UNIVERSITY OF OULU

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# Improved User Experience with Realistic Virtual Environments and Environmental States



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# ABSTRACT

**Virtual reality has been a topic of keen research for last three decades. Recent advances on display technology and wireless network systems combined with easily maintainable and expandable social networks allow more pervasive experiences and better collaboration than ever before. Still the virtual reality remains as rarely used resource and a niche form of entertainment.**

**Virtual Reality is still far from its Science Fiction epitome. Sci-fi presents virtual reality as a ubiquitous technology that generally provides an immersive experience that transforms the concept of communication and collaboration by taking the user into completely another reality.**

**Thanks to leaps in technology, users can experience previously unseen levels of resolution with minimal network lag on consumer priced products. Despite of this VR technology has not caught on. From users' perspective, this is affected by user experience.**

**This thesis sets out to discover use cases for realistic virtual environments and states and issues in user experience affecting adoption. It will also take a look on different hindrances and difficulties concerning the mass adaption of virtual reality tools and applications.**

**Keywords: virtual reality, realistic virtual environment, mirror world, user experience**

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# TIIVISTELMÄ

**Virtuaalitodellisuutta on tutkittu vilkkaasti 80-luvulta saakka. Näyttöteknologian ja langattomien verkkojärjestelmien viimeaikainen kehitys yhdessä helposti ylläpidettävien ja laajennettavien sosiaalisten verkostojen kanssa mahdollistavat aiempaa kokonaisvaltaisempia kokemuksia ja yhteistyömahdollisuuksia. Tästä huolimatta virtuaalitodellisuus pysyy edelleen harvoin käytettynä resurssina ja viihteen erikoismuotona. Virtuaalitodellisuus on edelleen kaukana sci-fi visualistien haaveesta: kaikkialla läsnäolevana, ubiikkina teknologiana, joka tarjoaa mukaansatempaavia ja ainutlaatuisia kokemuksia, sekä muuttaa käsitystämme sosiaalisesta kanssakäynnistä.**

**Uusimmat teknologiat tarjoavat käyttäjälle ennennäkemättömän korkearesoluutioista kuvaa ja minimaalista verkkoviivettä kuluttajahintaisilla laitteilla. Tästäkään huolimatta suuri yleisö ei ole lämminnyt VR-teknologialle. Käyttäjän näkökulmasta tähän vaikuttaa suuresti käyttökokemus.**

**Tämä tutkimus käsittelee realististen virtuaaliympäristöjen ja -tilojen vaikutusta käyttäjäkokemukseen, sekä ottaa kantaa erilaisiin esteisiin ja hankaluuksiin virtuaaliteknologian leviämisessä suuren yleisön suosioon.**

**Avainsanat: virtuaalinen todellisuus, realistiset virtuaaliympäristöt, peilimaailma, käyttäjäkokemus**

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# ABBREVIATIONS

| | |
|---|---|
| UX | User experience. Emotions, reactions and attitudes user feels when interacting with a product [3]. |
| HCI | Human-Computer Interaction. Area of research that studies interactions and interfaces between human and computer. UX is one of the major themes on HCI. |
| Player experience | Player experience analyzes the interaction between player and the game [27]. |
| GEQ | Game Experience Questionnaire [12]. Likert-scale survey that is used in evaluating player experience. |
| Ubiquitous computing | Concept where computer devices are integrated everywhere to the point they blend seamlessly into everyday life. |
| IoT | Internet of Things - embedded devices with internet capabilities. |
| VR | Virtual Reality - experience generated by artificial stimuli. |
| VE | Virtual Environment – computer generated environment for user to interact with. |
| Dual reality | Concept of both real and virtual reality merging and influencing into each other. |
| AR | Augmented Reality - superimposing computer-generated view on top of real world to aid user. Conceptually it differs from VR but in this study AR is considered being extension of virtual reality. |
| Realistic environment | Space or state that mirrors real life in realistic way. Realistic state could mean for example in-game circadian cycle or food spoiling and player character getting sick from eating it. Concept of realistic environment relates to mirror world concept that was introduced by Gelernter [26]. |
| Familiar setting | User already knows the setting from e.g. real life |
| Pervasive games | Games that take place on both virtual and physical world. |

| | |
|---|---|
| *Janitor Run* | Racing game with real-time weather conditions and circadian changes. Game environment is 3D model of Oulu University [1]. |
| Non-Player Character | Virtual character that is controlled by the system. These are usually found in video games, but definition could be extended to e.g. characters inside virtual reality |
| Real life | Physical reality that humans experience |
| Gameful Design | Concept of making learning or other activities fun by gamifying it. For example, using experience points, levels, sub goals, and achievements [36]. |
| Time Gating | Arbitrary forcing players to wait. |
| Desktop game | Game that is played with traditional computer with display screen, keyboard & mouse interface. |
| Mobile game | Game that can be played anywhere with different mobile devices such as smartphone or a tablet computer. |
| Pokestop | Pokestops attract different types of Pokémon depending on their geographical location in real life, i.e. ports and beaches attract water types. Pokestops hand out items when player interacts with them and interaction requires proximity with real world object. Pokestops in real world are objects that have minor geographical significance such as playfields or small statues. |
| Pokémon gym | Players in Pokémon Go can conquer places that have bigger significance in real world than Pokestops. These objects are for example hospitals, arenas and theaters. |
| SPSS | Statistical analysis tool for quantitative data by IBM [57]. |

# 1. INTRODUCTION

This study has been inspired by a game project *Janitor Run* [1]. *Janitor Run* is a racing game that takes place in a realistically proportioned 3D model of University of Oulu, Finland. Tied together with the game project was a study that was based on surveying player experience [27]. *Janitor run* study concluded that statistically significant portion of players who were most familiar with the campus felt least tired after the game [1]. This result suggests that concept of familiar setting and realistic states might be useful to utilize when planning for the intended user experience. This research aims to improve user experience (UX) when interacting with virtual reality and virtual worlds. This improved UX would be useful for pushing virtual reality to become more of a ubiquitous technology.

