Introduction

Video games are temporal artifacts. Unlike a photograph or a painting, which display the full amount of the information they carry at any given moment, a video game progressively unfolds in time, like a film or a theater play. In contrast to these last two media, however, which typically show a sequence of events in a pre-established order, video games unfold according to the player's decisions. Therefore, video games are not only temporal artifacts; they are also interactive artifacts in which the action culminates with one of two or more possible outcomes. In this latter sense, the video game is, perhaps unsurprisingly, more akin to sports or other analog games. But the video game is also a potent storytelling medium, which sets it apart from non-digital games or sports and brings it in many ways closer to film or theater.

As the above paragraph suggests, the video game is a complex medium. It shares properties with numerous other media and activities, combining them in novel and captivating ways. The purpose of this study is to further our understanding of the video game by dissecting it into the elements that structure its temporality.

The present work is also largely concerned with the psychology of time perception. Video games are human-made artifacts and, as such, are modeled by human perception and intuition. The same cognitive capacities that have helped us survive throughout the millennia and that we employ in everyday interactions are the ones that shape our cultural products. Examining the cognitive architecture of time perception is thus key to understanding the nature of the medium at the center of this study—for game scholars and developers alike. Game designer Jesse Schell warns those who wish to create games: "You must understand the workings of the human mind or you are designing in the dark" (2008, p. 4). Similarly, a study on the temporality of video games that ignored the mechanisms behind the experience of time would be missing half of the picture.

INTUITIVE BY DESIGN

Evolution has equipped us with a set of cognitive capacities that help us survive in a constantly fluctuating world. Among them, we possess the ability to sense the passage of time. We perceive events, can estimate their duration, and order them in chronological sequence. We can also remember past and anticipate future events. Intuitively, then, we have a notion of what time is. But the term "time" can have different meanings: it can be a coordinate, that is, a label used to locate events; a measure of the duration of events or the gap between them; and a medium in which we move or that flows through us (see Carroll 2010, p. 10).

It could be said that time is the measure of change, that is, of the different states of space. However, there is no absolute reference to measure change. We keep track of time by observing regular changes—the movement of clock handles or the rotation of the earth. However, for space to change *in* time, an external time reference would be needed within which space can change. Otherwise, all we have is that space and its different states, like a tapestry with different patterns. That external reference is, at least so far, nowhere to be found (ibid., pp. 340-342). Whatever the physical reality of time may be, we, as observers, perceive it as flowing in one direction.

The biologist J.B.S. Haldane stated that "the Universe is not only queerer than we suppose, but queerer than we *can* suppose" (1927, p. 286). Solid objects do not have continuous surfaces, but are instead composed of infinitesimal particles and, in between them, mostly empty space; subatomic particles can be in two different states at the same time in what physicists call a quantum superposition; and, according to special relativity, time can elapse faster for one individual than for another if they move at different velocities or are affected by gravitational fields. The more we discover about the universe, the more we realize that our intuitions are not attuned to cope with its profound mysteries. Time is one of humanity's greatest conundrums and its physical nature still puzzles scientist.[1] It is without a doubt one of those phenomena that are "queerer than we

1 In the book FROM ETERNITY TO HERE, astrophysicist Sean Carroll (2010) explains the arrow of time as a result of the Second Law of Thermodynamics (that is, that entropy can only increase in isolated systems). Entropy was lower in the beginning of the universe and has only increased ever since. That is the reason why we can easily make omelets (higher entropy) from eggs (lower entropy), but not eggs from omelets. Why this is so remains a mystery. The problem is that the laws of physics (as currently understood) are fundamentally reversible, while time is not. This is a contradiction that

can suppose." As Saint Augustine expressed in his Confessions: "What then is time? If no one asks me, I know: if I wish to explain it to one that asketh, I know not" (Augustine and Pussey 2008, p. 332).

