

VRBAN

Strategies of Representation and Degrees of Freedom in Virtual Cities

MATTIA THIBAUT*, MILA BUJIĆ*

ABSTRACT: Smart Cities and Virtual Reality technologies are at the centre of many scientific and political discourses and are generally presented as among the major technological innovations of our time. This chapter aims to investigate the relationship between cities and VR and, in particular, how urban spaces are represented through VR technologies. This chapter, hence, presents an overview of the VR representations of urban spaces, both providing an overview of the current state of urban representation in virtual reality contexts and identifying the untapped semiotic and technological potential in building urban VR experiences. To do so, we utilized a scoping method in order to collect a representative depiction of the entire field. A total of 37 applications containing both games and non-game apps were documented and analysed, yielding classification of both the cities therein and the users' roles relative to them. An interdisciplinary methodology focusing on the semiotics and affordances of the titles analysed, allowed us to create several concepts and typologies to engage VR spaces. Clear trends emerged from the analyses, indicating patterns in the interconnection of the purpose of the application, the presented city, and the presented user or citizen. However, considering the vast potential of digital environments, and immersive virtual reality in particular, it is dejecting to see that these applications are mostly simplistic and are far from utilizing all of the potential affordances of (digital) cities and of the ever-improving technology. With this potential in mind, we present this study as a starting point for enriching similar applications and several points for consideration depending on its type and purpose. Finally, possible future research directions that would delve deeper in different segments of the field are briefly noted.

* Tampere University.

KEYWORDS: Cities; Virtual Reality; Urban Representation; Avatar; Interactive Media; Human–Technology Interaction; Games.

1. Introduction

“Virtual reality is here” has been used almost as a slogan in the past few years. In reality, although the technology is getting more sophisticated and more affordable, somehow VR still does not seem to be quite “here”. Firstly, the majority of VR users still only own or use *mobile* VR headsets. While these undoubtedly provide immersing virtual reality experiences, they are full of limitations in their technological advancement and in the affordances they provide for designing applications, and enjoyable and memorable user experiences. Additionally, the medium is still in an early stage of maturity: good quality VR apps are still in thin numbers, and none of them has yet become mainstream. Finally, the very discourses that surround virtual reality are discourses around *novelty*: VR is often deemed interesting and worth investing not for its media affordances or for the quality of the experience design but as a symbol of innovation.

Nevertheless, virtual reality does show much potential in creating, for example, strong cultural experiences (Jung *et al.*, 2016), attitudinal change (e.g. Herrera *et al.*, 2018) and feelings of empathy through immersion, the illusion of body–ownership, or placing one in another’s shoes (de la Peña *et al.*, 2010; Herrera *et al.*, 2018; Peck *et al.*, 2013). In this paper we wish to overview and explore the potentials of this technology in particular in the representations of urban environments.

Cities are the quintessential anthropic space: entirely shaped by culture and technology, they are the social and economic hubs of most nations. However, while VR applications represent a wide range of human activities (from cooking to fishing) as well as environments (indoor and outdoor spaces alike, both realistic and imaginary), cities seems to be generally under–represented or used in quite simplistic and shallow ways.

This is particularly surprising if we think that the city is at the centre of the technocentric discourse of “smart cities”, which proposes the implementation of monitoring, geo–tracking, ubiquitous computing and Internet of Things (IoT) technologies as ways of making cities better at catering their citizen’s needs (Bowerman *et al.*, 2000) or more sustainable (Phillis &

Kouikooglou, 2017). This idea is still pervasive despite the criticism received throughout the years concerning privacy, technological lock-in and instrumentalist planning (Greenfield, 2013; van Zoonen, 2016). At the same time, cities are also the setting of fervid activities of digitisation and digital representation ranging from widely used apps such as Google maps, to the detailed and engaging cities of digital games, to “digital twins” at the service of urban planners and policymakers (Mohammadi & Taylor, 2017).

This paper, then, aims to contribute to our understanding of the semiotic features of VR representations by scoping, systematizing and problematising the existing approaches to urban representations in virtual reality. This will allow us, on the one hand, to draw an overview of the current state of such representations and, on the other hand, to identify some possible areas of intervention that could lead to more engaging representations by exploiting the technological affordances of VR and the semiotic properties of the cities.

2. Background — Urban Representations and VR Technologies

2.1. *Few Notes on Representing Cities*

Representing cities is a complex endeavour. From a semiotic standpoint, cities can be understood as polyphonic texts, perceived as organic wholes, but also characterised by structural heterogeneity (Volli, 2005). Urban representations, in order to be effective, have to simplify or to mimicry this polyphony. While the representation of a part of a city — e.g. by *iconic* means such as through a painting, or a photograph — do not necessarily raise these issues, any attempt to reproduce, in some measure, the complicated totality of the city has to face and model the semiotic complexity of the urban spaces.

Urban spaces, moreover, are not simply built spaces organised in accordance with functional needs. While these are obviously of central importance, the relations between citizens and cities (Lynch, 1960; Lefebvre, 1968) and between city and culture (Lotman, 1987 & 1990) go beyond the socio-economical uses of the space and the necessity of the circulation of people and resources: they also involve issues of cultural identity, communication and (self)representation.

Cities are rich *semiotic devices* that work as *models* of the cultures they host. They are what Lotman (1977) calls “modelling systems” and therefore have, at the same time, a descriptive and a prescriptive nature. On the one hand, they are a mirror of a culture and of a symbolic universe: their spatial organisation is homomorphic with that of the semiosphere, allocating spaces of centrality and periphery according to the current cultural values (e.g. churches being in the central squares, while factories are relegated in the outskirts of the city, as described in Lotman, 1990). On the other hand, cities are producers of culture: they communicate instructions to the citizens (with traffic lights, street signs, panels helping *wayfinding* cf. Lynch, 1960), but they also “make” the citizens — they make them “polite”, “urban” and “civilised” (all words from Latin and Greek roots for “city”).

Every attempt to represent cities has to deal in some way with this double nature of cultural model. We can see it even in the most utilitarian way of representing cities: mapping. City maps are *diagrams* of the city: iconic representations that simplify extremely the semiotic overabundance of urban spaces in order to create easy-to-use artefacts that allow operations on the representamen that are still valid for the representatum (Stjernfelt, 2007). Nevertheless, if we look at the history of maps it is easy to notice how what is represented is rarely the simple material reality of the city: recognisable monuments, expressions of political power and even fantastic elements find their place in the maps. The mapmakers are not simply representing the physical materiality of the city, then, but also, in part, its history and folklore, its cultural meanings and its values — an entire symbolic universe (Berger & Luckmann, 1966).