UX is one of the key aspects of pushing fringe technology for wider audience and towards mass adoption. UX by definition goes beyond mere usability and utilitarian efficiency that one might think would be the most important parts when thinking about Human Computer Interactions (HCI) [2,3]. UX starts to shape even before user has any interaction with the system or product, and its effects last long after the actual task and task-oriented interaction is completed [4]. The experience user had again affects the UX of next interaction with similar system or product.

The relevance of this UX-chain is more and more important in the future; information systems grow more ubiquitous, pervasive and mandatory to use as they are the preferred way for communication, transactions and learning. Developers and companies behind products must consider UX as an integral part of development process from the very beginning of the development cycle. Similar with the concepts of computer security, adding extra-layer of UX-related modalities afterwards will often lead to a worse result than if UX was already an integral part of original design.

Virtual reality is a computer-generated experience. User feels that his/her presence is taken from physical world into a different reality, an artificially simulated environment which allows interaction [41].

Player experience evaluates interaction between player and game [27]. Users inside virtual reality are effectively players so player experience is also valid aspect in UX. Player experience is game user research equivalent of what user experience is in human computer interaction research. Player experience is a topic on its own but it's important to highlight as this is a gaming study. This will be inspected in more detail in chapter 2.3.1.

The example application in this study explores player experience when using realistic VE as a game scene, in this study the target is UX when extending VEs with physical world elements [1]. The reason UX was chosen instead of player experience because it is wider and more granular topic. Term user experience is often used to describe usability related issues. Even though usability is a part of user experience, terms are not interchangeable and often term UX is hard to describe comprehensively. This abstractness results UX studies being ubiquitous and they are not always taken seriously as an actual field of science [47, 48]. However, companies behind consumer products have recognized the need and usefulness of UX concept as a guiding element in product development. This approach might help development of VR products and in pushing them towards mass adoption.

## **1.1.** *UX in Virtual Environments*

As stated, this study is about UX when extending VEs with physical world elements. Realistic environments and states are computer generated manifestations that reflect the real world and its conditions. These can be for example events, conditions, actions, aspects or objects. Data can be collected from real world using different sensors or indicators [8]. Collected data is modeled into digital form in real time to represent real world conditions. Modeling should be done in enough detail to user understand the meaning and quickly enough for it to feel realistic. Even small lag (>100ms) will destroy presence in VR and affect negatively to user experience [44].

UX is highly dependent on interface between human and computer. While most users are accustomed to working with desktop computer interfaces (i.e. Mouse and keyboard), using them with 3D environments requires familiarization. 3D models need to offer a clear point of view for user to convey complex spatial information, for example in motion control. This requires users to focus on forming a mental map of environment instead of actual task in hand. To reduce this mental effort, familiar settings could be useful. Overall users are well equipped to work in 3D environments if enough interfaces are provided.

Gathering the data is becoming more and more efficient with Internet of Things (IoT). Embedded and small devices are cheap and easy to use [9]. They are usually modular so changing or adding appropriate sensor is often trivial task. Frameworks for collecting sensor data and brokers to propagate the data for interested parties are relatively easy to use [10, 11].

Frameworks are even specially developed for places with long maintenance cycles or scarce network bandwidth. Many open-sourced projects can be found with simple online engine search and freely available tutorials ensure that developers do not have to start from the scratch.

The purpose of this thesis is to study the relation of realistic virtual environments and states to observed User Experience. By conceptualizing these findings, the aim is to provide guidance in creating a positive UX in VR to further adoption.

This Introduction is followed by Related Work that describes prior knowledge on the topics covered: Virtual Reality, User Experience and using realistic environments and states in gaming. VR chapter looks in concepts behind Virtual World: environment, immersion and presence, sensory feedback and interacting with virtual environment. Gaming chapter introduces four games where realistic environments and states are used. Other projects in related work chapter demonstrates different uses for realistic components in virtual environments. User experience chapter in related work explains problems in designing and evaluating UX.

Research approach chapter explains how this thesis was conducted and explains *Janitor Run* project in more detail: different realistic states that were used and authors' contribution in project.

Results chapter capsulizes findings and brings together different topics on how create better UX when using realistic virtual states and virtual environments.

Discussion chapter present ideas for VR application areas that could use realistic virtual environments to create positive UX. These ideas are meant for conceptual starting points for piloting VR studies and projects.

Future works chapter looks on *Janitor Run 2* and compares it to *Janitor Run.* Also, idea about possible *Janitor Run 3* project is presented. Ideas in this thesis could be useful and should be considered if the project utilizes VR technology.

# 2. RELATED WORK

Many studies, projects and concepts are related to this topic either from VR, UX or gaming fields. Following subjects were chosen as they have coverage through more than one relevant field, and they utilize less used realistic components in subject. Most of the realistic components referred here are implemented through developers' ideas as most appropriate manifestation instead of the most realistic one.

One interesting related project is *foldit* [14]. Players create realistic folds of proteins that could help solving real world problems such as fighting diseases. Due protein folding's high level of freedom (think of 3D puzzles with interlocking components), creating new proteins is difficult work for computers but relatively straightforward for human problem-solving. This is a prime example for mirroring realistic objects and their representative states from real world to virtual world and back again. Linking real-world problems into realistic virtual environment and solving protein-folding puzzles virtually is more time- and resource efficient and allows real-time testing and result-logging without e.g. human error when inspecting results and creating notes.