Gameworlds,[2] on the other hand, are not half as queer as they could be. Here is a technology that allows us to create mind-boggling virtual worlds. It can transport us to fantastic settings where magic and dragons are real, and to science fiction universes where we can travel through different planetary systems in our galaxy and meet extraterrestrial civilizations. Nonetheless, these worlds often remain very similar to ours in many fundamental ways. The alien species that populate the futuristic cities of science fiction games like MASS EFFECT (BioWare 2007) tend to be markedly anthropomorphic, use spoken language to communicate, experience human emotions, and behave in ways that would be expected from humans. And not only depicted social worlds remain familiar, gameworlds also tend to preserve the same physical characteristics of the real world as we perceive it: Objects are made up of surfaces (sprites or polygons), and their physical behavior features no quantum superpositions or laws of special relativity.[3] By and large, the fictional worlds of video games are slightly modified versions of the world as we intuitively understand it.

There are two main reasons why virtual worlds in video games do not deviate radically from the real world. One is that we would not be able to interact with gameworlds if they defied too many of our intuitions. The other one is that

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scientists have not been able to reconcile yet. Possible answers have been hypothesized, but there is no concrete evidence yet to support them.

2 For the most part, I will use the terms *gamespace* and *gameworld* interchangeably. *Gameworld*, however, will be more often used to reference gamespaces that also represent fictional worlds. TETRIS (Pajitnow 1984), for instance, could be said to have a gamespace but not a gameworld, whereas SUPER MARIO BROS.' (Nintendo 1985) gamespace is also a gameworld where fictional characters live. Nevertheless, a strict differentiation is not necessary in the context of this study.

3 The MIT Game Lab developed the OpenRelativity engine, which simulates the physical phenomena related to special relativity and allows players to perceive them by modulating the speed of light. At very low speeds of light, these phenomena become directly observable. However, this engine has so far been used to develop two small games (both by the MIT Game Lab, one in cooperation with the Boston Museum of Science). Even if it were used in the development of a fully-fledged AAA game, this engine supports the point I am making: Our intuitions are not tuned to understand special relativity. To demonstrate the effects of this theory, the simulation needs to accomplish something that is not possible in real life, namely decrease the speed of light.

those very same intuitions constrain game developers' imaginations, making it exceptionally difficult to imagine what a completely different world would look like. For these reasons, video games offer settings that are in many ways like our world but that differ in just enough aspects to make them look and feel alien, futuristic, or magical, without being impossibly unintuitive.

Those characteristics of games that differ from the usual physical world we inhabit are quite often the elements that make a game fun to play by providing a challenge (traversing a zero-gravity environment) or by serving as practical skills or tools (the ability to teleport). However, most of the other variables remain predictable, allowing players to focus their attention on the salient, unfamiliar aspects of the game. Gameworlds are modified versions of what biologist Richard Dawkins (2005) calls Middle World,[4] that is, a world of a scale somewhere between subatomic particles and astronomical bodies such as galaxies. In this world, the space between atoms is irrelevant and the space between galaxies is an endless black void. Our intuitions evolved in Middle World, and are consequently attuned to the laws of physics as they manifest at this particular scale.

We also evolved in a highly social environment, which led us to develop an intuitive psychology (Wimmer and Perner 1983; Baron-Cohen 1995). It makes sense that extraterrestrial beings in a game have a similar psychology to ours. That makes a game like MASS EFFECT playable, given that an important part of the gameplay involves conversing and negotiating with aliens, which demands that players are capable of anticipating the reactions of the characters they are interacting with.

Naturally, our perception of time has been shaped by the temporal scale of Middle World. Some phenomena occur so slowly that they look static to our eyes and others happen so fast that we are not able to perceive them. A tree does not grow in real-time as we direct our gaze at it, but appears static; light does not travel from a flashlight towards the wall, but it instantaneously projects itself on it. Even our sense of causality (analyzed in chapter 1.3) is driven by assumptions about the behavior of Middle World objects in time and space. A central aspect of this study is to show how our temporal intuitions shape video games.

