The Transdisciplinary Nature of Virtual Space

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Abstract. This paper presents a transdisciplinary view on virtual space, through a description of how different domains of knowledge inform the concepts of virtuality and space. The aim is to show how these different perspectives come together in the virtual space that facilitates combining science and technology with cultural aspects coming from arts and other domains of knowledge. The argument leads to two models of the understanding of virtual space. The first model is an explanation of virtual space as a hybrid that has emerged from both nature (represented by sciences) and culture (represented by arts). The second model puts the observer in the center, exploring the physical-virtual space through an embodied interaction. The contribution of this paper is twofold. First, it presents virtual space as a platform for transdisciplinary work, exposing its underlying processes from both theoretical and practical point of view. Second, it introduces a model for the way transdisciplinarity can inform the understanding of virtuality that is taking increasing part of our everyday lives as well as variety of knowledge production in form of advanced visualizations, simulations and virtual reality approaches.

Keywords: Virtual space · Transdisciplinary · Natural philosophy

1 Introduction

Virtual Reality research is a multidisciplinary domain of knowledge that includes computer science, applied information technology, cognition, aesthetics and design. This paper aims to contribute to bridging the gap between the two separate academic cultures, the sciences and the humanities, using Virtual Reality with its spaces as a transdisciplinary platform. The two academic cultures are on one hand physics, chemistry, biology, astronomy and computer science, and on the other literature, history, philosophy, art and art practice. It is hard to find a more resistant division in the academic world, than the mutual alienation of natural scientists and humanists. Nicholas Maxwell explains in his In Praise of Natural Philosophy how transdisciplinary research has been lost, and how vital it is for the scientific communities to find their way back to the ideals of natural philosophy [1]. Transdisciplinary research strategies cross disciplinary boundaries to create a holistic approach, and apply to research efforts focused on problems that combine two or more disciplines. Here transdisciplinary research, especially where philosophy meets science, can fulfil the "need to recreate natural philosophy – a synthesis of science and philosophy" [1]. The development of contemporary natural philosophy is encouraged by the possibilities of quick and efficient communication among different scientific, humanistic and cultural

disciplines which made visible the pressing need for better understanding and common semantics. Nowadays there is an alarming division and separation of knowledge fields that live in their isolated worlds, without awareness of each other. This fragmented understanding of the world presents a problem for the further development of sciences, humanities and arts. Transdisciplinarity occurs when two or more disciplines transcend each other to form a new holistic approach. The outcome will be completely different from what one would expect from the addition of the parts. Transdisciplinarity results in a type of heterogenesis where output is created as a result of disciplines integrating to become something completely new.

Concurrently with the tremendous developments of research and technologies, the emerging phenomenon of virtual space is winning new grounds. The understanding of virtual space requires new insights in the relations between human and space, from philosophical, cultural and artistic, as well as technological and scientific (cognitive, biological, neuroinformatic, etc.) point of view. This paper investigates an understanding of virtuality through a transdisciplinary approach, where sciences meet philosophy. The methodology originates in semiotics and hermeneutics, connecting the production of signs with a human-centered view on interpretation and creation. The contemporary phenomenon of virtual reality with its virtual spaces provides a platform for conceptualizing natural philosophy through multidisciplinarity. In order to support this idea, the paper investigates an understanding of virtuality through a combination of natural sciences, cognitive science, philosophy, and art. The aim is to show how these different perspectives come together in a holistic view of virtual space. The focus on 'space' is motivated by its wide range of connotations and applications in different research disciplines and practices. Space is here used as a concept for the structural properties of an entity where objects and events are related. Space is the conceptual framework that gives the conditions for these relations, while at the same time being constituted by these relations.

2   Physical Space

Through the history of humankind space has been experienced and investigated in different ways, in the traditions of a variety of specialist fields. Space has been measured in distance, connected to real-time and related to motion, through explorations in natural sciences. Space has been the subject of extensive research and literature, where philosophy is deeply connected to physics [2]. The fundamental concepts for space created in the 17th and 18th centuries (by Leibniz, Newton, Kant and others) have formed our knowledge of space to this day. From these theories 'Space' can be seen as an abstract and discrete set of objects and voids formed by relations, a continuous and measurable entity formed by forces, or a synthetic framework for organizing experiences. It is the combinations and relations between these different explanations, theories and models that have formed our understanding and knowledge of space.

However, the scientific and philosophical theories do not cover all our understanding of space. Space has also been explored culturally and understood through literature, architecture and art. Spatial representations in visual art, fiction movies and books have contributed to the understanding of space as physical phenomenon. Our perception of

space and the relations between what we see and what there is has also been formed by ground-breaking artistic work, such as Picasso's cubism or Magritte's surrealism. Architects have developed theories and skills how to analyze and create physical spaces for human life. The dimension, organization and shape of physical spaces are created in relation to certain needs and certain contexts. Different human needs and human activities require different spatial structures, and these structures are shaped by technological, topological, economic, environmental, social and other conditions.