Another example is the *riot!* - digital narrative [34]. It is a pervasive play that blends historical and current day environment [49]. The location-sensitive, interactive audio play took place in Queen's Square in Bristol, England. Participants were given a PDA, headphones and GPS receiver. Their movement in Queen's Square would trigger sound files that made up a play. The play re-enacted the real riot that took place in 1831 on the same place. Conceptually thinking, if typical visual feedback is swapped to auditory feedback, this interactive play is straightly comparative to immersive virtual reality with auditory and spatial feedback.

Some relation could also be drawn with 3D learning environment Quest Atlantis (QA) [35]. The study is more about gaming design, but notions about UX could be made based on its results. In QA the students explored a 3D world and learned about water cycle. Study discovered that students were eager to explore the environment and learned the concept well. It took more time than traditional studying, but students were more inspired. Instead of someone telling them, they built the knowledge themselves from quests and tasks inside the virtual environment. The relation of QA to this UX study is inspiration that students' felt, their attitude for inquiring scientific information and new insights about what distracted the learning process during QA session.

### 2.1. Gaming with realistic components

In professional gaming field, three examples are taken to this study: *Darkest Dungeon*, *Don't Starve* and *Pokémon Go* [37, 38, 39]. First two were chosen by their similarity to *Janitor Run* project, small developer team and realistic states modeled to game. Realistic physics manifestation can also be considered a realistic state. However, physics are a norm for many games, the physics implementation has generated a whole new genre of game engines and specially tailored hardware. It is a big topic on its own and because of this it does not belong to scope of this study.

#### 2.1.1. *Janitor Run*

*Janitor Run* is a desktop game project and study which acts as a basis for this thesis [1]. Gameplay was analyzed based on player experience in relation of frequency they had visited the campus. Besides the familiar setting of university environment, the real-time day and night cycles and current weather conditions were implemented to game as reflections of the reality.

After playing, the players' User Experience was analyzed with Game Experience Questionnaire [12]. GEQ modules utilize Likert-scale questions for evaluating player experience before, during and after the game. In *Janitor Run* player experience was surveyed using core and after modules from GEQ. Familiarity with VE setting in made statistically significant difference on players' exhaustion levels after the game when results where ran through Kruskal-Wallis analysis [25].

At the time of the study *Janitor Run* was still lacking some key areas of properly experiencing virtual environment. Especially sensory feedback received negative reaction from users. Player avatar was controlled with keyboard and realistic weather condition resulted floor being slippery. However, this was not properly indicated to players so they ended up blaming the controls and this resulted into a bad user experience [1].

#### 2.1.2. *Don't Starve*

*Don't Starve* is a resource management and base-building desktop game. Player must gather resources and build enough shelter against harsh weather conditions and monsters that loom in the dark. Character must sleep or risk losing sanity. Enough lost sanity leads to permanent character death. Character also gets hungry when in-game time passes, so player must collect and prepare food to prevent character from starving to death. Collected food will remove hunger, but it will also spoil gradually in different rates. Both attributes depend on type of food, type of cooking, and conditions the food is stored in.

Mechanics that create *Don't Starve* are basically realistic states modeled into game. Circadian and seasonal cycle together with hunger and food production/consumption and time spent on spending and regaining resources is practically what everyone is doing already in real life. Slowing game-time to match real-time would result it being mirror world to real life with heap of realistic states. Slowing time this much would probably be frustrating and too laborious to player if game would still be actively played. That being said, in some simulation games the real-time simulation is big part of gameplay experience. Due their niche nature, being developed for specially players interested in them, they are not being included in this study.

### 2.1.3. *Darkest Dungeon*

*Darkest Dungeon* is turn-based combat desktop game where player character has an unusual stress attribute. Characters that build enough stress will start behaving erratically, refusing to act, damage themselves, or taunt other characters and build up their stress. Building enough stress after first threshold is crossed will kill the character permanently.

*Darkest Dungeon* captures the essence of stress from real life and represents its' effects fittingly for immersive and engaging user (player) experience. Same as in real life, there is no magic potion that will reduce stress to zero. Removing stress is time-consuming and not all cures fit everyone. Characters' building up stress in game will build up players' stress in real life. This affects the choices player makes and wrong choices will quickly snowball to disastrous result. Even though the game is otherwise not very realistic, the player feels real stress and anxiety, and this provides for deep psychological presence.

### 2.1.4. *Pokémon Go*

*Pokémon Go* is a mobile game [39]. It became huge success in 2016 by using a nostalgic and well-known brand together with blending physical, social and virtual aspects in game. Player moves around physically in real world and game displays *Pokémon* on virtual map that is created based on topology of real world in area player is currently. Minor landmarks in real world are special places, Pokestops, where virtual Pokémon population is denser. More notable landmarks e.g. stadiums or city hall are gyms, where player can combat other players using Pokémon. Different Pokémon also appear in different geographical locations: water-types appear when players are near bodies of water and so on.

*Pokémon Go* is dual world that binds together real-world places and real-world social relationships with superimposed virtual environment. Players gather up together in same physical location to battle against enemies that cannot be defeated alone.

Different reasons for playing ranges from fun and exercise to escapism and social well-being [39]. This is especially remarkable because the game reaches the groups that are traditionally considered low physical activity groups [43]. Because of this, future research is required for super complex interventions. Pokémon Go improved users' health and social conditions, so systems using aspects from *Pokémon Go* could be useful in preventing people from falling out of social networks, motivate previously unreached population to better take care of themselves and improve education concepts.