4 Dawkins introduced the term Middle World in his talk "Queerer than we can suppose: The strangeness of science" (Dawkins 2005), on which the above paragraphs are loosely based.

THE OBJECTS OF STUDY

This study's first object of analysis is the artifact, that is, the medium of the video game. This work scrutinizes the formal aspects of video games that are responsible for their temporality. To this end, I analyze numerous titles, both old and contemporary, across different genres. For this study, direct play of the analyzed games constitutes here a crucial criterion (compare Aarseth 2003). This first-hand experience is often reinforced by the reading of game reviews, guides, and other sources like game Wikis or forum discussions.

The second object of study is the perception of time. Video games are created by humans for humans. Therefore, to understand the temporality (as well as many other aspects) of this medium, it is necessary to understand the intuitions that guide developers and players. To this end, I draw from theories of time perception from the field of cognitive science and aim at providing an overview of relevant aspects of the current scientific understanding of our cognitive architecture. These theories are presented here in a succinct way, with the aim to provide an overview of the features of our temporal perception that are central to a temporal aesthetic of video games. A thorough description of each theory would prove impossible in the scope of this study, since they are based on decades or even centuries of scholarship and scientific research.

This study is *not* concerned with the physical properties of time—a subject that widely exceeds the scope of the present analysis. Logically, the video game's temporal characteristics only exist because there is such a thing as a physical arrow of time. But, within the boundaries of simulated gameworlds, the passage of time is much more malleable than it is in real life. Gametime is reversible, it can be slowed down and sped up, and it can be paused. Many, perhaps most, games make use of these forms of temporal manipulation—though they are seldom included as parts of fictional worlds when games depict them. Thus, even though time in video games is attuned to our Middle World cognitive capacities, it presents some features that distinguish it from real-world time.

Some concepts need to be defined before proceeding, including those in the title. Time and Space in Video Games may sound like an overly ambitious heading, but it is one that is justified by the contents of this study.

Time

Time is treated in this study as a "mental construction" (Pöppel 1997, p. 1). Therefore, to understand temporality in a medium created by human minds for human minds, we need to understand how we *arrive* at time—to paraphrase psychologist Ernst Pöppel (1988, p. 10). Temporal perception is a complex construction that "comprises phenomena, such as simultaneity, successiveness, temporal order, subjective present, anticipation, temporal continuity and duration" (Pöppel 1997, p. 1). All of these aspects of time perception are present in the pages of this study.

The structure of time perception is tripartite: we think in terms of past, present, and future. However, as Saint Augustine said:

> "[N]either things to come nor past are. Nor is it properly said, 'there be three times, past, present, and to come': yet perchance it might be properly said, 'there be three times; a present of things past, a present of things present, and a present of things future.' For these three do exist in some sort, in the soul, but otherwhere do I not see them; present of things past, memory; present of things present, sight; present of things future, expectation." (Augustine and Pussey 2008, p. 338)

In other words, concerning our experience, the present moment is all there is; it is the temporal window in which we think and act. Within this window, we can recall information stored in memory and make conjectures about future events. The past is memory and the future, expectation. The mechanisms that allow us to remember and anticipate events are central to the understanding of video game temporality.

The work of several psychologists informs the pages of this study. Most prominently featured is the research of Marc Wittmann,[5] Ernst Pöppel, Alan Baddeley, Karl Friston, Mihaly Csikszentmihalyi, and Walter Michel. The section on causality (1.3) is primarily informed by a theory of linguist Leonard Talmy.

Both the exploration of cognitive-scientific theories of time perception and the formal analysis of games go in tandem. While some chapters are more focused on player psychology and others on the inspection of formal aspects of video games, the theories explored here were chosen precisely because they have the potential to enlighten our understanding of the temporal structures of video games. For this reason, the reader should not expect a comprehensive summary of the cognitive science of time perception, but rather an exploration of those theories that are most relevant to video games. As an example, circadian rhythms, which synchronize our bodily processes according to outside light conditions and coordinate our sleep cycles, are not included in this thesis. While this system is well-understood by psychologists (see for instance Pöppel 1988, pp.