3   Virtual Space

Today we have a completely new world of virtual reality with its spaces. New rules and conditions apply for the development of virtual spaces. There are different conditions for dimension, structure and gravity in virtual spaces compared to physical ones. Contemporary knowledge about virtual spaces is based on natural sciences and developed through computer graphics, architecture, art, interaction design, cognitive science, semiotics, hermeneutics, and social science.

The term 'virtual' is loosely defined. With all its widespread use in both popular culture and academic discourse, what does this term actually mean? As a starting point in the framing of 'virtual' in this text, there are some definitions that have to be made. The word 'virtual' could stand for anything that is seemingly unreal or intangible, yet maintains some kind of existence on some other level of reality, in other words, something that exists on a metaphysical level. This can be related to the idea of alternative realities parallel to ours (as found in physics), which remain 'virtual', until they 'actualize'. The view (as found in fiction and poetry) is that the world in which we live might be nothing more than a result of our imagination, and thus what we call 'reality' is virtual as well. The meaning of 'virtual' as something unreal or metaphysical is however not used in this paper. Other uses of the word 'virtual' may have a somewhat metaphysical sense as well. For example, virtual can be used to describe how objects and spaces are imagined through books, music, or other media. This notion of 'virtual space' as a space that is envisioned or visualized internally is not used here, but rather referred to as cognitive space. In quite a similar way, virtual is commonly used to describe our experiences when we browse the Internet or as the third space between two people communicating over distances. In all these cases there seems to be some other dimension in which the contents of these experiences exist – beyond the vibrations in the air, the printed letters on the paper, or the electric signals running through computers – and we need a name for it. So, the word 'virtual', with its inherent ambiguity, often satisfies us as a replacement for a wide range of different things going on. But virtuality is not primarily about computers and definitely not about metaphysics. Here 'virtual space' is not a matter of imagination but rather perception, interpretation and experience. A written text is therefore not a virtual space in this sense, because the reader would have to create a mental picture fundamentally different from the pattern of black and white on the book page.

For the framing of the term 'virtual space' I highlight the concepts 'image space' and 'digital space'. Image space is a space that is not physical, and yet not imaginary. Image space is the abstract space that is accessed through and in images, the overall

space of all pictorial media. The notion of 'image space' suggests that what we see in a pictorial image is located in another space that is neither physical nor imaginary. Image space is not just the space of a particular picture, but rather the overall space of all pictures, and of all pictorial media. This is stated in analogy with physical space that is the overall space of all physical places. Image space is the abstract space that is accessed through and in images. Structurally, images work as interfaces to image space where the semiotic code forms the language of creating and reading images. Meaning is produced in a communicative process that involves context, space, representation, and interpretation. Consequently, 'digital space' is the overall space of all spaces created by digital media.

In this text I make a distinction between (mutually overlapping, but still distinct) spaces: physical space, virtual space, image space, and digital space. The focus on digital space is motivated by a media perspective, where the means of production and modes of interaction are forming both the experience and the structure of the space. Present day communication of knowledge is done via media – journals, online, etc. and thus this digital space of knowledge communication plays a role in creating, communicating and adopting knowledge. The notion of 'image space' is related to human knowledge such as found in art, art history, visual culture, while 'digital space' relates to natural sciences such as computer science, computer graphics, systems and simulations. The intersection of image space and digital space is used to explain the use of 'virtual space' (Fig. 1). This model is an explanation of virtual space as a *latourian hybrid* that has emerged from both culture (art) and nature (science) [3].
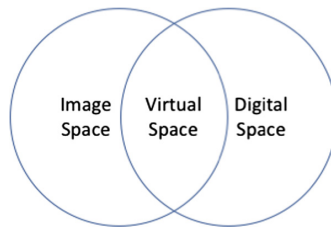

Fig. 1. Virtual space as the intersection of image space and digital space

Seeing the image as an interface to image space emphasizes the importance of understanding the functions of the image: its dimensions, properties, and its function as a sign. An important function of the image is visualization, in the sense of representing something externally in visual form. That 'something' might be concrete information or abstract ideas, real or imaginary, but its representation in visual terms is physical and concrete. Visualization is the act of communicating this something using the image as medium. This communication does not follow any given rules or simple recipe, but is rather open to a continuous negotiation and development of new concepts. In the evolution of images, from the first cave paintings to the high-resolution, interactive visualizations of today, the development has not only been technological but of course also conceptual. Contemporary image media have not only created new ways of accessing image space but they have also transformed the space. New ways of creating

and interacting with images have made new spaces possible. The image is not just an interface that is disconnected from image space but rather closely interconnected with the 'something' it is communicating.