### 2.1.5. *Virtual Environment for Virtual Reality*

Any game scene can be considered a virtual environment. Transition from virtual environment to virtual world is well defined: virtual environment becomes a virtual world when used virtual space is persistent, online and it is used for social interaction [41]. Virtual environments vary from simple rooms to complex and complete ecosystems depending on intended usage [1, 45, figure 1].

There are many ways for accessing VEs. Most common is through a screen display on a desktop computer or other traditional devices such as hand-held digital assistants and mobile phones. One of the more recent way is through head mounted displays and specially designed controllers made for interaction in 3D environments. Interaction in VR is one of the key topics on its own and it is covered better on section 2.2.3.

Today VR is a buzz-word that is clamped together with promotion for head-mounted-displays such as Oculus Rift or HTC Vive [29, 30]. The term Virtual Reality is however much older, and the VR-technique has been used in medical and military training purposes for decades. Next chapters will cover what differentiates actual VR from run-of-the-mill virtual environments.

Figure 1. Example of VE, Virtual Campus 3D model in *Janitor Run*.

#### 2.1.6. *Virtual World*

Virtual world is being described as a collection of objects and their descriptions inside simulation [13]. It is also important that users have feeling of "being there". This is called presence and is described more accurately in next section. Without presence the computer-generated manifestation is just a virtual environment.  Presence inducing, interactive, persistent and collaborative virtual environment is called a Virtual World [41]. Persistence here means that user can turn off the virtual environment and it saves the state of environment and continues when user returns. For example, user picks up an object and places it on the table in virtual world then exits the system. When user returns, the object is still on the table and not in the place that it was originally rendered. Another form of persistence is when virtual world is kept running and new events might happen without any user even being online. Presence an important aspect in immersion and sensory feedback [50]. Besides just persistent saving, the world is not stopped when one user leaves, it's possible for other users to interact with the world and each other.

### 2.1.7. *Immersion and Presence*

According to Slater et al: immersion is a physical engagement with a medium [54]. Immersion is created by systems' different interfaces and technology creating the virtual environment [54]. Different aspects of immersion are inclusiveness, extensiveness, surrounding and vividness [54]. *Vividness* measures quality of the physical displays and *surrounding* is the field of view for user which the virtual environment can be seen. *Inclusiveness* asses how much physical reality is shut out while interacting with VE. *Extensiveness* measures amount of sensory feedback is included. These immersion aspects are physical qualities of the system [54]. Another requirement for immersion is a representation of user in virtual world. This representation should match users' movement in real world so at least some body tracking is required, and system should respond to that: if user turns his/her head, the viewpoint in virtual world should change accordingly and the bigger the extensiveness of system, the sensorial modalities should follow this.

The more comprehensive the immersion is, it creates a sense of user being in virtual world. This psychological sense of being there is called presence [54]. Presence affects how users react in virtual world, the stronger the presence the more users behave in virtual world as they would in physical reality. Presence can be both psychological and physical. For example, with virtual roller coaster ride, users' presence in virtual world might be strong enough to cause user tumble down from dizziness in real life. This effect is strongly associated with next chapter, sensory feedback.

### 2.1.8. *Sensory feedback*

Sensory feedback is achieved by for example by VR system tracking users' movement and giving immediate feedback by moving the point of view in VR [13]. In this case visual sense receives the feedback by seeing the movement as the scene moves. The more sensory feedback is given the more presence inducing and interactive the virtual reality is expected to feel.

Other aspects about visual feedback are depth perception, field-of-view and critical fusion frequency [44]. Vision is usually most dominant sense so it's crucial part in creating immersion. Other senses such as sound or force perception could be used to indicate movement. Big enough lack in sensory feedback are reported to result into feelings of disorientation and nausea [44]. This phenomenon is known as VR sickness and is result of sensory conflicts of two or more human sensory systems such as visual (stimuli in VR) and vestibular (stimuli in real life) systems.

### 2.1.9. *Navigation in Virtual World*

Navigation in virtual world requires two-way communication between user and virtual world. User requires an interface to move around in environment and respectively the virtual world needs to inform the user about movement. Due the complex interaction system with virtual environment (more in the next chapter), new navigation interfaces have been developed to cater the needs for both user and the virtual world. One of the most interesting ways for user to move in VR is to user a treadmill [55].

At best, omni-directional treadmill allows user to move in any direction, just like they would in regular ground. Problems with treadmill include moving diagonally to the track, turning, and user moving too briskly and falling off the platform.

The treadmill introduces aim to amplify the feedback to senses [15]. As users move around VR they will feel as if terrain would move beneath them and will get tired eventually from walking in real life. This also promotes immersion and might help with VR sickness. Traditionally game controls for desktop PC are keyboard, mouse or joysticks [31]. Feedback therefore is mediated by game controls and is not “sensory feedback”.

Being able to control the game character e.g. controllability is however an important aspect in allowing UX (or player experience) to happen in games and it’s closely related to immersion [28].

### 2.1.10. *Interaction*

Interaction can be defined in various ways. User can be interacting with the world by for example picking up objects and throwing them, talking to non-player characters or changing the users’ location inside virtual environment [13]. It is important to have enough level of interaction in VE to induce presence. Traditional desktop interfaces such as mouse and keyboard are not enough for 3D interaction and VE must accommodate this. Users should be able to understand what they are permitted to do and obvious way to achieve it. This should be presented in a way that is easy to understand for user.

Perspective offers new ways to present information but also creates new problems such as users' field-of-vision and line of sight. These need to be considered when planning information visualization and interactions with 3D environment.

## 2.2. User Experience

UX is an asset for users and companies alike. Users get more appropriate and refined products, whereas companies get happy customers that will keep using their products and give positive user reviews. Aiming for better UX also makes more loyal customers and targeting certain UX will help separate the product from rivals and assist in identifying different user groups.