5 For the sake of full disclosure: Marc Wittmann acted as one of the supervisors of this study.

100-110; Wittmann 2012, pp. 89-92), it is not as relevant to the experience of gaming as the selected theories are.

Finally, by temporal structures I mean any device that permits video game developers to display events and arrange them in succession—from lower-level technical aspects of the medium to higher-level design elements. There are many ways in which developers can sequence events, but many sequences are not necessarily determined by the developer; they are dependent on player choice. In a linear game like SUPER MARIO BROS. (Nintendo 1985), where the levels are structured from left to right, the further to the right an object or enemy is, the later it will be encountered. This game exhibits a fairly predetermined succession of challenges when compared to an open world game like THE ELDER SCROLLS V: SKYRIM (Bethesda Softworks 2011), in which the direction of motion is not fixed, and hence the developer cannot entirely foresee the order in which challenges will be encountered. In SKYRIM, players start the game in a city fairly at the center of the game's vast map and, from there, they can go in virtually any direction they please. Nonetheless, both games possess temporal structures and obey some of the same principles, even though they might manifest themselves in different ways. Section 1.2 introduces these temporal structures and the language that will be used in the subsequent pages of this study.

I will refer to the temporality of video games as *gametime*. While several scholars have scrutinized gametime,[6] the game studies literature is still lacking a broad systematic analysis. Providing such an analysis constitutes a fundamental motivation of the present work. One of the main goals of this study is, then, to

6 A few examples are Espen Aarseth's APORIA AND EPIPHANY IN DOOM AND THE SPEAKING CLOCK (1998); Mark J.P. Wolf's chapter on time in THE MEDIUM OF THE VIDEO GAME (2002b); Juul's papers, INTRODUCTION TO GAME TIME/TIME TO PLAY (2004) and VARIATIONS OVER TIME (2007), and the section of his book HALF-REAL (2005) based on the former; a few papers and book chapters by Michael Nitsche (2007), Serjoscha Wiemer (2018), and Michael Hitchens (2006); and the efforts of José P. Zagal and Michael Mateas (2007, 2010) of the Game Ontology Project. The anthology TIME TO PLAY: ZEIT UND COMPUTERSPIEL (2016) also compiles a series of texts on the topic (including an earlier version of section 2.2 of the present work). Gametime is also discussed with relation to video game narrative, as in the case of the Henry Jenkins' (2004) GAME DESIGN AS NARRATIVE ARCHITECTURE, and Jan Noel Thon's TRANSMEDIAL NARRATOLOGY AND CONTEMPORARY MEDIA CULTURE (2016). Gundolf S. Freyermuth (2015) analyzes the specific ways in which video games can tell stories in space and time with relation to previous narrative media. All of the above-mentioned sources (among others) have informed the pages of the present work.

conduct a formal analysis of the temporal structures of video games. To this end, I will follow the steps of previous scholars and complement their efforts with the direct observation of video games. This work will expand existing models and provide a detailed and systematic understanding of the temporal structures of video games. Additionally, I will examine these structures through the lens of cognitive-scientific theories of time perception, adding a still absent layer to the current understanding of time in video games: The player's mind.