Now, what does 'virtual' mean in relation to 'real'? Is not Virtual Reality just another medium or technology and as such a subset of the real world? Is the virtual a simulation of the real or a representation of an imaginary world? Or the both at the same time? Is it the real that stands for something else or is perceived as something else? The distinction of real and virtual, reality versus virtuality, is an idea that has been investigated and represented over thousands of years, one of the most fundamental being Plato's cave. Pierce defines virtual as "something that is 'as if' it were real" [4]. Virtuality as a philosophical concept in Deleuze builds on Proust's idea of a memory as "real but not actual, ideal but not abstract", developed in the following formulation:

> *"The virtual is opposed not to the real but to the actual. The virtual is fully real in so far as it is virtual. Exactly what Proust said of states of resonance must be said of the virtual: 'Real without being actual, ideal without being abstract'; and symbolic without being fictional."* [5]

The virtual is a potentiality that becomes fulfilled in the actual. Hence, it is not material but still real. If we search the answer to the question of virtual vs. real in cognitive science, "the difference between real (actual) and virtual is not as sharp as one might believe" [6]. Already Minsky in his *Society of Mind* reminds us that even our everyday experiences are not direct and they are not even happening in "real time" [7]. There is always a time delay between the event in the world and our perception of that event, that relies on memory. When observing a scene in "real time" we actually observe only a small part of the scene which is expected to be changing, while the majority of the scene is retrieved from the memory.

4   Physical-Virtual Space

In the beginning, computer technology was not integrated in our physical environment. With the emergence of digital media in the 1980–90's an explosion of development has led to a completely different situation. Concepts from information technology, such as the Internet and computer graphics, are closely related to television, film, and radio. In entertainment areas, like computer games, the two worlds are completely unified. Today there are no important distinctions between digital media and computer technology. More and more physical objects and spaces become digital, computers are becoming ubiquitous, embedded in our everyday objects and environments and embodied in the way we experience them in our everyday life. In human-computer interaction the concept of *embodied interaction* is a way to resolve this physical-digital divide [8, 9]. The concepts of 'physical space' and 'digital space' have been developed further into the *Four Space Model*, including also 'interaction space' and 'social space' [10].

In our everyday life, in our homes and work places, we are not always present only in a physical environment. We also experience virtual environments, mediated through different devices. In certain situations, both professional and otherwise, the relations between physical and virtual spaces become essential for the experience and understanding of the spaces.

Using Deleuze's terminology, the virtual is a surface effect produced by actual causal interactions at the material (physical) level. When one uses a computer, the screen displays an image that depends on physical interactions happening between the actor (user) and the computer (at the level of hardware). The virtual space is nowhere in actuality of the outside world, but is nonetheless real and can be interacted with as it is present in our cognition. Simultaneously, the actor is present in a physical space, where the screen works as a window into the virtual world. An actor who interacts with both a physical and a virtual space simultaneously, can be said to be present in a physical-virtual space.

In order to investigate the relations between physical and virtual space I focus on the *experience of space* in the phenomenological sense and the *structure of space* in the architectural sense. In the holistic approach presented here, virtual space is the inter-section between 'image space' and 'digital space'. Virtual space is seen as separate from physical space in an architectural (structural) sense, but the two worlds co-exist in an interdependent relation. An actor/user/observer can experience presence in both physical and virtual space simultaneously, through an interaction space that involves both physical and virtual space, meaning that this actor interacts in physical-virtual space through an embodied interaction (Fig. 2).
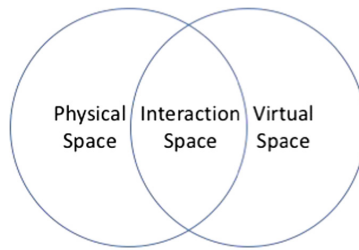

Fig. 2. Physical-virtual space as the interaction space

Physical space and virtual space are entities that exist in reality as subsets of the wider entity of space. The co-existence of physical and virtual space makes it possible to experience both physical and virtual space, even simultaneously, creating a unified physical-virtual space in a phenomenological sense [11]. From a phenomenological perspective, the level in the hierarchy of physical space and virtual space is equal, so one is not a subset of the other.

The emergence of augmented reality and mixed reality spaces has led to new experiences and possibilities. From a practice-based perspective, we can see that this co-existence of physical and virtual space also creates a challenge for designers, architects, and artists that work with spaces for human interaction and experience. In the domain of interaction design, the physical-digital divide has been resolved with the notion of embodied interaction, and connected to space through an increased interest in presence [12].