Maps answer to the desire of making the urban space understandable, to reduce its complexity to a manageable simplicity so to be able to navigate it, administer it and organise it. At the same time, maps are also tools to manipulate the city: simulations, blueprint, projects, all use maps of the city-to-be as a basis for decision-making. While these maps attempt to represent the urban spaces in an objective way, they cannot escape their socio-cultural context and the ideologies that motivate and guide their creations — as, for example, the Victorian era values enshrined in Charles Booth’s maps of London poverty (1889–1902) (Kimbal, 2006). In all these cases there is an effort to keep out of the map everything that is not relevant for the purpose of the mapping either for practical matters, or for ideological ones (for ex-

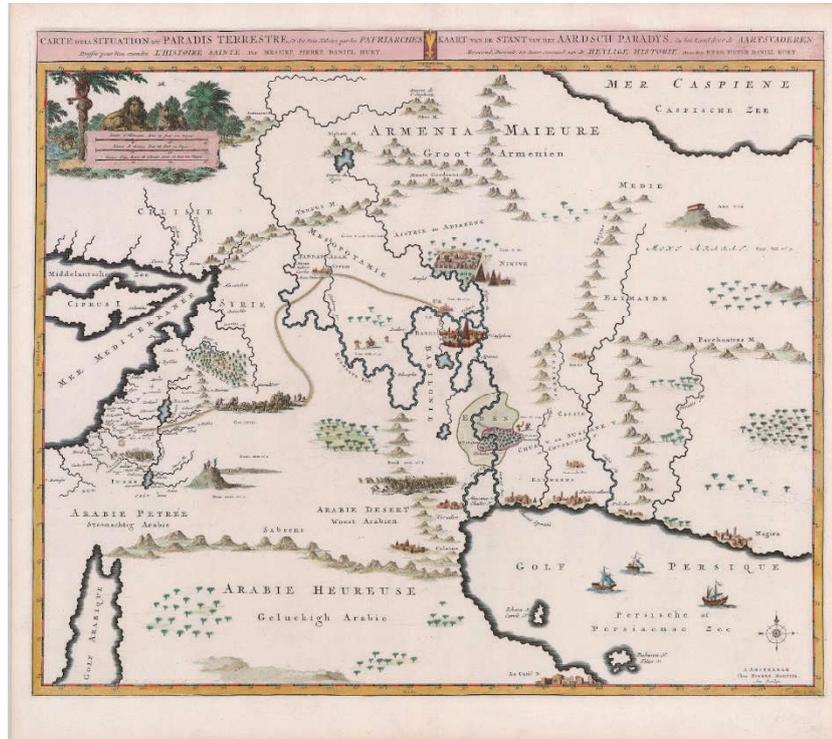


Figure 1. Situation du Paradise Terrestre by Pierre Mortier (1700) representing several cities and the supposed location of the Eden, the earthly paradise, Cornell University Library.

ample, excluding the not-so-temporary settlements of homeless people or other marginalised groups). It is not rare, in these cases, to try to make use of pictures — aerial photography first and then satellite images — in order to give an aura of indexicality to the map and to try to adhere, as much as possible, to its physical morphology.

Notable urban representations can be also found, very easily, in fiction. Throughout history, cities have been often the backgrounds of stories and narratives, from Ilios to Gotham City. Novels, in particular, were so keen to adopt urban settings that Rousseau famously claimed (in an appendix to *Julie ou la nouvelle Héloïse* published in 1761) that thousands of people were leaving the French countryside and moving to the cities because they wanted to live where the stories happened. Regardless of the real causes

behind urbanisation in the 18th Century — and the eventual role of literature among them — this is symptomatic of a common perception. Cities are *interesting*, they are the setting for countless narratives be it the Paris of Arsene Lupin, Dickens' London or the New York of so many Hollywood films and TV series.

Fictional cities, however, are not necessarily invented and represented only as flavour-giving inert backgrounds. The city can be at the forefront of the story, its organisation and appearance can be the very engine used for world building (it's no coincidence that Eco explains his theory of narrative *possible worlds* using as starting point literary representations of Paris and London, Eco, 1979 & 1994). Much of cyberpunk science fiction, for example, features highly hierarchic cities, clear representation of a society imbued of degenerated capitalism (see, for example, *Gunnm* aka *Battle Angel Alita*, a manga by Yukito Kishiro, among many others). The city, again, is used to represent a culture, its values, structures and ideologies.

It is for this reason that cities have been so often used to imagine utopian societies (and while Utopia itself was an island, we can think of Plato's "Ancient Athens" in the *Republic* or Saint Augustine of Hippo's *civitate dei* and *civitate terrena* or Tommaso Campanella's *City of the Sun*) or to explore the human spirit (for examples Gabriel García Márquez with the fictional city of Macondo which appears in many of his novels, or Italo Calvino in *Le città invisibili*).

When we come to digital representations of the urban spaces, the most common and successful ones are related to digital mapping. There are a lot of efforts to digitise urban spaces. Some attempt to transform them into responsive and interconnected maps that place the city and the economic activities it hosts firmly in the Web. Others try to create complex simulacra composed of countless photographs of public spaces. The possibility of creating adaptive and reactive sophisticated digital representation of cities has led to the emergence of the idea of Urban Digital Twins (Mohammadi & Taylor, 2017). The latter would be digital *copies* of the urban spaces that can be manipulated, reshaped, transformed and modified at will so to explore the possibilities of the city *before* implementing any actual change.

Nevertheless, many of the most skilfully realised digital representations cities are fictional ones, and in particular those created for digital games. Several important titles use complex and aesthetically enticing urban scenarios as setting. The representations of cities in games can vary a lot.

Some are little more than simple symbols indicating a city as one ele-

ment in the game that the players can interact with (e.g. in strategic games such as those of the *Civilisations* or *Total War* series).

In other games the players have to create and/or organise metropolitan areas and structures that, if mismanaged, will collapse. In these games the degree of complexity of the representation can vary greatly, from basic representations of a metro network (e.g. *Minimetro*) to complex urban simulations that take into account many elements related to logistics, traffic, well-being, presence of basic services, etc. (e.g. the *Sim City* series or *Cities Skylines*).

Finally, digital games also feature sophisticated urban environments to explore and interact with via some sort of avatars. These complex city representations encompass existing cities, both present (e.g. Chicago in *Watch Dogs*), past (e.g. the many cities depicted in the *Assassin's Creed* series) and future (e.g. the sci-fi Paris in *Remember Me*) as well as purely fictional ones (e.g. the megalopolis appearing in the *GTA* series or the fantasy cities in *The Witcher*).

The richness of urban representations, across history and across media, and the different affordances that each medium provides to relate and eventually interact with these representations are one of the reasons that induced us to wonder about cities in VR.



Figure 2. The city of Neo-Paris in 2084, screenshot from Remember Me (2013) Dontnod entertainment.

2.2. *Virtual Reality*

Virtual reality (VR) technology has been around for several decades, after Sutherland and colleagues built the first headset in 1968. For a long time, it has mostly been unaffordable and unattractive to the general public while often used for industry and military purposes (Bailenson, 2018; Koźlak, 2013). However, with the release of Oculus Rift (2012) and later HTC Vive (2015) its popularity has been on the rise with ever richer content being put out on the market¹. In recent years, the technology has rapidly grown more sophisticated and a wide assortment of headsets has become available. All of these, at least to some extent, differ in their specifications and sometimes offer very distinct features for the users and their experiences.