Time and Space

While the title of this thesis is Time and *Space* in video Games, space is only relevant as it relates to and helps us understand time. In the context of this study, a *gamespace* is a computer-simulated, Cartesian coordinate system that is presented to the player on a screen.[7]

Gamespaces can be seen, but time cannot be perceived directly. As stated above, our minds construct time, but there is no specific organ dedicated to time perception—like eyes sense light or ears sense soundwaves—nor a corresponding mental module that processes temporal information (Wittmann 2009, p. 1955). Our sense of time emerges from our bodily processes. Our minds capture

7 Game scholar Michael Nitsche (2008, 15-16) lists five spatial planes relevant to video games: the rule-based space, the mediated space, the fictional space, the play space, and the social space. The definition presented in this text corresponds to Nitsche's mediated space, that is, space as presented by the visual signals of the computer screen. The way we interpret these signals is also of importance to the construction of time, but these mental processes do not correspond to any of Nitsche's planes. Fictional time, defined as "the space 'imagined' by players from their comprehension of the available images," does overlap with time perception, but it is not an accurate enough description of how we perceive time through the processing of spatial cues. We need not "imagine" space in order to sense it. Many of the cues our minds process from the environment never appear in our conscious experience and are thus not accurately described as "imagined."

Text adventure games do not represent fictional space, but they still present a space where words are organized, and thus also have a space in the sense defined above. The spatiality of the *fictional* world of the game, however, is a mental construction that results from the interpretation of language, and is thus not a direct cue that the game provides. Thus, the temporality of these games responds to spatial properties in two ways: one, words are ordered in space, and we read them in a particular sequence by following certain rules (in English, from left to right and top to bottom); and two, in the mental reconstruction of the fictional space (compare Chatman 1978, pp. 96-97).

environmental and bodily information through different senses and can detect if this information remains constant or if it changes. In the words of psychologist Marc Wittmann: “Ultimately, the notion of time is based on the elementary temporal relation of two events, A and B, which can be judged in their temporal order, ‘A occurs before B’ or ‘A occurs after B’” (Wittmann, 2011, p. 2). Our minds register events and assign them temporal labels, which then allow us to determine if something happened before or after something else. When we arrive at a traffic light and see that it is red (event A), we stop and wait until it changes to green (an expectation). Once it changes to green (event B), we can see it change and at the same time recall that the light was red before (a memory). This mundane sequencing task of the different states of a traffic light is habitually performed by millions of people a day, and it would be impossible without an innate capacity to label events according to the order of occurrence.

Physicist Julian Barbour formulated an analogy to Hans Christian Andersen’s tale “The Emperor’s New Clothes” that works as a fitting description of how we arrive at time: “Unlike the Emperor dressed in nothing, time is nothing dressed in clothes. I can only describe the clothes” (Barbour 2008, p. 2). While Barbour expressed his claim in the context of an argument about the physical nature of time, it accurately describes how our minds construct time. Our brains have no access to time itself (if there is such a thing), but to indexes that we interpret, mostly subconsciously, to construct the notion of time. The events we perceive in the world are time’s clothes. Gamespaces are filled with signals that inform us that time has passed. The movement of objects in these spaces is perhaps the most salient. Video games are, in this sense, temporal garments.

The perception of time is therefore dependent on mental states and the ways these are altered by environmental and bodily signals. Aristotle already remarked in his PHYSICS that “when we experience no changes of consciousness, or, if we do, are not aware of them, no time seems to have passed” (Aristotle 1957, p. 383). In the real world, we know that time is constantly passing. Even if there is no motion around us, our bodily processes are always active. In the simulated worlds of video games, time can be paused, and we become aware of this due to the lack of motion on the screen.

Additionally, it is not only objects in space that change state and move in our sensory fields. We also have the capacity to move in space relative to other objects. When I choose to go somewhere (say, the supermarket), I not only think of the distance between my point of departure (my home) and my destination but also of the time it takes me to cover this distance. According to this information, I will decide if it is best to go by foot, ride my bicycle, or take the tram. Space and time are deeply interwoven in our minds, to the point that we understand time in terms of space. We can think of ourselves as moving through time towards a certain event just like we move through space ("I am nearing the day of the exam"), or of events approaching us ("the day of the exam is approaching"). These are the *ego-moving* and *time-moving* metaphors respectively (see Clark 1973; Lakoff and Johnson 1980; Haspermath 1997). Navigation is a central mechanic in numerous video games and, therefore, a comprehensive analysis of the temporality of video games cannot leave space out of the equation (section 1.2 will look further into this topic).

