning new languages, as they can immerge themselves into a VE and practice their skills and get more confident without the travel costs. VR in classrooms can be used for students of all ages. For instance, elementary students can improve their retention an deepen engagement. According to [26] students are more motivated when using VR in specific settings.

During the “COVID-19” pandemic many schools and universities moved their studies to online as it was an essential element for safety to reduce in-person contact between people. Many students couldn’t access laboratories and equipment that was critical for students to develop practical skills. The solution to this problem was the implementation of modern technologies such as artificial intelligent and virtual reality. [24]

On the other hand, the cost of implementing VR technology in classrooms is still very high, compared to the costs of textbooks and tablets. The authors in [25] compared traditional teaching methods with VR teaching. They stated that the use of VR in an educational setting can enhance the user’s engagement and learning outcome. Users also find the VR teaching more enjoyable

* + 1. Entertainment

Entertainment field

The definition of the entertainment field is widely broad. It can be divided into many subcategories, including Gaming, Film industry, Galleries & Museums, Music & Nightclubs, Arcades/Theme Park, Tourism, and Sport events. [27]

The application of VR in the film and television industry is less popular than in other branches. The reason for that is the need to wear heavy HMD throughout the whole experience and the occurrence of Virtual reality sickness can be very unpleasant to some users. The production of the film also appears to be extremely difficult, as it requires special production methods and technical means. VR movies require continuous shooting, and the editing process is different in contrast to traditional movies. [28]

The use of VR in museums is helping to overcome two major problems: *authenticity* and *new museology*. The former describes the need for museums to present an authentic experience to visitors and the latter outlines the enhancing experience of the visitor by providing edutainment (education and entertainment). [29]

In cultural tourism, VR reduces the barrier between travelers and their destination and allows them to enhance their knowledge and provide information about the destination before their actual visit. However, as the authors in [29] mention, VR does not replace or threaten real world traveling, whereas it is an effective tool to prepare for the real vacation. [29]

Due to the COVID-19 pandemic, nightclubs, bars, and other nightlife venues were forces to shut their doors. Not only has this led to a higher unemployment rate but it also took away social contact from people. The nightlife scene completely reinvented itself when it shifted from in-person to a virtual performance. [30]

VR clubs are gaining more recognition, as it combines the excitement of the traditional nightlife with the new ideas of virtual environment. Club Qu, Bootshaus, and VRChat are examples for VR nightclubs. Tribe XR and Vinyl Reality offer DJs a platform for virtual training and performance opportunities. For instance, Tribe XR provides a cost-effective and accessible way to learn and perform with digital DJ equipment. Users can stream and listen to their performance. [31]

1. Virtual reality sickness

As mentioned above, VR technology has found its use in many branches. However, beside all the advantages, there are also some drawbacks of virtual reality.

During VR experiences, some users can experience symptoms that are similar to motion sickness.

Humans get their orientation and self-movement via various sensory organs. To be more precise, they use information from the visual, vestibular (balance system) and proprioceptive (body awareness) senses to form an accurate perception of self-motion within a three-dimensional space. Because the information from the visual, vestibular, and proprioceptive senses are processed synchronously, we can accurately recognize our movement and position without any difficulties.

However, modern transportation systems can disturb the perceptual system. When riding on a vehicle (e.g. plane, car, train), people can feel the movements through the vestibular organs, but sometimes the corresponding visual information is missing, which causes sensory conflicts. When a human consistently receives sensory information that is different from their expectations, the person can experience motion sickness.

Visually induces motion sickness (VIMS) is the term used, when the dominant sensory input that causes motion sickness is visual stimuli. Depending on the context, VIMS can be referred as something else. In the use case of virtual reality, VIMS is referred as simulator sickness, cybersickness, or VR sickness. [16] The terminology simulator sickness originated from the early use of flight simulators in military training [22].

Users that experience virtual reality sickness get symptoms like headaches, vertigo, nausea, disorientation, and eye fatigue.