The two largest groups of virtual reality technologies, in this sense, are mobile and room-scale headsets. The first one is very crude, but allows for public familiarization with the technology due to its very affordable price range and a variety of applications accessible in mobile app stores. The greatest difference between the two is their capability of tracking users' movements in space which would then accordingly affect the world(view) in VR. These categories are referred to as 3 and 6-DOF (degrees of freedom). Mobile VR only allows only for 3-DOF, or in other words, the headset and the controller track solely the rotations (the roll, yaw and pitch), while 6-DOF technology is capable of tracking also the movements of the body in space (moving back and forward, left or right, up and down). These properties refer both to the headset and controllers (i.e. their respective tracking of user's head and hands). Due to these substantial differences, 6-DOF VR is usually referred to as *immersive* VR, emphasizing its technical immersive capabilities compared to 3-DOF, or mobile, VR (e.g. Bailenson, 2018).

In this study we will take into consideration both these technologies. Whilst 6-DOF is more sophisticated and offers more to the experience of urban representations, mobile VR is still very much in use, as it is more affordable for the users and requires less resources for its production. Consequently, this is the VR content that can largely be seen on the market and it spans from simplistic or intricate 360-degree videos to interactive games.

1. <https://www.statista.com/statistics/426469/active-virtual-reality-users-worldwide/> (Retrieved on 30.12.2019).

2.3. Representations of Self

Every representation of an urban space, be it a photography, a novel or an immersive digital environment, also entails some degree of representation of the *actant observer* that experiences such representation. Visual representations of cities, in particular, always create a system of gaze that draws the observer into the picture, assigning them a point of view, and therefore a spatial position in the city (or above the city). The morphological complexity of a city can only be experienced in visual fragments, in *perspectives* and *scenes*, hence the position of the observer and the ability to move through such spaces is a salient feature of each urban representation. VR representations, furthermore, creating a dynamic effect of *trompe-l'oeil* (cf. Calabrese, 2010), allows various forms of representation of the observer while proposing a strong identification between the user and the observer themselves. In such cases, therefore, the representation of the observer is perceived and interpreted as a representation of a “self” — that is a subjectivity built by the use of the technology and the experience of the representation. In order to analyse urban representations in VR, then, we also need to approach the representations of their observers. In order to do so, we will build on the affordances that are offered by the medium itself.

2.3.1. Interactivity, Agency, and Embodiment

As mentioned, technological immersiveness of virtual reality relies on the hardware specifications. These are primarily: positional or motion tracking, field of view enabled by the headset, and resolution. However, not all applications utilize all of the possibilities of the technology and we ought to specify what types of affordances users can expect to encounter.

One of the main concepts in studies on virtual environments (VE) is “presence”, or the subjective experience of non-mediation (Lombard & Ditton, 1997; Lombard *et al.*, 2000). Virtual reality has been particularly praised for inducing presence, for the most part through visuals by sensorimotor contingencies and immersing the user in the digitally projected world (Slater, 2009). *Place illusion* refers to the phenomenon which plays an important role for the sense of presence as it situates the individual via cues such as seeing one’s body when looking down (Slater, 2009).

We can already see that some kind of interaction is desirable for giving an illusion of presence, but it is mostly limited to interacting with the system, not the environment as such. For example, in 360-degree videos it is impossible to interact with the content or influence it (i.e. have agency over it), but only to change the direction of one's view. However, the interaction with the content is closely interconnected with user's experience of agency and autonomy in the virtual environment (Witmer & Singer, 1998). Some interaction forms of interest for the context are moving through the VE and manipulating virtual objects (Preece *et al.*, 2015). User's own sense of presence along with agency in the VE contributes to the plausibility illusion (Slater, 2009), or the believability of the virtual world. This illusion in turn contributes to users' processing, acting, and reacting as if the virtual world and the events therein were real.

Finally, in connection to place illusion, virtual environments in general enable embodiment of visual representations, or avatars, through which one acts in the VE (in connection to motion gaming see Gregersen, 2011). In the context of video games in particular, the relationships between the user and their avatar as inhabitable protagonists (Isbister, 2016), as well as the accompanying affective, cognitive, and behavioural effects are being studied at length (e.g. Banks, 2015; Hudson & Hurter, 2016; Isbister, 2016). Immersive virtual reality, however, enables for the illusion of ownership of a virtual body by, in a way, transporting the user in it. For example, seeing avatar's movements congruent and synchronous with one's own via motion controls enables an effect of meaning, a powerful trick on their perception and cognitive processing (Maister *et al.*, 2015; Maselli & Slater, 2013; Peck *et al.*, 2013), where again agency over one's virtual body plays a crucial role in inducing the illusion (Tsakiris *et al.*, 2006).

All of these points need to be taken into consideration when investigating VR. It is worth noting that further advances, such as biofeedback (e.g. Salminen *et al.*, 2019; Yang *et al.*, 2019) and wearables and haptic interfaces (e.g. Kim *et al.*, 2019) render the described phenomena only rudimental in virtual reality and greatly build on them. However, interactivity, agency, and embodiment in somewhat simple forms likely still make up for the majority of current virtual reality applications and therefore shape the VR experiences.

3. Methodology

In order to explore the current situation on VR representations of urban environments and due to the relatively small numbers of such representations we decided to scope the existing titles and to try to systematize them in order to analyse their possible articulations. Our methodology, therefore, is divided in three parts:

- the scoping of VR titles in which urban spaces are predominantly represented and their organization in “naïve” categories based on their content or purposes;
- an analysis of the aspects of the city included in the representation and the competences such representations confer to the users, based on semiotics of culture and urban semiotics (Volli, 2008; Marrone, 2009);
- an analysis of the representations of users (avatars), or lack thereof, and the afforded interactions and experiences.

3.1. Scoping

Virtual reality content today is available on a number of platforms, applications, and Internet websites. For example, the most simplistic ones such as 360-degree videos for mobile VR can be found on YouTube as well as on numerous websites with different themes, from presentations on cultural heritage, through immersive journalism, to advertisements. Somewhat more complex and usually interactive examples such as games, gamified, and game-like content can mostly be found on mobile app stores and common game stores (e.g. Steam, PlayStation Store). However, there is no positive way of encompassing all sources and noting all existing VR content.

Therefore, the scoping of the sample content used in this study was conducted through extensive manual search and examination of all known sources and depositories of VR content, as well as through Google searches comprised of a combination of two sets of search terms: the first relating to the content theme, containing terms such as *urban*, and *city*; the other relating to the type of content with terms such as *virtual reality*, *VR*, and *360-degree video*.

While it is possible that VR titles that feature urban representations might not be tagged either as “urban” or “city”, this search ensured that the titles included in the research focused with particular attention on the representation of urban environments.

The inclusion criteria consisted of two parts coinciding with the two sets of search terms: first, the content would have to be available for VR, either mobile or room-scale; second, it had to be set entirely or for a significant part in the digital reproduction of an urban environment that the users can move through or explore. The final sample consisted of 37 VR titles (cf. Appendix 1).

The collected examples were assessed using the content that was available online with no cost, either at the source or on platforms such as YouTube. When there was no demo available, YouTube was searched for a gameplay or preview video that would be used for the analysis. These consisted mostly of preview and gameplay videos and were representative of the aim, the surroundings, and the environment’s affordances, including for example interactivity and 3D movement through the virtual environment.