5   Seeing Virtual Space Through Perception: "Being There"

Virtual space can best be studied when created by Virtual Reality (VR), an invention, engineered by advanced computer technology. VR technology presents both a "tool" and a "world". VR is a computer medium used as a tool to convey a message to a user, just like any other medium. At the same time, as a medium, VR can be so perceptually persuasive and interactive that the user/actor can experience *presence in* the virtual environment which thus plays a role of a world. Using Virtual Reality as a way of exploring what a virtual space is, and what it can be, goes back to the pioneers of VR [13]. The technical definitions were stipulated in the 1980's by researchers in the field of computer science and neuroscience [14]. An important conclusion of these views was made in *The Metaphysics of Virtual Reality* [15] that analyzed virtual reality into seven different concepts: simulation, interaction, artificiality, immersion, telepresence, full-body immersion, and network communication.

A typical technical description of Virtual Reality reads *Interactive Visual Real-Time Computer Simulation*. Hence, in order to be able to claim an environment "virtual" we need to fulfill these five conditions (interactive, visual, real-time, computer-based, simulation). There are numerous variations on this definition, such as in *The American Heritage Science Dictionary* "A computer simulation of a real or imaginary world or scenario, in which a user may interact with simulated objects or living things in real time" [16]. Here *Interactive* means an active interplay between user and virtual space or between user and user in the virtual space, hence open for intervention from the user. The term *Visual* relates to that vision was the first sense to be used in VR, while the other senses were regarded more as complementary modes of virtualization [14]. In contemporary virtual spaces we see more of multimodal interaction, using aural and haptic interfaces, even though visual simulation is almost without exception in focus. The technical term *Real-Time* sets a limit for what is considered to be immediate response.

Virtual space is changing the way we live our daily lives, both as a society and as individuals. We can be present in virtual worlds and have access to virtual institutions and work places. Through the technology of Virtual Reality, Augmented Reality and Mixed Reality we get new experiences and gain new knowledge. New hybrid physical-virtual spaces emerge with new possibilities for interaction. The majority of research and development in Virtual Reality has been to use it as a way to simulate physical reality [17]. Yet VR is a medium that has the potential to go far beyond anything that has been experienced before in terms of transcending the bounds of physical reality, through transforming your sense of place, and through non-invasive alterations of the sense of our own body. In other words, virtual reality has rarely been seen as a medium in its own right, as something that can create new forms of experience, but rather as a means of simulating existing experience [18, 19]. VR needs to be handled as something with its own unique conventions and possibilities that provide a medium where people respond with their whole bodies, treating what they perceive as real.

Virtual spaces give new experiences. In a virtual space, we could for example see temperature and air flow in a room, listen to molecules, walk around in buildings that are about to be built, alter the chain of events in a historical scene, or fly through

galaxies experiencing the birth of stars. Through Virtual Reality all these things can be communicated perceptually and not by suggestion, dreams or hypnosis. Concerns about Virtual Reality and other digital spaces are raised, that these offer a "low-resolution" life [20], which refers to the low granularity or low media richness of multimodal sensory input in comparison with "real life". Virtual spaces are here seen as "almost real". These concerns are valid for situations where certain aspects of realism or face-to-face communication are lost, but on the other hand we must realize that Virtual Reality also makes new experiences possible. We can be tele-present with others over long distances and augment our senses with new representations and layers. Virtual spaces are hence also "more than real".

Understanding virtual space through cognition, we need to focus on the user's experience of immersion and the concept of *presence*, the sense of "being there". Studies have shown that the degree of immersion in a virtual space has a positive relation to the degrees of user performance, communication and collaboration in VR applications [19, 21], meaning there is an objective to take the technology further, hence "more virtual". In this area of experience-oriented definitions, I see five factors connected to presence that are important to present here. These factors are *Perception, Transparency, Transportation, Attention* and *Social factors*. Here *Perception* means the sum of all sensory input that together give the user a sense of being in a space, other than the physical space that the user is physically present in. A higher quality of sensory input is regarded to lead to a higher degree of presence [17]. Image, sound and touch can today be virtualized to an almost life-like level, so that the user will have trouble telling the physical from the virtual, in a mere sense of perception. However, the *Transparency* of the medium is not always as high as one strives for in order to keep a high level of immersion. Computer screens can have poor resolution, there might be cables that users get tangled in, there can be delays in the communication or low frame rate. Apart from technical problems there can be disturbing real-world noise or light or the user can get nauseous. These are all examples of presence-breaking factors due to low transparency. *Transportation* is a factor that in my view actually reaches the core of Virtual Reality. It has to do with the sense of being in another place, to move away from or beyond physical space and "travel" to a virtual space. The comparison with Cyberspace is not far away here, in a very everyday meaning. When we use the Internet, we use metaphors such as "visiting" a website and "surfing" the Internet, even though we just download data from a server to our own computer. It is the same sort of agreement that a user can make with a virtual space, if the environment uses those sets of metaphors that encourage traveling. However, these three presence factors mentioned above could all be over-ruled by the *Attention* factor. This issue has to do with how interesting and meaningful the environment is for the user. It does not matter if the VR application runs on a giant screen in real-time, completely wireless and immediate in response, if the user is not interested or if it does not make sense. And the other way around, if the user is completely focused on or is fascinated by the content in virtual space, a lot of perception and transparency failures will be forgiven. The coherence of agreements and experiences creates the plausibility of the virtual space [17]. We all know how we start noticing what the chair feels like in a movie theatre if the film is boring, or how we can forget thirst or hunger when we get lost in an exciting book. I have on many occasions seen people so excited about a virtual world that they