The relevance of space to video games has certainly not gone unnoticed by games scholars.[8] Space has, in fact, received more attention than time in the game studies literature. What has remained somewhat ignored is the importance of space to the structuring of gametime—a key component of the present study.

Time and Space in Video Games

The final term in the title is that of the medium at the center of the question. The video game is a multifaceted medium that defies a definition in terms of necessary and sufficient conditions. The artifacts grouped under this concept can differ considerably: Some are primarily ludic experiences that have rule systems and give players objectives to achieve within a limited frame of action, like TETRIS (Pajitnow 1984); others are more interested in allowing the player to

8 Janet Murray argued for the importance of space in cyberdrama in her influential book HAMLET ON THE HOLODECK of 1997. Murray enumerated four central characteristics of digital narratives, one of which is that they are spatial (1997, pp. 71-90). Espen Aarseth (2000) focused on space in video games in his article ALLEGORIES OF SPACE. Mark J.P. Wolf dedicated a chapter of his book THE MEDIUM OF THE VIDEO GAME (2002a) to space. Henry Jenkins (2004) introduced the concept of narrative architecture in GAME DESIGN AS NARRATIVE ARCHITECTURE. Clara Fernández-Vara, José Zagal, and Michael Mateas (2005) published a paper on the EVOLUTION OF SPATIAL CONFIGURATIONS IN VIDEO GAMES within their broader Game Ontology Project. The anthology SPACE TIME PLAY. COMPUTER GAMES, ARCHITECTURE AND URBANISM (2007) compiles over 50 essays of several scholars, most of which—despite the word "time" in the title—focus on the topic of video game space. Benjamin Beil analyzes the relation between avatars and space in a chapter of his book AVATARBILDER. ZUR BILDLICHKEIT DES ZEITGENÖSSISCHEN COMPUTERSPIELS (2012). The work of Marc Bonner (2015a, 2015b) analyzes video games in relation to space and architecture. Finally, both Michael Nitsche and Stephan Günzel devoted books to the analysis of space with VIDEO GAME SPACES. IMAGE, PLAY, AND STRUCTURE IN 3D WORLDS (2008) and EGOSHOOTER. DAS RAUMBILD DES COMPUTERSPIELS (2012) respectively.

freely discover worlds with rules but without particular objectives, such as in MINECRAFT (Mojang 2009); a further group of games is concerned with telling a linear story that players need to discover as they advance through a gameworld that opposes almost no resistance, as in the case of DEAR ESTHER (The Chinese Room 2012). Most video games are likely found somewhere in between these broad groups.

Ludwig Wittgenstein (2009) postulated in his PHILOSOPHICAL INVESTIGATIONS that some terms are not defined by a set of essential properties. These are open terms with blurred boundaries, and the objects they refer to present a pattern of overlapping features. There is thus no single essential property that all the objects under this type of concept possess. He calls them *family resemblance terms*. The primary example he uses to illustrate his point is the term "game." The characteristics of artifacts under the term "video game" overlap significantly with those under the term "game," but not entirely (compare Freyermuth 2015, pp. 38-41). Following Wittgenstein's logic, this thesis will treat the concept of "video game" as a family resemblance term.[9]

The definition under which this study will operate is that proposed by philosopher and game scholar Grant Tavinor:

> "X is a videogame if it is an artifact in a visual digital medium, is intended as an object of entertainment, and is intended to provide such entertainment through the employment of one or both of the following modes of engagement: rule and objective gameplay or interactive fiction" (Tavinor 2009, p. 26).

This definition does contain some necessary and sufficient conditions that an artifact needs to possess in order to be considered a video game—namely, to be an artifact (that is, a human-made object) in a visual digital medium intended as an object of entertainment. However, it also includes an either/or clause with properties that are *disjunctively* necessary—the employment of *one or both* modes of engagement: rule and objective play or interactive fiction. That is, for an artifact to be a video game, it needs to be either designed to be played with, or to tell an interactive story, or both.