However, UX requires certain amount of comprehensive design alongside of technical planning. User experience should be taken into consideration from the very beginning of development, at very least in requirement specification. Often good UX is implied in requirements specification but if it's not accurately voiced and designed from the beginning, treating it as an afterthought can lead in bad UX instead. Enough conceptual UX planning will help shaping the product and reduces the trial and error in testing and evaluation. Aiming for clearly defined UX will also help in iterating better end-product.

### 2.2.1. *Designing for Good UX*

One of the most difficult part in designing UX is its dynamic nature. User's individual expectations, past experiences and current emotional state when using the product have an effect to UX [5]. This is especially important with products that are meant for entertainment or delicate collaboration. Hedonic attributes such as fun and feelings of satisfaction or refreshment are completely dependent on subjective experience. Subjective experience is closely tied to UX. Nevertheless, designing and aiming for desired experience is possible and for example, game design patterns can be applied for standardizing the design [33].

In his book, Schell talks about creating frameworks for intended experience [42]. Trouble with designing experience for a player is that game experience is not linear. Even when comparing to close subjects, such as use cases on general software planning, the mapping between created software and experiences the user has is unclear.

Collaborative environments introduce a social aspect to user experience. Distinguishing the difference between actual, users' own subjective UX and users' social interactions that strongly influences UX is difficult [7]. Users that are familiar with each other have different UX than complete strangers and distinction between these two experiences is important.

Let us take e-learning as a concrete example. Deliberate usage of planned UX is amplifying the learning process. The concept of e-learning has been transforming the field of education [16]. Methods of learning have shifted from traditional tools such as books, teachers, classrooms and exams into plethora of different new mediums, motivators, and assessment techniques [17].

### 2.2.2. *Evaluating UX*

Good UX is what creates and affects the difference between enjoyable and tedious activity when using information systems. Continuing with e-learning example: the effect of UX in last paragraph is two-fold. Motivating the students by for example gamifying the learning process is effective because it's making learning and progress more tangible to students. Achievements, badges, trophies, and so forth are something to be proud of when they are awarded. At the same time, they are an outsider's validation of students works.

However, as chapter 2.2.1 stated experience is subjective and depends from plethora of preconditions and by their core nature cannot be guaranteed. Something that is exciting and interesting to one person might be boring and trivial to another. Standardizing experiences is currently impossible due differences in user aesthetics.

Same as with planning for desired UX, evaluating it is also multi-faced problem. Questionnaires, interviews and observations cannot comprehensively capture complex UX and they should gather as much background-information as possible besides actual UX related questions to provide proper context for felt experience.

On gaming field, the player gets control over pace and even some event sequencing and this creates a distinguishable gap between game and the sensed experience. For example, metrics for measuring fun (for example time spent in game) and *experienced fun* might not correlate at all. Reasons for playing specific time varies strongly between users and what developers aim to be fun might not be fun at all and vice versa. This will get especially highlighted on games where players' time spent in-game is considered an important metric [56]. By *artificially* forcing players to stay online longer, the metrics measuring the fun will look good on developer (or business) side, but from players' perspective this is terrible UX that gets reinforced in collaborative environment.

### 2.3. Black Mirror

Netflix series *Black Mirror* is about near-future, where the technology has changed the society completely [40]. While the type of society and implemented technology changes from episode to episode, the core-concepts are closely related to this study. It is also a good representation of Mark Weiser's vision of ubiquitous computing [46]: pervasive technology that seamlessly blends into everyday life. Assumed exceptional UX combined with VR themes and use of realistic, familiar states in VEs gives this series legitimate place in this study.

In *Black Mirror* the people use either Augmented Reality or VR comprehensively. Technology is used much like in our real life, for communication, keeping up with social events and status, health monitoring, leisure activities and so on. Though the series itself is still closer to science fiction than real life, the user experience of people using technology in *Black Mirror* is something to aspire. To them real life often feels incomplete if users are cut off from technology or in some cases the VR is used in escapism, to escape from real world. While this clearly still science fiction, we can use it as point of reference when aiming for inducing strong presence in VR and considering many aspects of UX in VR, on both designing and evaluating it.

# 3. SCOPE AND IMPORTANCE OF THE TOPIC

This is a conceptual study on planning UX in VR with realistic states. Quantitative results from *Janitor Run* game inspired this study; they are used as an example application, and what was learned from the experimental part of *Janitor Run* is reflected in the discussion part. The results on *Janitor Run* project shaped the idea that familiar setting is improving UX [1].

The main objective in this paper is to explore usages of realistic virtual environments and realistic states affecting user experience in VR. Examples are aimed to benefit both parties, the user and provider. Providers should be additionally motivated to improve UX in genuine part of customer service. Customers that are enjoying themselves are naturally inclined to continue using services.

Topic is relevant to any industry working directly with consumers. Industries should be additionally motivated to improve UX in inherent part of customer service within the product. Customers that are enjoying the service are naturally inclined to continue being loyal to a good service provider. Providers are already utilizing this aspect by for example by offering products as bundles, using their own distribution platforms and turning off-the-shelf products into personalized services.

From another side of service desk, attending to this topic helps individual customers analyze their expectations, feelings, and reactions concerning UX. By addressing these issues and behave accordingly they know to either praise, change, or provide palpable and well-defined feedback to service providers. Most importantly, customers enlightened with concepts of UX will notice when they are being manipulated instead of serviced.