laugh out loud, cry, jump back or even fall over, from just a crude set of polygons shown in the right way at the right time. *Social factors* are also very important for the degree of presence, due to the obvious reason that we are social beings and as such we are affected by other peoples' interactions. If there are other virtual subjects (avatars) users can meet and interact with, the user will feel more present in the virtual space, in the sense of "being there together" [22, 23].

Virtual Reality is often seen as a medium where the human body is detached, that an actor in a virtual space is disembodied. One reason for this is that VR has a background in the ideas about cyberspace, which is explored by the mind rather than the body. Another reason is the conceptual and technical background of VR in its early military and scientific use, where the actor in a virtual space is regarded primarily as a camera with a point-of-view and secondly as a hand with some type of interaction device. The actor is actually somewhere else, outside the virtual space. It can of course be argued that, no matter how transparent the interface is, the user is always in front of a screen or looking into the virtual space, he or she is not actually "there". But what is actually the difference? Isn't it true that we see, hear and interact with a virtual world using our bodies and senses just as we do in the physical world? We are as humans trapped in our own bodies; we can never really be disembodied [24]. We can always in our dreams and fantasies leave our physical reality, but when it comes to perception of an outside world, there is no fundamental difference between reality and virtuality. What Husserl says about our *life-world* applies well to how we experience the virtual as real and vice versa. Husserl's idea of *lebenswelt (life-world)* shows how everyone lives primarily in a subjective world of cognitive space, rather than in directly in a shared physical one [25].

A key aspect of presence in virtual space is the difference between watching and acting. One of the fundamental concepts of VR as realistic simulation of physical environments, is that the user is understood as a viewer that gets access to the virtual world through a camera (point-of-view) in the virtual model. Here presence is measured through the degree of immersion in the virtual environment by realism, in frame-rate and screen resolution. This immersion creates a "place illusion" that gives the user presence, in the sense of "being there" [17]. The presence can be broken by inconsistencies in behaviors and actions. Therefore, a high degree of presence also requires that the "plausibility illusion" is fulfilled. This does not mean that the virtual space has to be realistic, but rather coherent in relation to the agreements that are made between actor and space. Virtual space becomes a place for human life through the cognitive processes of navigation and identification.

6   The Role of the Observer

In the current renaissance of natural philosophy triggered by the rise of multidisciplinarity, we want to understand the relation between the observer and the world. In this context, the works on phenomenology by Husserl and Heidegger have found new interest. Husserl's phenomenological reduction (the suspension of judgment about the natural world and focus on subjective experience) and Heideggers concept of Dasein or "being-there" are now used to create new frameworks and extended theories for the

relations between the observer and the world, philosophy and natural science, between culture and nature. The human is not only an observer, but importantly also an actor in relation to the world.

Brier's transdisciplinary theory of *Cybersemiotics* [26], presents an attempt to meet this challenge of connecting the observer with the outside world. By combining the 19th century Piercean semiotics, with contemporary theories of phenomenology and cognition, Brier constructs a non-reductionist framework for the integration of natural sciences with first-person experiences (cognition) and social interactions (culture). Cybersemiotics sets semiotic cognition in the centre for the understanding of reality, connecting to the four aspects; surrounding physical nature, biological corporality, subjective experience, and our social world. Through Brier's distinct analysis it becomes clear that humanities and sciences enrich each other and that this mutual dependence create not only a wider perspective but also a deeper understanding.