9 Freyermuth (2015, pp. 35-38) argues that attempts to define video games systematically (that is, in terms of necessary and sufficient features) have consistently failed. These definitions typically exclude artifacts that could be classified as video games, and are vulnerable to new technological and artistic developments. Instead, Freyermuth provides an insightful historical analysis of the evolution of digital games with relation to analogue games and linear audiovisual media, such as film and television.

Sound is not included in the definition because it is not a necessary condition like visual cues, but it does not follow from this that this study will neglect it (and neither does Tavinor's). While sound plays a secondary role in the present analysis, it is too important to both video games and the psychology of time perception to be overlooked entirely.

Tavinor included the entertainment condition to differentiate the video game from "similar artifacts that have purposes besides entertainment" (Tavinor 2009, p. 28). As examples, Tavinor mentions military and commercial flight training simulators and virtual museums. According to this definition, these are not video games because their main purpose is not to entertain but to train or educate (even though they can still be entertaining). Video games can naturally do more than "just" entertain, but entertainment is a necessary condition for an artifact to be a video game while education or training are not.

A key term in the definition is "interactive." Tavinor places it only next to "fiction," but when saying that a video game "is an artifact in a visual digital medium," he is in a way implying that video games are interactive, given that nowadays digital media are typically so. However, the digital nature of a medium does not necessarily make it interactive (compare Beil 2012, p. 46). Before the advent of interactive computers in the late 50s and early 60s, batch processing was the norm.[10] This type of processing entails running a program with no human interaction. The user feeds the computer the instructions and only receives the results once the machine has completed the computations. Nowadays, batch processing is used in combination with interactive computing—for example, when rendering a video in an editor like Adobe Premiere. Interactive computing enables users to influence programs as they are running. In this sense, all video games are interactive. A way to state this point more explicitly in Tavinor's definition would be to say that "X is a video game if it is an *interactive* artifact in a visual digital medium." Even so, the disjunctive aspect of the definition should remain unaltered—that is, with the adjective "interactive" still modifying "fiction." The fully amended definition would then be: *X is a video game if it is an interactive artifact in a visual digital medium, is intended as an object of entertainment, and is intended to provide such entertainment through the employment of one or both of the following modes of engagement: rule and objective gameplay or interactive fiction.* The term "interactive fiction" is still necessary in that it stresses the interactive nature of the fiction itself. A Blu-ray movie, for example, is an interactive digital artifact intended for entertainment, but its fictional aspect (that is, the movie) is not interactive—it is a linear narra-

10 The seminal video game SPACEWAR! (Russell 1962) was created on one of the first interactive computers, the PDP-1, by a group of students at MIT (Levy 1984, 50-69).

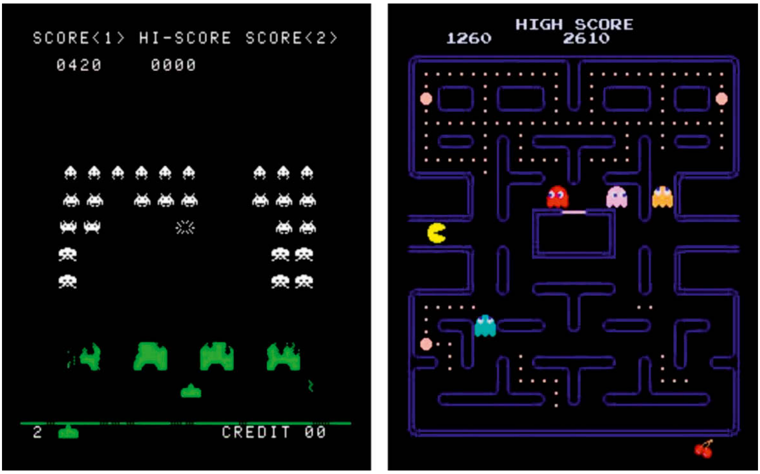
tive that is run by the interactive program (compare Tavinor 2009, p. 32). This precludes Blu-ray movies from being classified as video games.