3.2. *Limitations*

Our methodology suffers from some limitations. First of all, due to the diversity of platforms and variety of independent projects there was no practical way to scope a complete sample. While we devoted a significant effort in discovering and including as many titles as possible, we could not ensure to include all examples of urban representation in VR. While this should not affect the soundness of the categories and typologies that we draw from the semiotic analysis of urban representation and the analysis of user representations and affordances of the system, we recognise that a larger sample could allow more general considerations on the current situation in VR representation of cities. We believe, nevertheless, that the titles that we were able to collect and analyse, especially because of the homogeneity of the characteristics features by titles in the same categories, constitute a sample sufficient to outline some meaningful general trends.

Secondly, in our analysis the concept of “interaction” is used both to indicate the degrees of authorship/readership representations of VR cit-

ies and to define different types of avatars. Some of the overlapping that emerge from our analysis could be symptomatic of this fact. However, it should be noted as well that the *interactions* we refer to are not identical but rather looked at from the two different perspectives utilized throughout the study. When analysing cities, interaction refers to the responsiveness of the representation of the urban space; when analysing the system affordances and consequently user avatars, interaction is viewed in the lens of users as controllers (e.g. Roth *et al.*, 2017) and their agency in the virtual environment.

Finally, as this study was meant as a scoping one, all VR content was included regardless of the specifics of the technology. The biggest differences stem from whether the content was produced for mobile or immersive room-scale VR. However, including this additional layer of analysis would overcomplicate and cloud the results without any guarantee that it would be thorough enough and yield a meaningful addition to the results. Namely because users can opt out, for example, to view 360-degree videos on screen instead of mobile VR or use non-gesture-based controllers with an immersive VR headset.

4. Analysis

4.1. General Categories

As a precursor to the analysis, we attempted to group our titles in a few categories, in order to be able to handle the sample in an easy and clear way and to devise a meaningful overview of the content.

First of all, we separated the titles between games and non-games. These were identified based on official descriptions and distribution channels. We have, therefore, 12 non-game titles (numbered 1–12 in the appendix list) and 25 games (# 13–37). We then proceeded to articulate them in the several “naive” categories according to their purpose, features or game mechanics.

In particular we divided non-game titles in: Design and Management (applications meant to be used by architects and urbanists dealing with city policies, design and planning), Cultural Heritage and Tourism (apps allowing to enjoy digital reconstructions of culturally relevant cities, of-

ten in the past) and Experience / Art (one application allowing to navigate through a city made of real-life tweets and intended to evoke a poetic feeling of connectedness with other citizens).

The games were instead divided in: Racing and Free Movement (games in which cities are used as tracks to race or as paths to cross with parkour/ jumps/ acrobatics), Fighting (games in which players shoot at enemies or targets), Construction (games in which players build and/or modify the buildings and other objects in the urban spaces), Simulation (driving and traffic simulation games, where players cannot act on the city, but only on its viability), Eroticism (games in which players explore Red Lights districts and whose game mechanics are built around erotic displays), Puzzle (one puzzle game in an urban setting) and Social (games whose main mechanic is that of allowing free and playful interaction between players).

4.2. Representation and Authorship

In our first analysis, based on semiotics, we will focus especially on two features of urban representations in VR: the *modelling strategy* — that is, the rationale behind what aspects of the city are selected to be represented — and the *degrees of interaction* — in what measure the represented urban spaces are reactive to the users' actions.

Urban spaces are extremely complex and rich semiotic objects. Every attempt of representing them requires, then, an act of selection: which characteristics of the city do we want to include in the representation? This question goes beyond choosing which buildings or streets or neighbourhoods to depict and includes the meaning of the urban in a representation. *What is the city that we represent?*

As we have seen while approaching several kinds of urban representations, we can choose, for example, to map the city, and therefore to select some relevant information about the urban space and to represent it in a schematic way. On the other hand, we can also represent cities in order to represent (or invent!) entire cultures — as done by Plato, Saint Augustine, etc. Any urban representation, then is an act of modelling that follows some strategies, both related to the aspect of the city selected for representation and the specificities of the medium used for the representation.

The sample we have collected features three of these strategies:

- the city as a wallpaper. In these titles the city is a mere background. A purely aesthetic element that can be admired or ignored, but whose main feature resides in its aspect. The representations aim to create an effect of meaning related to the presence in an urban space but is not interested in the complexities that urban spaces generally connote;
- the city as a system. These modelling strategies represent the city as a net of relations, values and resources. The circulation, logistics, dynamics and other systemic factors are represented in more or less sophisticated way. The urban environment, then, is used as a sort of metaphor for this complexity, while the meaning of the system is all within the representation itself;
- the city as a culture. Both real cities and fictional ones, as we have mentioned, can cast around themselves a semiosphere — or the illusion of one. This modelling strategy aims to use the representation of the city to refer to something else: shared cultural values, heritage, new possible social spaces and so on.

While they all rely on visual 3D representations of urban environments — quite obviously seen their mediatic statute — the titles in our sample also vary considerably according to the degrees of interaction they allow. We can group this continuum around three polarities:

- interacting *in* the city. It is possible to move within the city and to look around. Buildings and other objects mostly work as obstacles stopping the movement. The city may host other elements (characters, vehicles, creatures...) that the users can interact with. In other words, the city can be a space in which to interact, but it is not possible to interact with it. The users are essentially “readers”;
- interacting *with* the city. The city responds to the users’ actions. It can allow complex paths on its buildings (that are not anymore simply “off-limits” but acquire plastic characteristics and functions) or provide new information about its elements when the users engage them. The city itself is immutable, but it is reactive. The representation provides a sort of “augmented readership”;
- acting *on* the city. The city is created, modified or reshaped by the users. Its elements may be destroyed coloured or replaced, new elements may be added. In this case, the users can be “co-authors”.

The modelling strategies and degrees of interaction that we have outlined can be crossed in order to identify nine types of urban representation. In them we can fit the titles from our sample and their categories (Table 1).

	City as wallpaper (17/36)	City as system (6/36)	City as culture (13/36)
Interacting in (22/36)	Racing / free movement (15, 17, 18, 19) Fighting (20, 21, 22, 23) Eroticism (33, 34)	Simulation (31, 32)	Cultural heritage and tourism (2, 3, 4, 5, 6, 7, 8, 9, 10, 11)
Interacting with (7/36)	Racing / free movement (13, 14, 16) Fighting (24) Puzzle (35)	Design and management (1)	Experience/Art (12)
Acting on (7/36)	Construction (27, 30)	Construction (26, 28, 29)	Social (36, 37)

Table 1. Types of urban representations.

Interestingly, some clustering appears to emerge when we look at how categories fit in our model. Seven of them (Eroticism, Simulation, Cultural heritage and tourism, Puzzle, Design and management, Experience / Art and Social) fit in one single slot of our table. While in some cases it is unsurprising (as some of these categories only feature few, or even one single title) this trend also involves one of the largest categories: that of Cultural heritage and tourism. On the other hand, the three categories left (Racing / free movement, Fighting and Construction), which include many of the most numerous ones, fit in maximum two adjacent slots. This suggests a convergence in the ways the titles pertaining to certain categories deal with interactivity and aim to represent cities. If some of these correlations are quite obvious (e.g. the fact that titles related to cultural heritage represent cities as culture) they do not explain the whole picture (why these do not allow more complex forms of interaction, for example). We can try to make some informed hypothesis on why.