Rössler's Endo-physics presents philosophical extension and interpretation of the natural sciences [27] that is important to the understanding of virtual space. Much as Rössler proposed in endo-physics, reality as the interface between outside (exo) and inside (endo) worlds, Virtual Spaces are understood from within the spaces, through their interfaces. Observer and interface are therefore just as central issues in endo-physics as in conceptualization of virtual space. The observer is represented in the virtual space as a camera or a viewpoint that changes the space. From the exo-perspective, virtual spaces can be measured in bytes, polygons or pixels, while it is only from the endo-perspective that the space can be subjectively experienced. The human being is therefore part of this virtual universe, and the world is the interface between the observer and the rest of the world, using Rössler's terminology. The difference between virtual space and the actual world that Rössler discusses is that we as creators of virtual space have access to the interface, and design the interface, meaning that we can actually step outside the virtual world into the remaining (actual/physical) world. Still, the observed reality from within relies on subjectivity as the observer inevitably distorts the world or *actively* perceives and constructs the world locally. Virtual space has the potential to work as model worlds that simulate exo-models of endosystems.

All of these post-modern theories strive to find meaningful analysis of complex systems, without reducing these systems to mere physics and/or information. They show that one can include first-person experience and thought as well as social communication in natural science without making it arbitrary or random. Virtual space is a true *hybrid* in Latour's meaning, with its emergence from nature and culture: "Nature and culture shape each other, producing hybrids" [3].

This first-person perspective in natural philosophy connects to the human-centered understanding of virtual space. These connections are different in different domains, which contribute to a diverse understanding of virtual space. From a semiotic perspective, new connections can be made between the codes of the overlapping domains that inform the knowledge of virtual space. The relations between natural philosophy and virtual space extend the semiosis (sign process) in these domains. When natural science meets philosophy and arts in this context, new knowledge is created. This production of new knowledge does not only happen by random connections, but also from intentional, designed efforts by the communities (both theorists and practitioners) from the different domains.

When the *observer* discussed by Rössler in terms of interface with endo- and exo-reality, is the observer in virtual space, its interactions are often focused on visual aspect (optics). The observer in a three-dimensional virtual space is represented as a camera that changes the projected view from the observer's perspective by the rules of optics. In analogy, sound and haptic feedback can adapt to the observer's location in the virtual space. In interaction design (the practice and theory of designing interactive digital products, environments and systems) the human is understood as the *user*. From this user-centered perspective, the focus is on human-computer interaction and behaviors. This means that interaction design synthesizes digital space, physical space, interaction space and social space through an embodied interaction between human and space [10]. In performance arts the relations between human and space is articulated by the triangular relations between actor, stage and spectator [28]. The *actor* makes use of the stage in relation to a narrative with the spectator as audience. In visual arts the human is seen as a *viewer* and/or creator that relates to the work of art in different ways. This view of the creating and observing human puts virtual space in an artistic discourse, leading to the understanding of virtual space as image.

7   Science Related to Arts and Aesthetics in Virtual Space

From the ancient time of Aristotle, via Newton, Leibniz and Kelvin, natural philosophy or philosophy of nature was the philosophical study of nature and the physical universe, where universe was synonymous with "reality". With the development of new technologies as well as new scientific methods including simulations and advanced visualisations, the immediate connection between the observer and the world "out there" has become increasingly complex. More and more of information we perceive about the world is heavily "pre-processed", it is also entering complex associations with other knowledge. Thus, increasing part of information in our knowledge about the world is not directly perceived but is mediated through steps involving instruments and equipment including computers that transform original data observed "in the world". With the computer technology of today we have the possibility to both dig deep into the microscopic world and see the big macroscopic picture, and also connect different areas of knowledge belonging to various domains and levels of abstraction. This means that a deeper understanding of images and virtual spaces as an interface to the world becomes important for natural science.

Natural science has always been subject to aesthetic concepts such as symmetry, harmony, simplicity and complexity, and aesthetic values such as finding beauty in nature and the beauty of truth [29]. These aesthetic concepts and values create subjective relations between the scientist and the science. Today the connections between science and aesthetics go even further and are more concrete, with the increased use of advanced visualizations in science. These visual representations have developed from simple graphs to images, animated images, simulations, and virtual environments. Advanced visualizations are increasingly becoming the interface to the world that is observed in science. As such they are developed in a design process that includes decisions about color, framing, grid, perspective, etc., using the aesthetic concepts of symmetry, harmony, parsimony and similar. This also means that these images and

spaces are related to other images made and thus part of our visual culture. What is observed by the scientist is perceived logically and rationally but also intuitively through various filters of senses and aesthetic judgement. The visualizations are not only representations of data and relations but also carriers of aesthetic, artistic qualities. They have become a medium for representing and exploration of data generated by observations/measurements and theoretical models.

Also, the multimodality of these interfaces has become richer in the use of not only visual, but also auditory and haptic interfaces, turning them into interactive virtual spaces. This development of virtual spaces is a result of transdisciplinary progress in technology, sciences and arts. Virtual spaces are as such not only technological constructions with functional purposes but also designed artifacts, and subject to values and aesthetics.