Learning institutions should also take note on using VR to enhance the learning experience. For example, a study states that collaborating in virtual reality made students spend most of their time on learning task, instead of socializing, even without teacher’s supervision to guide them [20]. Students were curious beyond the scope of learning task and besides being more focused, they were having more fun while doing it.

# 4. RESEARCH AIM

Research aim is to give development ideas and additional tools for multidisciplinary teams and researchers in VR field. Combining VR to positive UX and gradually cheaper components will aid in introducing and spreading VR technology to wider audience. VR is still missing its killer app and it can be expected that users will stop using VR products after products' novelty disappears. By providing better UX, the users will stay happy longer. This requires a conscious effort from manufacturers, developers and marketing teams. Instead of focusing to new VR apps, maybe it is time to design a whole killer *system*. As UX is granular and wide subject, it requires its' own dedicated experts to join the effort.

## 4.1. The research question is as follows*: How to design for better UX when using Realistic Virtual Environments?*

# 5. RESEARCH APPROACH

This research was initiated by results of *Janitor Run* study [1]. The study found out that familiar setting on virtual environment improves the gaming experience. These results provoked the idea of using familiar realistic states in VE could affect positively to presence in VR and therefore improving UX. While the idea for this study was born from quantitative results of *Janitor Run*, this is a conceptual study about UX in VR and how to design for better UX using realistic states. Related work chapter presented different concepts from VR, UX and examples of realistic states being used in games. Results from *Janitor Run* are explained and concepts from Related Works chapter are blended for improving UX in VR with realistic states.

## 5.1. Methods and materials

A game called *Janitor Run* is used as a case example of applying and researching UX in relation to the use realistic virtual environments [1].

Research papers were explored in the fields of virtual reality, user experience or both. Books were chosen by their close relation to subject of this paper [13, 21]. Virtual technologies were studied by reading online articles from different manufacturers and advertisers as well as observing how users felt during and after using the tech.

Keywords such as “virtual reality”, “virtual world”, “user experience design”, “user experience evaluation”, “immersive virtual reality”, “collaborative technology” were used on Google Scholar and Oula-Finna databases [51, 52]. Only studies available online were taken into consideration. After picking some studies, their references were combed through to dig deeper into concepts and in search for relationships in realistic states and UX. Aim was to take newer studies about designing and evaluating UX and blend them to older VR concepts such as presence and interaction to create new relationships.

## 5.2. *Janitor Run*

*Janitor Run* was built using Unity 3D [22]. Unity scenes hosted most of the gameplay and leaderboard data and user surveys were stored on back-end service App42 [23, figure 2]. OpenWeathermap application programming interface [*] provided real-time weather data [figure 3].

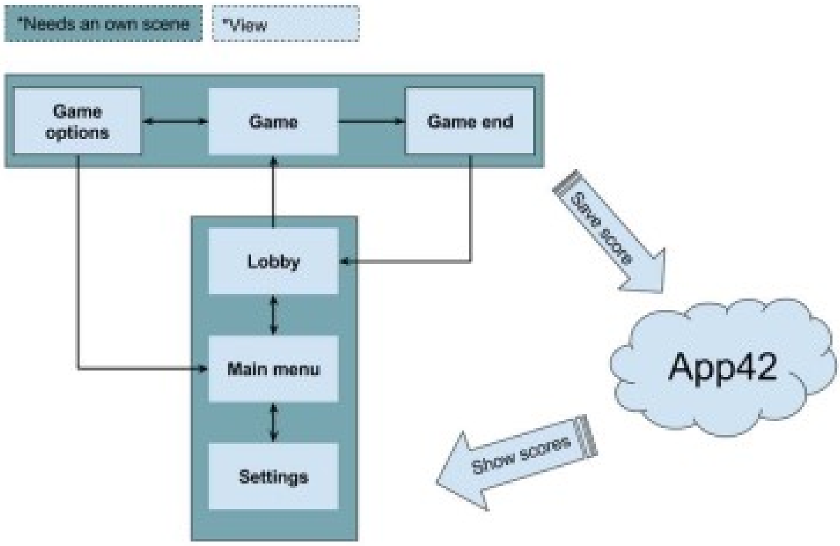


Figure 2: *Janitor run* overall architecture

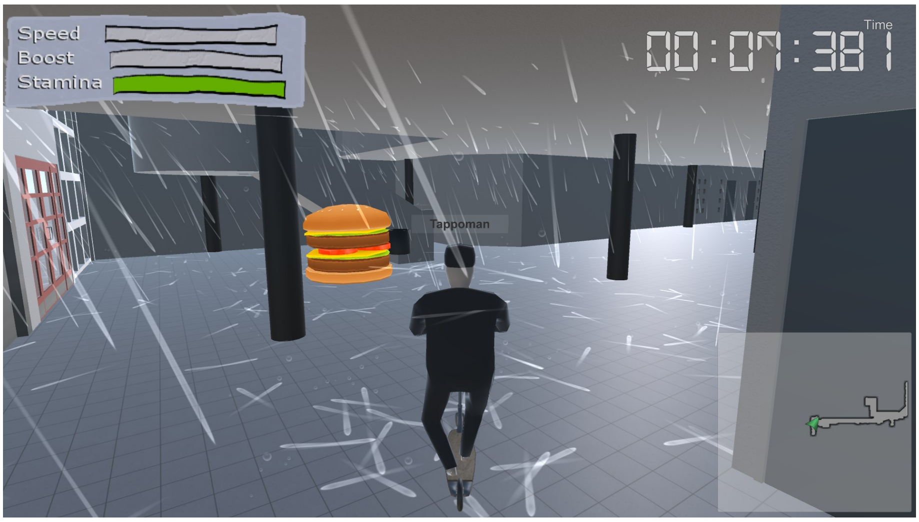


Figure 3. real-time rain modeled to *Janitor Run* game.