First of all, it is easy to notice that the titles are distributed in a very uneven way in our model. First of all, the majority of the titles adopts forms of interaction *in* the city, appointing to their users the role of mere readers of the urban spaces. While this might reflect the dominant urban

ideology of cities as objects that the common citizen can't or shouldn't modify (unauthorised urban writing is often considered "vandalism"), it is also probably a consequence of budget limitations and of a rhetoric that sees VR experiences as innovative *per se* and therefore is reluctant to invest to allow more complex forms of interaction.

At the same time, we can notice that there is a high number of titles (almost the half) that represents the city as a wallpaper. In many of them, the urban setting is a scenario to host other meaningful activities, such as fighting or racing. Some of these representations can be very simple, only offering an arena, while others can be more aesthetically sophisticated and participate in the pleasure offered by the activity. In some other cases, like in the erotic games, the city offers a glittering context to the core activity which attempts to offer an aura of good taste and luxury. It can also be seen as a device for procrastination (the pleasurable *indugio* described in Eco 1994) that builds the expectations and possibly the enjoyment of the users. Finally, some gameful urban representations of the city as a wallpaper acknowledge the heterogeneity of the urban spaces, transforming the objects of the city in single elements in the game that might have to be interacted with in order to proceed successfully with the game or that can be modified or positioned for aesthetic purposes (the Construction games 28 and 31).

The representation of the city as a system, while adopted by few titles, is generally implemented in quite a curated way. It includes simulations of the traffic and viability in urban spaces, tools for urban planning that allow professionals to retrieve data about buildings and neighbourhoods while immersed in VR and construction games in which the players have to create or manage different kinds of urban infrastructures (regarding energy, transportation, nature, etc.). The very complexity of this form of representation, even in the titles with the lowest interaction strategies, probably explains the low number of titles.

The representation of the city as culture is the second most used and includes the vast majority of the non-game titles we have scoped. Most of these representations limit their users to interactions *in* the city and belong to the category of cultural heritage and tourism. In all these examples the city is quite clearly represented as a *museum*, to wander in, but semi-deserted and where we are not allowed to touch anything. Again, to the ideological aspect of the representation we can easily join some practi-

cal concerns regarding the budgets of these projects and a lack of literacy in VR that seems to characterise the institutions that commissioned them. The more interactive forms of city representations (Experience/ Art and Social), while featuring few titles, are also among the most interesting, combining the complexity of the urban spaces with the possibility of the users to navigate, reshape and write on them. They often feature a high level of carnivalesque and free playfulness and aim to facilitate creativity and self-expression.

4.3. *Who Am I in a VR City?*

In the second step of the analysis, we coded user representations in each of the examples in the sample. The coding was conducted using three binaries which were constructed according to the possibilities of representations — agent/observer, embodied/disembodied, and diegetic/extradiegetic. These are based on the possibilities of the technology or content itself in presenting the users: interactivity and agency, embodiment, and congruency of the representation with the virtual world, respectively. They are of course not completely independent considering that disembodiment, or lack of presentation, cannot be neither diegetic nor extradiegetic.

From these binaries five categories of user representation emerged in the collected sample:

- *witness* (disembodied observer): particularly in 360-degree videos. Users are only allowed to change their view by rotating their head;
- *god* (disembodied agent): users can interact with the world but with no corporeal presentation of themselves in it;
- *spatial manipulator* (extradiegetic partially embodied agent): in the world, user is limited to simplistic presentation, such as crude representations of hands or even only controllers, incongruent with the virtual environment. These presentations seem to mostly serve usability purposes for easier interactions as they situate the user in the 3D world;
- *storified manipulator* (diegetic partially embodied agent): different from the spatial manipulator by its consistency with the virtual world. The hands or some other extension of self is presented in a

- visually congruent manner with the surroundings. For example, in shooting games a firearm can be visible instead of the hands;
- *character* (diegetic embodied agent): user's corporeal presentation is fully incorporated in an interactive virtual world.

	Witness	God	Spatial manipulator	Storified manipulator	Character
Design and Management		[1]			
Cultural Heritage and Tourism	[5][6][7] [8] + only moving: [3] [4] [9] [10] [11]			[2]	
Experience/Art		[12]			
Racing and free movement			[19]	[13] [15] [16] [17] [18]	[14]
Fighting				[20] [21] [22] [23] [25]	[24]
Construction			[26] [27] [28] [29]	[30]	
Simulation		[31] [32]			
Eroticism		[33]		[34]	
Puzzle					[35]
Social				[36] [37]	

Table 2. Occurrences of avatar types across categories.

The suggested categories were cross referenced with content types as shown in Table 2. Overall, we can again see some trends emerging as the five avatar categories mostly tend to cluster in specific content types. There is a certain emerging gradation visible in the avatars' complexity which allows that each type contains and builds on the affordances of the previous one. For example, *God* has all the affordances as a *Witness* does, but with the added agency in the environment.

Witnesses are placed in an environment relating to cultural heritage and tourism with no self or agency in the environment. They are silent watchers immersed in a 3D digital space and are either guided through it or enabled to roam it freely. Apart from possible free movement, the particular difference between viewing the same content on a screen or in VR is the technological immersiveness. The panoramic representation in VR completely occupies the field of view blocking all external stimuli, to an extent placing the user amidst a city instead of in front of it. This is true for all VR applications but is the essential advantage of mobile VR, however simplistic the technology may be, over 2D screens.

Gods are found in more diverse types of environments, such as design and management, artistic pieces, simulations and erotic games. They are invisible to self but sometimes the environment eerily notices them regardless of that [33]. They can interact with, and in some way at least influence the environment. It could be driving a car with no hands on the wheel [32] or controlling city objects from a bird view hovering position [1].

Spatial manipulators can see either their cartoonish or abstract hands, or controllers. These serve solely as a tool for managing the digital environment. These users are usually builders, managing the cities from high above. The parts of them that are presented are there only for usability purposes — to provide for an overall sense of one's source of agency in space, and usually to enable smooth interactions with the city.

Storified manipulators are possibly appearing in the most diverse applications. Like the previous one, these representations are there to orientate the user, but are also the first ones that include them in the virtual environment. The little that is one's self in the virtual does belong there instead of appearing as an incongruent intrusion. Again, the parts that contribute to usability are presented, but with some consistency.

Characters are users that are fully visually presented in the VR. They are fully fledged inhabitants of the virtual cities. However, they are scarcely found and limited to games, but not tied to any particular genre.