Artworks, as well as virtual spaces, are meant to generate perception. Virtual spaces take form as representations of intentions and are interacting with and being experienced by users (actors, viewers) as a gestalt. These aspects imply that virtual spaces have an object-subject relation with the user, that is similar to the relation of an artwork with its observer. In addition to this, virtual spaces cannot be "looked at" in the same way as a painting or a photo. It is the experience of the virtual space from *within* that gives meaning. This means that we can talk about the *endo-aesthetics* of virtual space, leading to research in media art.

One of the most important issues of media art research is the relation between the viewer and the work. The pioneer works by Heilig (Sensorama) in the 1960's for the head-mounted display, by Weibel ("Inverse Space", "Tangible Image") in the 1970's for the works on observer-dependent worlds, and by Davis (Osmosis) in the 1990's for the immersive VR-cave have shown how virtual spaces can work as alternative artificial worlds and their interfaces as windows to another world [30, 31]. These metaphors of windows (and doors) to another world are important for the semantics as well as aesthetics of virtual space, since the observer acts within two parts of reality; the perception of virtual space, and the consciousness of acting in a simulation. The interactions of the observer result in spatial and temporal experiences that then lead to new interactions in this endo-system. However, for the discussion of endo-aesthetics of virtual space it is important to see that the observers' presence in the virtual space is only part of their cognitive processes. Another part is still controlling the presence in the physical (actual) world outside. An aesthetic experience of virtual space is dependent not only on the endo-system but also on the exo-system where the world outside constitutes the context. Therefore, we can talk about a degree of presence on a continuum from virtual to actual, keeping in mind that presence is dependent on physical interaction, whether in virtual or actual space.

This makes the semantics of virtual space quite complex. From a semiotic perspective, the semiosis (production of signs) takes place in an interplay between the experienced virtual space, the observer's physical space and body, the observer's cognitive processes, and social/cultural context. Here Cybersemiotics [30] can be used to analyse these relations. Although the internal observer (inter-actor) is physically located in the real world, he/she contributes to the creation of an artificial model world in which the observer (actor) participates. The observer is in fact "in the picture" while his/her body remains in the actual physical space. This means that a coherent and

understandable space for an observer (actor) is dependent on the semiotic code created in an interplay between endo- and exo-system. The experience depends on a double-duality; on one hand between world-observation and self-observation, and on the other hand between the immateriality of the virtual space and the materiality of the physical body. These various levels of reality (endo and exo) show the double game played by endo-semiotics (endo-aesthetics). The observer-dependent reality, that is the reality as the interface between the observer and the other world, in combination with the distinction between internal and external observers' phenomena [43] create conditions for the development of an endo-aesthetics; the aesthetics of self-reference, of virtuality (the virtual space), of interactivity (the actions and the role of the observer within the system), and the interface (the conception of the world as the interface). As such, endo-aesthetics enable an analysis of virtual space from a media art perspective, where the observer (viewer/audience) is located in the system where it interacts.

This understanding of virtual spaces from an endo-aesthetic perspective evolve from Welsh's concept of an "aesthetics beyond aesthetics" [32] and from the transition from art to space to system. These spaces can be described from various perspectives as complex, flexible, context-conditioned, hypermedia, and multidisciplinary systems. From the endo-aesthetic perspective these virtual spaces "exist" (make sense and appear) as such only through an active relationship between actors and the (actual or virtual) system. The virtual space as system is always potential, and does not exist autonomously. It is constructed based on semantic/semiotic/aesthetic conventions where user has possibility of changing or choosing the "rules of the game" that govern the space. Understanding virtual spaces from an endo-aesthetic perspective enables creation of virtual spaces and realities as systems or model worlds. It supports flexibility of observer-dependent systems, and the integration of internal observers into a virtual system that can be observed from the external perspective.

For example, a condition for the endo-aesthetics of virtual space concerns mixed reality, where both internal and external participants are inside a virtual space in which they exchange messages in order to generate new communication structures that become constitutive elements of the simulated world. An endo-aesthetics of virtual space is reliant on the relativity of an observer-dependent world and the possibilities resulting in reference to internal observers, to the world as interface, and to the relationship between physical and virtual spaces. The phenomena of telepresence and co-presence, where the interactors physically located at different places come together as telepresent inhabitants of the same virtual space, create semantic and aesthetic conditions unique for virtual space. Also, alternative biological-virtual interfaces open up the interaction to natural processes of the body such as eye movement and breathing. This embodied interaction unfolds the observer's self-perception via the self-controlled activity of the body, giving the interactor the impression of taking part in a natural fashion in the virtual space. This integration of body and space provides new conditions for the semantics and aesthetics of virtual space [28].