What causes these symptoms are the frequently moving images and the mismatch between expected and perceives sensory information while using a Head-mounted device (HMD). [15]

There is a balance between how likely a user is to feel VR sickness and their sense of presence in the virtual environment. This balance is based on the speed and angle of the visual information. The problem is, if more attention is payed to the visual information design to enhance the feeling of presence, the user might develop virtual reality sickness. On the other hand, if more attention is payed to reduce VR sickness, the user’s sense of presence will be impaired.

Therefore, the relationship between the occurrence of cybersickness and the sense of presence is very closely linked and can lead to an unpleasant experience if it is ignored. [15]

4.1 Factors inducing virtual reality sickness

There are many factors that can influence cybersickness. The authors in [16] categorizes these factors into 3 domains: hardware, content, and human factors.

1. Hardware factors include changes to VR devices, such as display mode, display type, time delay, and many more.
2. Content factors include variations in VR scenes or scenarios by changing graphics or task-related features.
3. Human factors cover differences of individual user that are related with cybersickness.
   * 1. Hardware

Like mentioned above, there are a few factors that reduce or induce virtual reality sickness. One critical factor is the quality of your hardware. There are devices, like HMD, that deliver stereoscopic images, and other devices, like large screens and monitors, that deliver monoscopic images to user. Although, stereoscopic content can provide high-fidelity and seems more realistic, it also enhances cybersickness. [16]

**Hardware FOV**Another factor, that can influence VR sickness is the field of view (FOV), also described as external FOV, display FOV, physical FOV, and real FOV. It is the maximum visual angle of a display device. According to [16], reducing the FOV of a device, decreases the motion sickness, especially during rotational movements or acceleration. There are several studies, that researched the relationship between hardware and content FOV. Draper et al. [17] introduced an ‘image scale factor’ that calculated the ratio between hardware and content FOV. Three categories of images scale factors were assigned based on their values: **minification** (hardware FOV < content FOV), **neutral** (hardware FOV = content FOV), and **magnification** (hardware FOV > content FOV). While this study revealed that participants find the neutral condition the most comforting, other studies reported participants showed greater cybersickness when experiencing the neutral type of VR [17].

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**Latency**  
When a user explores and interacts with the IVE, the system needs to calculate the body movement and transmit it back to the user. However, calculating and sending the information back to the user can create a time difference, which causes a divergence between what the user expects to see and what was actually viewed. This effect can lead to VR sickness. Studies found, that if the time delay increases, the motion sickness also increases. However, if the time latency is consistent during the whole VR experience, it will not lead to more severe cybersickness [16]. This is because, the user can adapt to the time delay and therefore predict their surrounding precisely. When designing an IVE and wanting to reduce VR sickness, it is important to minimize time delay or, at least, keep the time lag consistent. [16]

**Flicker**  
Display flickering can cause VR sickness. It can be visually disturbing and also decrease the user’s eye health. Factors, like the display’s refresh rate, luminance and FOV can influence flickering. A brighter screen needs a higher refresh rate to minimize the flicker effect. In addition, the size of the screens can also influence flickering. Nevertheless, due to an improvement in hardware systems in the last few years, flickering was reduced to a minimum and therefore is no longer a major influence in cybersickness. [16]

* + 1. Content

Content is a critical factor which determines the degree of VR realism and therefore the user’s immersion into a VE as well as VR sickness. Due to the advances in hardware systems, developers could implement a higher fidelity in VR. However, a higher fidelity does not contribute to a better user experience. In order to better understand the influence of context in VR sickness, the authors in [16] categorized 6 different aspects of VR content: Optical flow, graphic realism, reference frame, content FOV, duration and controllability. [16]

**Optical flow**

vfev

**Graphic realism**

Although, a more detailed IVE results in increased immersion, it also increases VR sickness.