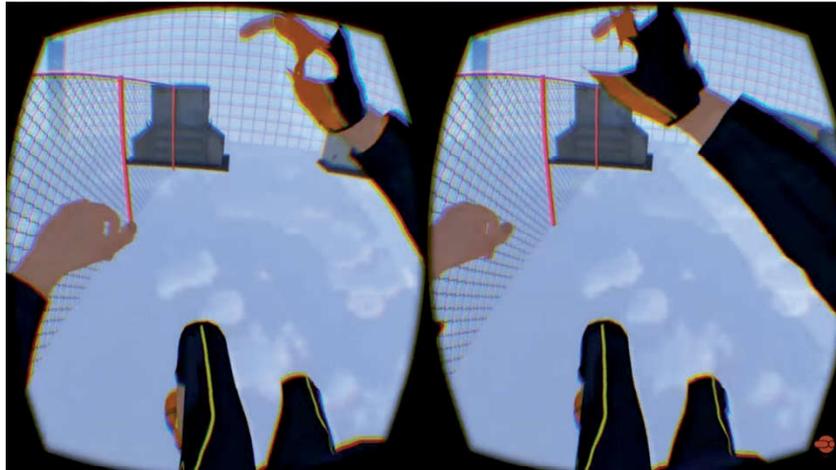


Figure 3. The Character avatar of *Parkour VR* [14].

4.4. Current State of Urban Representations in VR

In the following table are synthesised the occurrences of specific types of avatars in particular urban representations, with the (few) exceptions listed where appropriate.

	City as wallpaper		City as system	City as culture
Interacting in	Storified manipulator (exceptions: 19, 33)		God	Witness
Interacting with	Storified manipulator	Character	God	God
Acting on	Spatial manipulator	Storified manipulator	Spatial manipulator	Storified manipulator

Table 3. Types of urban representations and avatars.

Table 3 outlines some clear correlations between the types of avatar implemented and how cities are represented. In most cases (seven out of nine), to each specific representation corresponds only one type of avatar used in all the titles. In the other cases, the avatars implemented are two and rather similar to each other. Some types of urban representation include only few titles — or even only one — and in those cases the lack of variety in types of avatars is not surprising. Nevertheless, the types that encompass the highest number of titles (interacting in the city as a wallpaper and interacting in the city as culture) also feature one single type of avatar, with minor exceptions.

In general, we can see some general trends. First of all, the titles that offer the most elaborate experiences, that is, those which provide higher levels of authorship over the city, tend to give more importance to the representation of the subject. The titles allowing to *act on* the city all feature a Spatial or Storified manipulators. Authorship, therefore, is supported with a representation of a *model author* (Eco, 1979) that is clearly present in the representation, while never completely *actorialized* (in our sample, Characters never occur in titles featuring the possibility to *act on* the city). In other words, the users are offered the representation of *agency*, of some digital prostheses (Lahti, 2003) that allow them to act in the virtual environment but are not invested with any character identity.

Secondly, all non-game titles make use of disembodied agents (Witnesses in most cases, or Gods), while all the games, with the exception of the Simulation ones, use embodied agents, often anchored to the diegesis. This is probably due to a different importance that the two elements have across genres: games put the players at the centre of attention, while non-games focus on the urban environments themselves.

5. Discussion and Conclusions

We investigated representations of urban environments in virtual reality from two perspectives — that of cities and that of technology and users. We have outlined several types of urban representations as well as several types of avatars, and we investigated the relationships between these two dimensions.

Our scoping of the current situation on urban representations in VR returned a picture of quite shallow use of the technology and the semiot-

ic potentials of the represented objects. On the one hand, while VR technologies are still relatively young and expensive for wide commercial use, and production is somewhat resource-heavy, these applications have been developed over a course of several years and we expected to find more nuanced, rich, and engaging interactive experiences. That does not seem to be the case. Looking at the currently available applications there are very clear patterns of how these two perspectives — of the city and the user — are used depending on the type and/or purpose of the application itself. In other words, we found that the vast majority of urban representations in VR seems to follow some unwritten patterns in design, usually following a principle of economy. They attempt to simply convey the mere idea of a VR representation through the minimum viable product or even a proof of concept. For example, if it is a construction game (acting on the city type), based on the results we can assume that the user will only play a functional role, with their “tools” — hands or controllers — visible in the environment².

These patterns are also quite similar to the ones used in other platforms and media, such as digital games. VR therefore is rarely addressed as a distinct media technology with its own particular affordances found in no other one, its strengths and weaknesses in regard of possibilities of representation and of creating experiences, but most of the design principles implemented in VR are simply ported, imitating older and well-established media.

On the other hand, the flatness of many urban representations in VR seems to reflect the structures of power and authorship that are embedded in real cities. VR cities are often “untouchable”: spaces to cross and to look at, but not to modify and transform. As we have mentioned, this is particularly true if we approach titles that deal with tourism and cultural heritage: while they present to the users a digital replica of the buildings and objects, they still require them to be engaged while keeping a respect-

2. These patterns are visible in all types of content in virtual environments and are not necessarily detrimental to the experiences. We can see how in video games, as very rich interactive media experiences, there are similar patterns as found here. Strategy games, and in general those that primarily focus on the system rather than the affective experience, rarely employ the representation of the user, it is simply unnecessary, and the user might not even exist as a recognized entity in the game. They are rather treated simply as if they were moving chess pieces on the board. On the other hand, role-playing games (or RPGs) are defined by the user controlling and leading, or “being”, one character.

ful distance. The “do not touch” rule is here enforced by the very choice of the avatar, which is always a Witness. While a lack of resources for more elaborate experiences can partially motivate this choice, these representations also evidently suffer from a lack of imagination. VR technology is not seen as an opportunity to create something new, but just as a mean to recreate what is already existing, be it city spaces or digital games.

The novelty effect that VR still exercises on many users — and possibly on many of the people that commissioned such works — even in its most simple, 3-DOF forms has probably balanced out the shallow nature of such representations. VR has been used as a form of valorisation in itself, regardless of the quality of its implementation, that overshadowed other concerns. However, as the technology becomes more widespread among the general public, the “bare minimum” will not be able to offer a satisfactory effect on users for long. Bolder and more imaginative implementations will be needed to keep urban VR representations meaningful and attractive. VR, in fact, would have much to offer in this sense. There are several kinds of implementations that could positively use the affordances of technology to present something in a way otherwise impossible or to stimulate users’ memory. Indeed, there are various examples of testing virtual reality for learning (e.g. Parong & Mayong, 2018; Markowitz *et al.*, 2018), including Google Earth VR, which proved to be more effective over more traditional paper-based methods (Gorham *et al.*, 2019). It is worth noting that the Google Earth is only utilizing the technological immersiveness of the system in terms of presence or place illusion (Slater, 2009). However, there is also a drawback that warrants caution when using embodied applications. Creating avatars that are *not quite* human might instead impede the suspension of disbelief necessary for the psychological immersion to occur. The uncanny valley (Lugrin *et al.*, 2015; Mori *et al.*, 2012) describes the phenomenon originally from the field of robotics where the likeness with humans will have a positive effect, unless the representation looks too much like a human but *not quite*, causing the observer to feel uneasy. The slight nuances of human (nonverbal) behaviour are still impossible to perfectly replicate to make sure to surpass this critical point of likeness and release users’ attention. Therefore, embodiment should not necessarily strive for a photorealistic presentation, but instead simply giving the user a skin to wear and act through while inhabiting a virtual world.