Virtual space can be seen as a system where art meets science. In this space the actor becomes part of what (s)he observes. Distortion triggered by the observer in the reality of the environment is provoked likewise by an actor participating in the artificial, interactive system. In a simulated artificial world, the internal observers have access to certain actions and interventions of which the effects allow them to draw

conclusions for their own environment. When these actions, interventions and effects are different in virtual space compared to physical space, a different semiotic code is established. This code forms the fundament for the space and for the agreements and experiences that are made. The complexity of the semantics of virtual space shows how aesthetics, as subordinate to semantics, becomes complex and different from aesthetics in the actual world. Hence the "aesthetics beyond aesthetics" is fundamentally different in virtual space, and form conditions for an aesthetic experience of a setting in virtual space different from the aesthetic experience of the corresponding physical setting.

8 Discussion

In the current renaissance of natural philosophy and transdisciplinarity, we need to interconnect the best theoretical knowledge and best practice from different domains. Contemporary phenomena, such as virtual spaces, create common platforms where computer science and technology can meet human sciences and arts. We can see that the concepts of virtual space relate to a wide range of research disciplines; natural sciences, philosophy, psychology, cognitive science, social science, and fine arts. The relations between virtual space and these disciplines go two ways: (a) virtual space can connect transdisciplinary research in different combinations of these disciplines providing visualizations and simulations, and (b) all of these disciplines inform the understanding of virtual space as a phenomenon and technology.

We can see how science and arts come together, not only side by side, but also transcending in new forms in the wide range of expressions and applications of virtual space. For natural science, a deeper understanding of images and virtual spaces as an interface to the world is vital. With the development of new technologies as well as new scientific methods including simulations and advanced visualisations, the connection between the scientist and the world has become increasingly complex. Information in our knowledge about the world is not directly perceived but is mediated through interfaces that transform original data observed "in the world". This transformation is dependent on the semantics of virtual space and its semiotics.

With the emergence of a variety of virtual environments and hybrid physical-virtual spaces in our everyday life, a deeper understanding of virtuality is needed. This calls for transdisciplinary approach on virtual space, in the line of Maxwell's ideas. This perspective is important for the understanding of virtual space, since it embraces both natural sciences, philosophy, and art. I highlight the potentials of the emerging area of virtual space to become a platform for transdisciplinary research. The transdisciplinary nature of virtual space is demonstrated by its richness in aspects, connecting the inherent concepts of virtual space with a wide range of knowledge and practice domains. Here the contemporary phenomenon of virtual space provides a platform for conceptualizing natural philosophy through multidisciplinarity.

An aesthetic perspective on virtual space is also vital, since aesthetics (beyond aesthetics) shows the relations between actors and objects and the specific conditions of virtual space. From the endo-aesthetic perspective these virtual spaces exist as such only through the interactions between actors and the system.

On the other hand, understanding virtual space requires a broad philosophical perspective, with insights where physical nature, digital information, corporal embodiment, first-person experience, and social aspects come together. Holistic and transdisciplinary approaches like Brier's *Cybersemiotics* provide important framework for understanding virtual space. It becomes clear how meaning in virtual space is created in a semiosis of nature, embodiment, language and subjective experience. The discussion shows how these different perspectives come together in understanding of virtual space. In this synthetic view, virtual space is seen as a framework for making experiences and agreements. The human is put in the center of virtual space, and therefore in the center of the understanding of natural science and philosophy in this context.

Virtual Space as a *hybrid* combines aspects that would be considered to belong to the traditionally separate natural and social realms. For Latour, the distinctive characteristic of modern societies is that they differentiate between nature and society, whereas the premodern civilizations did not make this difference. Latour opposes this duality, and argues that our culture needs to reconnect the natural and social aspects. The hybrid of 'virtual space' successfully accomplishes this synthesis for us. The notion of 'image space' is related to human knowledge fields such as art, art history, visual culture, while 'digital space' relates to technical and natural sciences such as computer science, computer graphics, systems science and simulations. This virtual space hybrid bridging traditionally separate fields facilitates transdisciplinary research in new fields such as interaction design and cognitive science and offers possibilities for studies of variety of other transdisciplinary, cross-disciplinary and multidisciplinary fields.

9   Conclusions

This paper is based on arguments, examples and discussions resulting in two models of the understanding of virtual space. For the first model, the paper elaborates the notion of virtual space offering the suggestion that virtual space can be understood as the intersection of 'image space' and 'digital space'. This view has the potential to give new insights in virtuality, as a contemporary example of a Latourian hybrid. The second model shows how the physical-digital divide can be resolved for spaces, from a focus on embodied interaction and the role of the observer. The contribution of this paper is twofold; first it presents how virtual space creates a common platform for transdisciplinary collaborations crossing the boundaries of sciences, philosophy, humanities, and arts, and secondly in the way transdisciplinarity informs the understanding of virtuality.

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