**Reference frame**

**Content FOV**

**Duration**

**Controllability**

* + 1. Human factors

**Age**

**Gender**

4.2 Factors reducing virtual reality sickness

1. Immersion

In the world of VR, the terms *immersion* and *presence* are often used interchangeably. However, there is a difference between those two terminologies. *Presence* is generally defined as a user’s subjective sensation of “being there” in a virtual environment. It allows the user to fully immerse into a VE, as if the virtual world is the real environment [5]. Factors like a stable image and accurate tracking can influence the presence of a user. Probably the most important factor is low latency because the virtual world needs to react to a user’s movements as quickly as in real-time [14].

*Immersion* is considered to be a quality of technology, that has the ability to trick your mind into thinking you are somewhere else. Different virtual reality devices can influence the immersion.

A virtual system that consists of highly detailed visual content, haptic feedback, and spatialized sound is considered to be more immersive compared to a scene displayed on a desktop monitor.

Increased immersion is typically associated with an enhanced sense of presence. [5]

The next section describes the different levels of immersion in greater detail.

* 1. Level of Immersion

The quality and the type of computer generated sensory determines the level of immersion and therefore the users feeling of presence and experience in VR. Ideally, information should be presented to all of the user's senses with high resolution, quality, and consistency across all displays. In order to maintain the illusion of immersion, the VE should react accordingly to the user’s action. [4]

VR systems can be categorized into levels based on the degree of immersion they provide to the users. There are three levels of immersion which all differentiate by their physical setup and therefore depend on the degree to which the user is disconnected from the real environment while engaging with the VE. The first level is called a non-immersive system. It has the least amount of physical hardware since it only consists of one computer. Video games and online games belong to this type of system. The next level of immersion is a mix of the non-immersive system and fully immersive system . The hardware setup of a semi-immersive VR contains a display, stereo shutter glasses and some type of input device. Advantages of this system are simplicity, high resolution, low cost, and versatility [12]. The last level of immersion is called a fully immersive VR system. It includes a Head-mounted display (HMD) which provides the user with high-resolution content, with a wide field of view. In addition to sight, the user can also experience sound, which makes this type of VR the highest level of immersion.

According to the authors in [11] a higher level of immersion does not improve the experience of a user, in some cases they even decrease the performance.

* + 1. Non-Immersive VR (Desktop VR)

This type of immersion is the least complex to implement in applications, for the reason that it does not need special equipment. It is the simplest type of VR systems, and it is still commonly used today. Desktop VR is when the user experiences the VE using one or more computer screens.

One characteristics of a non-immersive VR system is that the user can control and interact with a character, but the environment is not directly interacting with the user and therefore does not immerse the user fully into the game. The only sensory output is the display. The real time visualization and interaction within a VE that simulates a real world is the reason it became popular in the first place. [4]

* + 1. Semi-Immersive VR (Fish Tank VR)

Semi-immersive system is a combination of non-immersive and fully immersive VR.

It provides users with a partially virtual environment where they remain connected to their physical surroundings. It generally does not support sensory output. [4]

The user can experience the VE without any physical sensation and still provides them with the feeling of being there. By using a VR headset, the user will not be able to see the real world, only the virtual environment, which will create a strong immersive experience. Semi-immersive VR is the most cost-effective system and therefore the most commonly used form of VR after non-immersive VR. It can be both device-based and web-based [8].  
According to the authors in [8], semi-immersive VR is being used by many businesses such as real estate websites, hotels and local bars or pubs, universities and schools, to promote their location.

* + 1. Fully Immersive VR (HMD-VR)

With the help of head-mounted devices (HMD), users can completely dive into the VE. This last level of immersion is called fully immersive VR, and it has the highest degree of immersion. It is different from other types of VR in that they capture full body motion and can be enhanced by audio, haptic, and sensory interfaces. [4]  
However, this type of VR is the most expensive one, because you need to buy pricey haptic feedback devices like VR glasses, gloves, vests, controllers or even a body suit with body connectors with sense detectors, that allows user to touch and feel objects within the IVE. These devices are crucial for providing a tactile sense of immersion since they add a sensory dimension to the experience. [9]

In addition, fully immersive VR needs advanced technology that can detect and handle the movement of the users with powerful graphics processing units (GPUs) that all together create a seamless and responsive virtual environment [8].