Some of the titles we have examined, in fact, go in these directions, allowing complex forms of action and interaction with the VR urban spaces.



Figure 4. Players painting the urban spaces in *Hypatia* [36].

Nevertheless, diversifying the avatars used in different types of urban representations and moving beyond simplistic approaches to city representation would make it possible to tap on the potential of the medium. For example, touristic applications affording some degrees of authorship to their users through Storified manipulators would allow new way of negotiating the experience of cultural heritage. Similarly, construction games engaging the complexity of the city as culture and their nature as a complex, polyphonic meaning-making devices would add a new layer to the existing possible relationships between individuals and the urban. In other words, the “gaps” that emerged from our analysis offer, at the same time, opportunities for the creation more meaningful and innovative VR cities.

On the theoretical side, our study also underlines the importance of updating analytical tools and epistemological strategies to adapt to new media and texts. On the one hand, it is important to avoid being blinded by the novelty effect that VR technology can have, and look beyond the simple use of the technology to analyse *how* the technology is used and implemented, what effects of meaning rise from it, what languages and modelling systems are shaped by it and what are its semiotic features. On

the other hand, we also must avoid looking only for old languages when dealing with new media. While confronting them can indeed be productive, and while many of the early implementations are attempt of transposition from the old media to the new, a thorough understanding of VR can only come from focusing on what makes it unique.

This research, that has been based on an interdisciplinary collaboration, also aims to propose a possible approach to the semiotic study of Virtual Reality, that integrates the analytic toolbox of the discipline with concepts derived by media-specific studies and theories.

5.1. *Future Directions*

While our study had a rather narrow focus — urban representations in VR — many of the concepts that we have outlined in these pages can indeed be applied to other objects of study.

First of all, the types of avatars in VR, while built around our sample, can be generalized and systematized in order to be adapted to a variety of VR applications. The titles in our sample did not cover all the possibilities of avatar implementation in VR and, as such, we were able to outline a small number of types. Future works might include specific work on VR avatars and their implications on users' affect, cognition, and behaviour. This typology could go beyond the need of a sharp typology and allows for a deeper look at the variety of possible implementations.

Secondly, while here we focused on cities, our approach can be adapted to other forms of spatial representation in VR. It would be possible, for example, to analyse the representation of nature and natural spaces. Some of the categories would need to be adapted (nature generally doesn't represent culture, but its ideological opposite — sometimes with euphoric, sometimes with dysphoric charges — and can be seen as a space outside the semiosphere) but the general approach would be the same.

Finally, some of these categories, such as cultural heritage and tourism, deserve more systematic and focused reviews due to their relevance and a wide array of intended uses and effects. This chapter, then, is also an exploration of the possibilities and an invitation for further analyses of subjectivity and spatiality in different VR contexts.

Acknowledgments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska–Curie grant agreement No 793835, as well as from Business Finland (5654/31/2018) as part of the GARMENT project.



Marie Skłodowska-Curie
Actions

Bibliographic References

- Bailenson J. (2018) *Experience on demand: What virtual reality is, how it works, and what it can do*, WW Norton & Company, New York.
- Banks J. (2015) *Object, Me, Symbiote, Other: A social typology of player–avatar relationships*, “First Monday”, 20(2).
- Berger P., Luckmann T. (1966) *The Social Construction of Reality. A Treatise in the Sociology of Knowledge*, Anchor Books, New York.
- Bowerman B., Hall R.E., Braverman J., Taylor J., Todosow H., von Wimmersperg U. (2000) *The vision of a smart city*, Brookhaven National Lab, New York.
- Calabrese O. (2010) *L'art du trompe l'oeil*, Citadelles & Mazenod, Paris.
- De la Peña N., Weil P., Llobera J., Giannopoulos E., Pomés A., Spanlang B., Friedman D., Sanchez–Vives M.V., Slater M. (2010) *Immersive journalism: immersive virtual reality for the first–person experience of news*, “Presence: Teleoperators and virtual environments”, 19(4), 291–301.
- Eco U. (1979) *Lector in fabula*, Bompiani, Milano.
- Eco U. (1994) *Six walks in the fictional woods*, Harvard University Press, Cambridge.
- Gorham T., Gorham J., Courtney M.W. (2019) *Virtual embodiment and project–based learning with Google Earth VR*, Toyo Gakuen University, Tokyo.
- Greenfield A. (2013) *Against the smart city (The city is here for you to use Book 1)*.
- Gregersen A. (2011) *Genre, technology and embodied interaction: The evolution of digital game genres and motion gaming*, “MedieKultur: Journal of media and communication research”, 27(51), 96–109.
- Hudson I., Hurter J. (2016) *Avatar types matter: review of avatar literature for performance purposes*, “International conference on virtual, augmented and mixed reality”, Springer, Cham, 14–21.

- Isbister K. (2016) *How games move us: Emotion by design*, MIT Press, Cambridge.
- Kimball M.A. (2006) *London through rose-colored graphics: Visual rhetoric and information graphic design in Charles Booth's maps of London poverty*, "Journal of Technical Writing and Communication", 36(4), 353–381.
- Jung T., Tom Dieck M.C., Lee H., Chung N. (2016) *Effects of virtual reality and augmented reality on visitor experiences in museum*, "Information and communication technologies in tourism 2016", Springer, Cham, 621–635.
- Kim M., Kim J., Jeong K., Kim C. (2019) *Grasping VR: Presence of Pseudo-Haptic Interface Based Portable Hand Grip System in Immersive Virtual Reality*, "International Journal of Human-Computer Interaction", 1–14.
- Kozlak M., Kurzeja A., Nawrat A. (2013) *Virtual reality technology for military and industry training programs*, "Vision Based Systems for UAV Applications", Springer, Heidelberg, 327–334.
- Lahti M. (2003) "As we become machines: Corporealized pleasures in video games", in Wolf M.J.P., Perron B. (eds.), *The video game theory reader*, Routledge, New York, 157–170.
- Lefebvre H. (1968) *Le droit à la ville*, Anthropos, Paris.
- Lombard M., Ditton T. (1997) *At the heart of it all: The concept of presence*, "Journal of computer-mediated communication", 3(2), JCMC321.
- Lombard M., Reich R.D., Grabe M.E., Bracken C.C., Ditton T.B. (2000) *Presence and television. The role of screen size*, "Human Communication Research", 26(1), 75–98.
- Lotman Y.M. (1977) "Primary and secondary communication–modeling systems", in Lucid D. (ed.), *Soviet Semiotics: an anthology*, Hopkins University Press, Baltimore.
- Lotman Y.M. (1987) "Architektura v kontekste kul'tury", Sofia (trad. it.: "L'architettura nel contesto della cultura", in *Il girotondo delle muse. Saggi sulla semiotica*, Moretti & Vitali Editori, Bergamo 1998).
- Lotman Y.M. (1990) *Universe of the Mind, a Semiotic Theory of Culture*, I.B. Tauris & Co, Londra.
- Lugrin J.L., Latt J., Latoschik M.E. (2015) *Avatar anthropomorphism and illusion of body ownership in VR*, "2015 IEEE Virtual Reality (VR)", IEEE, 229–230.
- Lynch K. (1960) *The Image of the City*, MIT Press, Cambridge.
- Maister L., Slater M., Sanchez-Vives M.V., Tsakiris M. (2015) *Changing bodies changes minds: owning another body affects social cognition*, "Trends in cognitive sciences", 19(1): 6–12.