### 5.2.1. *Janitor run* - Data collection and Analysis

Data collection period in *Janitor Run* was two weeks. Data was actively collected from players using GEQ that was implemented to in-game survey. Survey consisted GEQ-modules that measured player experience during and after playing the game. Passive data collection stored the results if player completed the game (i.e. made it to the end) and marked total completion time. GEQ module results were compared to time player had spent on university campus by using Kruskal-Wallis Test [12, 25]. Only fully completed questionnaires were considered. Analysis concluded that players that were most familiar with the campus (visited daily) were least tired after the game. Data was fed to SPSS and players' tiredness was used in dependent variable and frequency of time visited on Oulu University was used as an independent variable [1].

Another part of data collection was qualitative analysis on feedback. Most prominent complaint was about lagging avatar control. Data collection period was done on February, so prevalent weather in Oulu, Finland was freezing cold. This mirrored to *Janitor Run* as slippery floors but there was not a clear indication for it besides the visual effect that froze the screen. Our best guess is that this was the main reason for bad controls complaints.

### 5.2.2. *Janitor run* - Implemented realistic states

University of Oulu 3D model was provided by project instructors. The model was updated during the project. Initially it had only floor, walls and roof. Pillars, doors, glass-walls, colors and textures were added during implementation. Additional obstacles made steering considerably harder but added the immersion by closely imitating the textures and materials in real-world Oulu University.

Janitor model and the kickboard is relatively real-sized on campus. This affects the gameplay in tight spaces and multiplayer mode. One player could block the narrow door with janitor-avatar and prevent another player from going through.

The circadian cycle-controlled sunrise and sunset as well as lighting conditions inside hallways. At the beginning of the game the time of day was checked by the application and it was same for every player.

Weather inside the game was programmed to follow data from OpenWeathermap. Different weather conditions affected the gameplay differently. Fog made colors bland and obstructed vision, rain and snow made floor slippery and affected steering, and snowing created a frosting effect to screen. Weather conditions were modeled inside the building to have an extra effect to gameplay beside the visual que.

### 5.2.3. Contribution of the Author

*Janitor Run* was created on the Applied Computing Project – course. The project was a group work and was spread across two semesters. During the course, the students designed, implemented, and evaluated the pre-assigned project.

I was a junior developer and my biggest influence on the project in actual programming was the in player resource system. attributes and the pick-up objects, hamburgers and coffee mugs. Players used resource called stamina. By spending stamina, the player would get a short burst of speed that also made steering more difficult. Spent stamina did not regenerate and only way to get more was to pick up hamburgers.

Two types of food consumables were located at restaurants inside 3D-model of Oulu University. Restaurants inside 3D model were not marked as such and did not look like restaurants, they were just plain walls and doorways. I had an idea to fill place with food pickup items to help players remember the location for restaurants in real life, after playing the game.

The two items were hamburgers and coffee mugs. Coffee mugs gave big burst of speed and hamburgers replenished the consumed stamina. The idea was to add into the game design an element that relates to the physical campus. In addition, this might help new students to remember the location of restaurants from the game.

With little tweaking the concept remained also in the sequel, the new and improved *Janitor Run* II [32].

Another my idea was to add gameplay mechanics to different weather conditions instead of them being just visual effects to make steering more exciting and to increase replay value.

Lastly, I did the qualitative analysis on feedback text that was left by some players. My idea of weather affecting the gameplay proved to be badly designed; the players did not have any indication that ongoing effect outside affected also steering conditions on the corridors. They blamed bad implementation on controllers and us as a team learned valuable lessons about designing UX; there can be different UX problem from perceived or intended one.

### 5.3. riot!

Results from riot! [34]-narrative are closely related to this study. As stated, before in Introduction chapter, UX is formed from different experience layers merging: users' earlier experiences, users' mood, current company (co-players or other people affecting user), expectations created from previous similar systems and so forth. The riot! -play experience was about situated narrative: combination of technology, creative play, physical location and sum of all these.

The play resonated more with locals. Study reported that familiar setting of Queen's Square was defamiliarized and participants saw the space in different way after the experience. Some participants created own goals within the system. This perhaps unintentional gameful design creates challenge to user and while it is not deliberate, it affected the UX by promoting psychological presence.

### 5.4. Quest Atlantis

In Quest Atlantis the students felt more inspired because of gameful design [35]. They felt excited about 3D world and this created a new engagement towards learning task. However, some students were too eager in exploring the world and lost interest in the learning task. They required teacher's intervention to get back studying. Teacher got feedback from system and knew when to assist students. The important finding was that students learned better by exploring the 3D world and constructing the knowledge by themselves in comparison to someone telling them to.

The students' level of engagement had different indicators than with traditional learning. Good indicators for this are idle standing or movement around in 3D aimlessly instead of doing focusing on doing quests and tasks at hand. These indicators are considerably easier to notice in VE instead of traditional classroom. This could help teachers with big classes to intervene with students that need help, for example by progress updates or pointing students that are taking considerable amounts of time to complete tasks.

# 6. CONCLUSION

Related work underlined some problems on evaluating UX, but due it being highly dependent on respective context, evaluating UX requires deep, good quality inspection in that said context. Development plans and business goals might easily dismiss UX as an after though or make business decisions and hide it inside UX (Time gating for example). However, unhappy customers giving fiery feedback on social platforms might lead into disastrous results [56]. Therefore good, genuine UX is important.

Familiar environment will *affect* user experience [35,1]. Affect depends on the context and UX should be designed keeping that in mind; is it meant to excite or calm the user? As in Quest Atlantis -like applications, the learning environment could use familiar setting on VE [35]. Utilizing this would reduce the mental effort of exploring new environment and help students to focus better on actual learning tasks.