The core hardware of a fully immersive VR is the Head-mounted Display (HMD). Users wear this device on their head It contains two displays for each eye, which create a stereoscopic 3D effect. Oftentimes, these HMD have integrated sensors that can track head movements, which allows the users to look around in the VE.

Since this form of VR is the most immersive one, it is has found applications in industries like Training and Simulations, Architecture and Design, Gaming and Education. It enhances the user's ability to learn, create, and explore. [9]

* 1. Types of Immersion
     1. Tactical immersion

This type of immersion is experienced when performing tactical operations that require skills. Users are highly concentrated and focused while completing a task that result in success. [4] Specially in the VE, tactical immersion occurs when a user is intensely dedicated in the act of competing and playing a virtual game, which often requires a fast reaction time. There are not many factors that can influence the tactical immersion, it mostly is determined by the limited amount of time for the user to consider the whole gaming situation thoroughly and the spontaneous response and decision making of the user. Another word for Tactical immersion is cognitive immersion or strategic immersion. [13]

* + 1. Strategic immersion

Strategic immersion is more intellectual. The VE offers strategic problems that are mentally challenging the players. Users feel immersed when they find a working solution resulting in mastering a demanding problem. [4]

* + 1. Spatial immersion

Spatial immersion occurs when a player feels the VE is perceptually convincing. The player feels that he or she is really “there” and that a simulated world looks and feels “real”. [4]

* + 1. Narrative immersion

Uses get so invested in a game story that they feel like they are actually in the game. It is a similar experience to reading a book or watching a movie. [4] The difference to spatial immersion is, the user does not feel the “bodily presence” into the scene, but rather feels the connection and emotionally empathized with the story of a character or an avatar. A user can feel all sort of emotions when playing a game, like fear, joy, excitement, relief, anger & frustration, surprise, boredom, and so on. [13]

* + 1. Psychological immersion

This type of immersion happens when the user confuses the VE with the real life. [4]

* + 1. Sensory immersion

The player experiences a unity of time and space as the player fuses with the image medium, which affects impression and awareness. [4]

1. Design of a Virtual Environment

Virtual reality is a convenient tool to simulate real-life events and study human behavior as it allows researchers to fully immerse participants into a controlled virtual environment.

VR is considered to be a high-presence medium and allows for a high degree of experimental control.

Therefore, VR has been used for diagnosis, clinical education, and clinical and experimental intervention.

VR has the potential to study human behavior without exposing the participants to the risk and inconsistencies that can occur in the real-world environment.  
Another advantage of studying human behavior in immersive virtual environments (IVEs) is the full control of the social interaction and other environmental factors, such as noise and crowding, that can take place in the real-world environment and change the way a human would react naturally [5].

An IVE that was designed with highly visual content, spatialized sounds, and haptic feedback is considered more immersive than a scene that was rendered on a computer. Thus, portable Head-mounted displays (HMD) that have the ability to block out the real-world surroundings are preferred while studying human behavior.  
Besides the advantages of HMDs, there are also some disadvantages that need to be considered when designing an IVE. As participants do not see their real body, developers need to consider the fact to include avatars. Participants also need the ability to navigate through the virtual space. The design of the IVE plays a crucial role in the immersion of the user. Therefore, developers need to consider a few elements when designing an VE. Factors like, avatars, audio, light, and other context need to be carefully studied [5].

**Degree of detail in the environment**

Researchers proposed that typical element features, such as furniture, need to be included in an IVE. However, they should have an appropriate amount of detail according to the kind of behavior that researchers want to study. For example, when studying gambling behavior, elements like paper slips, pens and stools in the betting shop need to be considered and included.