- Markowitz D.M., Laha R., Perone B.P., Pea R.D., Bailenson J.N. (2018) *Immersive virtual reality field trips facilitate learning about climate change*, "Frontiers in Psychology", 9, 2364.
- Marrone G. (2009) *Dieci tesi per uno studio semiotico sulla città*, "Versus", 109–111, 11–46.
- Maselli A., Slater M. (2013) *The building blocks of the full body ownership illusion*, "Frontiers in human neuroscience", 7, 83.
- Mohammadi N., Taylor J.E. (2017) *Smart city digital twins*, "2017 IEEE Symposium Series on Computational Intelligence (SSCI)", IEEE, 1–5.
- Mori M., MacDorman K.F., Kageki N. (2012) *The uncanny valley [from the field]*, "IEEE Robotics & Automation Magazine", 19(2), 98–100.
- Parong J., Mayer R.E. (2018) *Learning science in immersive virtual reality*, "Journal of Educational Psychology", 110(6), 785.
- Peck T.C., Seinfeld S., Aglioti S.M., Slater M. (2013) *Putting yourself in the skin of a black avatar reduces implicit racial bias*, "Consciousness and cognition", 22(3), 779–787.
- Phillis Y.A., Kouikoglou V.S. (2017) *Urban sustainability assessment and ranking of cities*, "Computers, Environment and Urban Systems", 64, 254–265.
- Preece J., Rogers Y., Sharp H. (2015) *Interaction design: beyond human-computer interaction*, Fourth edition, John Wiley & Sons Ltd., Chichester, West Sussex.
- Roth D., Lugin J.L., von Mammen S., Latoschik M.E. (2017) "Controllers & inputs: Masters of puppets", in Banks J. (ed.), *Avatar, assembled: The social and technical anatomy of digital bodies*, Peter Lang, New York, 281–290.
- Salminen M., Järvelä S., Ruonala A., Harjunen V.J., Jacucci G., Hamari J., Ravaja N. (2019) *Evoking Physiological Synchrony and Empathy Using Social VR with Biofeedback*, "IEEE Transactions on Affective Computing", 1949–3045.
- Stjernfelt F. (2007) *Diagrammatology. An Investigation on the Borderlines of Phenomenology, Ontology, and Semiotics*, Springer, Berlin.
- Tsakiris M., Prabhu G., Haggard P. (2006) *Having a body versus moving your body: How agency structures body-ownership*, "Consciousness and cognition", 15(2), 423–432.
- Van Zoonen L. (2016) *Privacy concerns in smart cities*, "Government Information Quarterly", 33(3), 472–480.
- Volli U. (2005) *Laboratorio di Semiotica*, Laterza, Milano.
- Volli U. (2008) "Il testo della città – Problemi metodologici e teorici", in Leone M. (ed.), *La Città come Testo – Scritture e Riscritture Urbane*, Lexia, Aracne, Rome, 9–22.

Witmer B.G., Singer M.J. (1998) *Measuring presence in virtual environments: A presence questionnaire*, "Presence", 7(3), 225–240.

Yang X., Lin L., Cheng P.Y., Yang X., Ren Y. (2019) *Which EEG Feedback Works Better for Creativity Performance in Immersive Virtual Reality: The Reminder or Encouraging Feedback?*, *Computers in Human Behavior*.

ANNEX I – The Sample

All hyperlinks have been accessed for the last time the 30th January 2019.

I. Non-Game Applications

I.1. Design Management

Connected cities VR, https://www.youtube.com/watch?time_continue=62&v=aCj_jChhXRg.

I.2. Tourism and Cultural Heritage

Chernobyl VR Project, <http://www.chernobylvrproject.com/en/>.

The VR City Experience, <https://cityvr.com/>.

Google Earth VR 8+ Streetview.

Curio-cité, <https://artsandculture.google.com/project/curiocite>.

Virtual Tour – Città Proibita VR, <https://www.maotorino.it/it/education/progetti-speciali/virtual-tour-citt%C3%A0-proibita-vr>.

Katara Cultural Village, <http://www.katara.net/en>.

Timescope, <https://timescope.com/>.

VR Rome, https://store.steampowered.com/app/964460/VR_Rome/.

Gèneve 1850, <http://institutions.ville-geneve.ch/fr/mah/expositions-evenements/expositions/geneve-1850/>.

Rome Reborn, <https://www.romereborn.org>.

I.3. Experience/Art

City of Sparkles, <https://cityofsparkles.art/>.

2. Game applications

2.1. Racing/Free Movement

To the Top, <https://www.youtube.com/watch?v=DljCutE9uDI>.

Parkour VR, <https://www.youtube.com/watch?v=rLsHrSA87Yg>.

Sprint Vector, https://store.steampowered.com/app/590690/Sprint_Vector/.

Doll City Prologue, https://store.steampowered.com/app/468170/Doll_City_Prologue.

Hover Boots VR, https://store.steampowered.com/app/672670/Hover_Bots_VR/.

Vertigo, <https://www.oculus.com/experiences/rift/203721827632946/>.

City Scape VR, <https://www.oculus.com/experiences/rift/1855910274463487/>.

2.2. Fighting

City Balls VR, https://store.steampowered.com/app/757400/CITY_BALLS_VR/.

Dawn City, https://store.steampowered.com/app/768110/Dawn_City/.

MSI Electric City: Core Assault, https://store.steampowered.com/app/691930/MSI_Electric_City_Core_Assault/.

ZombiesTown VR, https://store.steampowered.com/app/562740/Zombies_Town_VR/.

City Avenger, <https://www.oculus.com/experiences/rift/1423819361003940/>.

Outrageous Grounds: The Maze, https://store.steampowered.com/app/513050/Outrageous_Grounds_The_Maze/.

2.3. Construction

Cloud City VR, https://store.steampowered.com/app/662950/CloudCity_VR/.

Tiny Town VR, https://store.steampowered.com/app/653930/Tiny_Town_VR/.

Skytropolis, <https://store.steampowered.com/app/629040/Skytropolis/>.

Block'hood VR, https://store.steampowered.com/app/787720/Blockhood_VR/.

Strongbow Nature Remix, <https://www.unity.com/project/strongbow-nature-remix/>.

2.4. Simulation

City Traffic Control, <https://www.oculus.com/experiences/rift/1556750707686722/>.

City Car Driving, https://store.steampowered.com/app/493490/City_Car_Driving/.

2.5. Eroticism

Night City 2177, https://store.steampowered.com/app/994320/Night_City_2177/.

Paradise City VR, https://store.steampowered.com/app/989780/Paradise_City_VR/.

2.6. Puzzle

Cityscape Repairman 2.0, <https://www.oculus.com/experiences/rift/875702375875548/>.

2.7. Social

Hypatia, <https://www.wearvr.com/apps/hypatia>.

VR Chat, <https://www.vrchat.com/>.