## 6.1. *Regarding VR Adoption*

Inspecting these studies together, we can get insights about combined effect of VEs' and UX. For example, the next iteration of Quest Atlantis uses the concepts of water cycle, which could be directly modeled to VE and students could toggle through different states and see how missing e.g. condensation would affect the cycle and how the environment would behave. Teachers would get passive feedback from students' performance and this enables earlier and more precise intervention for guiding student.

VRs need to utilize induced presence more to achieve the desired level of engagement and promote better UX. Reported feeling of emptiness [15] in VR could be mitigated by taking real world states and mapping them to virtual environment. Adding e.g. dynamic sounds and object-persistence promotes sensory feedback. Sounds could also be used when providing information that is not in users' field-of-view or even to indicate elevation with same kind of effect as noise canceling headphones. It has been researched that even using cheap technology such as simple fan blowing air to users face to simulate movement could help with battling virtual sickness and create deeper level for felt presence through sensory feedback [53].

Using VR technologies might help with inherited traits mentioned in chapter 2.2 [29,30]. This is still expensive and difficult to use in everyday situations with head-mounted displays and special controllers that are required to interaction in 3D world. VR would be more approachable is it were complimentary and ubiquitous technology. Integrated to e.g. already existing surfaces, windows, walls and even floor mats and only requiring small glasses or contact lenses and earplugs instead of helmets that cover users whole head. Interaction should be haptic and could be done with thin gloves. Gloves work better with intuitive interaction, because user does not have to learn how to use new special controllers. Gloves would also provide feedback to touch and allow more intricate interface to interact with VR.

### 6.2. *Application Areas*

This chapter presents some ideas how developers might improve user experience on virtual reality project. The idea is to bring data from physical world and incorporate it to virtual reality. According to [1] this could help with creating better user experience.

Social media networks together with active online communities provide a useful feedback loop for gauging current state of users' satisfaction and can help to plan for future UX.

For example, users that enjoy the system could propagate their pleasure to other users. Through this social influence the former could get the affected users to enjoy more. This naturally works also with other swayed feelings such as discontent, time spent with the product or achieved level of satisfaction. Users should be able to interact within the system to share their experience and promote the level of engagement.

There are plenty of application areas for planning for better UX in combining real and virtual environments. To demonstrate use cases, here is applications for data logging, digital assistants, and health monitoring.

In Lifton's vision dual reality is a medium for effortless self-expression in the future [15]. VR could be used in similar manner in data logging for laborious tasks. For example, calorie counters require a lot of repetitive logging and even small changes to pre-saved meals will often nullify previous work. VR allows bigger interaction possibilities and makes data-logging easier. VR could also for example display nutrimental value and offer healthier choices. Visual or even olfactory representation in VR is more convincing than 2D pictures and verbal descriptions.

Online shops utilize digital-assistants. These chatbots exist to help customer navigate the site and offer productions based on customers' input. Often assistants are polite and one-dimensional and are even mistaken to be banner-ads. Instead, their behavior should be dynamic and reflect with customers. This would naturally require considerable amount of extra-work and careful balancing so that bot sound natural instead of tacky with glued personality.

Continuing with personalized services theme, one possibility would be using VE to map personal health status and use it as emergency response plan. For example, monitoring blood sugar levels with diabetics. During hypoglycemia the person may look drunk and could be unable to signal the distress. Bystanders would disregard the condition as being drunk and this could prove fatal. While this personal health monitor is not directly linked in gaming or UX but it's a representation mirror world with realistic states: the users' health status is represented by avatar in virtual world. This would give users a veil of privacy. Everyone is part of the same virtual crowd but let's imagine someone having a heart-attack. This triggers a proximity alarm and first-aid directions to people close by.

This would be of course a violation of privacy by todays standard. It could be proposed that these medical apps to be promoted to same category as for example glasses, walking sticks, and crutches. Everyone can see these aids with a glance, and they are ubiquitous to everyday life and nothing to be ashamed of. Besides diabetics, the health observer app like this could help persons suffering from all kind of dangerous and disabling conditions such as heart attack, stroke, epilepsy, migraines and so on.

# 7. CLOSING REMARKS

From designers' perspective it is easy to set aims for particular UX but difficult to evaluate if and how its' achieved. The analogy as [5] suggests about urban computing applies also for planning UX. Multidisciplinary teams should be used when combining real and virtual environments in VR and keep UX in mind from the beginning of the development.

## 7.1. Future work

This study contemplates finding ways for gaining good UX when using realistic environments and states in Virtual Reality. As concluding remark, it could be stated that using an array of tools to promote presence in VR and mitigate mental effort for user will make for better UX. Obviously better UX will result for happier users and they are more likely to keep using the product.

*Janitor Run* 2 fixed features that received bad user feedback from *Janitor Run* 1. For example, weather is now located outside, and movement is more responsive. New parts were added to Oulu University 3D. There is also realistic looking environment outside the walls. Hallways now contain objects such as stools and tables corresponding their color and location from real world campus. Wall and door colors and textures matches their real-world counterparts.

## 7.2. *Janitor Run 3?*

*Janitor Run* VR could be one persistent server instead of racing game. Instead of making new map for every match, it could host everyone on same world. The game would be played with stationed kickboard that uses treadmill to give sensory feedback on movement and fan blowing air to players face simulating wind, depending on how fast player moves. More presence is induced if treadmill stops when player hits something. Of course, this could be dangerous, but this should also excite the player more and take the racing more seriously. Mechanical students could help making the kickboard-fan combination at Oulu University fabrication lab.

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