Realistic textures are very important in studies where participants are expected to move around the environment and pick up items to investigate them [5].

Providing elements with a realistic texture can improve the participant’s sense of immersion. Visual realism has two components: the **geometric realism** and the **illumination realism**. The former investigates the similarity between virtual and real objects and the latter concentrates on the fidelity of the lighting model.  
However, designing complex IVEs can be very time-consuming, in need of heavy computational algorithms and can decrease frame rate when users view the IVE.  
Before committing to a final design, researchers need to decide the level of complexity of their IVE, as a suboptimal design can have a serious impact on the user’s behavior.

It also needs to be considered when using a high level of visual realism, it might rise the participants expectation for other aspects (e.g., nonvisual, and tactile) of the virtual environment.

Researchers also need to consider what elements are relevant and irrelevant, hence users could pay more attention to irrelevant elements [5].

**Relevant and irrelevant elements**

Prior to developing IVEs for behavior analysis, researchers must determine the essential contextual cues and assess VR's capability to integrate all the necessary elements. The inclusion of social elements, which are elaborated on in the next section, present particularly complex tradeoffs.

Participants often put their focus on objects most relevant to looking behaviors, such as windows. They also engage in more exploratory behavior, which are not very prominent in the real environment. Exploratory behavior in this context can be explained as paying more attention to objects that are not relevant to the research question [5].

Participants put their focus more on irrelevant parts of the IVE, like “see-through” objects (e.g., windows) instead of practical objects with functionality.

The intense attention to display surfaces or windows underlines the concept of multiple incorporation of elements during interaction in virtual environment.

The spatial awareness of participants in an IVE is however still embedded in their real surroundings. For example, if participants are more observant of windows or display surfaces that display information’s about the exterior, participants may be creating a mental model of the IVE’s location and themselves in the virtual space.

Therefore, researchers and developers should deliberate on whether certain features, like windows or displays, should be incorporated, or left out, given the fact that participants could pay more attention on irrelevant features [5].

**Stimulatory and instructional cues**

Cues, like stimulatory and instructional cues, can be very helpful to participants, considering they provide relevant information and navigation within the IVE. For example, using lighting and moving traffic allows the participant to develop a sense of time. However, such cues should be used carefully as it should only emphasize an emotion of the participant and not affect the playability and navigation in the IVE. Instructional cues can assist participants in navigating through the IVE [5].

**Animating interactions**

If IVEs contain features that are animated (e.g., walking avatars, moving cars), it is important to consider the right animation speed. When selecting the animation speed for a character or avatar, it is important to consider the age and gender of the character.

To maintain the feeling of immersion, there should be minimal to no movement mismatches. These mismatches can happen when participants rotate or move their body [5].

**Social cues**

Social cues are features that a participant can interact with, like avatars. In certain cases, avatars can enhance the realism of the IVE. However, they can also distract the participants and distract their focus to something unimportant.   
When avatars or self-avatars are introduced, it is essential to animate them appropriately [5].

**Self-avatars**

When introducing self-avatars in an IVE, there is a possibility that it can enhance a participant’s immersion. Users feel more immersed when there is a representation of themselves in the IVE and other avatars recognize them.

**Nonvisual sensory information**

vfeqveoi

**Audio**

There are not only visual aspects of VR that can have an impact on the immersion. Non-visual aspects such as audio or haptic feedback can also change the way a user feels immersed in a VE [6].

**Light and shadows**

Not only the design aspect of the assets has an impact on the immersion of a user. The realism of the assets is also very crucial. If a model is placed under light, the user expects the models to throw a shadow. Not only does the user expects there to be shadows, but also awaits the asset to look darker in the shade than in the sun. If there is water or some other fluid inside the VE, the player also wants to see some refraction of the light [6].

1. Interaction and Navigation

cefd

1. Storytelling
2. Character Design

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2. References

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