A further aspect that differentiates video games from other interactive programs is that the latter are typically created to aid the user with an activity and solve problems, while video games pose problems and make tasks intentionally challenging to perform. The word processor I am currently using is meant to aid me with the task of writing, and it is not designed with the purpose to hinder my progress. Ideally, the program would be transparent, allowing me to focus solely on the job at hand and not on deciphering how the program itself works. Similarly, if I press the "add to cart" button on an item's page on Amazon, I do not want a random number generator determining the likelihood of my success; I want the item to be directly added to my shopping cart, the transaction to run smoothly, and the parcel to show up on time at my doorstep. Video games, on the other hand, are meant to make tasks difficult to accomplish and have indeterminate outcomes. In the words of game designer Greg Costikyan: "games thrive on uncertainty, whereas other interactive entities do their best to minimize it" (Costikyan 2013, p. 15).

Nevertheless, events in video games are not completely uncertain; if they were, it would be impossible to interact with them. They provide what anthropologist Thomas Malaby (2007, p. 96) calls a domain of "contrived contingency." That is, video games are artifacts designed to generate events and relations between them according to a set of rules. Some events are unchallenging and occur straightforwardly: If the player presses a button, the player character jumps. That is an action that the player would typically want to occur with certainty. But how exactly the jump will be performed (how far or high the player character will jump) can be uncertain and depends on the player's skill. I will further analyze these topics in sections 1.2, Structuring Gametime, and 2.1, Predictive Thinking in Virtual Space.

The issue with the term "interactivity" is that it manifests on different layers of the medium and other digital media, granting it different meanings depending on where the focus lies. Additionally, the real world is interactive. We interact with other people on a daily basis, and the contents of our own minds constantly interact with each other. The discussion around the term is thus a complex, interdisciplinary hodgepodge (see Beil 2012, pp. 33-54; Neitzel 2012, pp. 80-82). Video games are, on the one hand, interactive in the computer-science sense described above. On the other hand, they also provide visual and auditory information about in-game entities that respond to player input to different degrees.

Figure 1: SPACE INVADERS (left) and PAC-MAN (right).



Source: http://www.gamersglobal.de/report/pac-man (accessed February 1, 2018).

The movement of the aliens in SPACE INVADERS (Taito 1978), for instance, follows the same pattern no matter what the player does. Their speed, however, depends on how many invaders remain present on the screen, but it does so according to one fixed rule: The fewer enemies on screen, the faster they move.[11] Other games take player-induced changes into account, like the ghosts in PAC-MAN (Iwatani 1980) (the enemies in the game), which track the avatar's location and chase it. If the direction of the action is taken into account, it could be said that the aliens in SPACE INVADERS *react to* and the ghosts in PAC-MAN *interact with* the player. SPACE INVADERS is reactive because the actions of the player leave a trace in the gameworld, but the gameworld does not *act back*. In this case, the descending alien block moves in a constant pattern, increases in speed according to one fixed rule, and does not alter its behavior to adapt to the player's actions. In PAC-MAN, influence flows in both directions: The player's actions change the game state, but the ghosts change their behavior according to their own objective—namely, kill PAC-MAN. More recent games include decision trees or artificial intelligence programs that make their non-player characters (NPCs for short)

11 The acceleration of the aliens' movement in SPACE INVADERS is, curiously, a consequence of processing limitations. The more aliens on screen, the slower the CPU can move them. As the player eliminates aliens, the CPU needs to render fewer of them and, as a result, they move faster. For a detailed technical breakdown see Höltgen 2016 (in German language).

behave in agent-like ways. Their response to the players' behavior is variable and less predictable, forcing players to react in turn. But contemporary games also include entities that simply react to the action of the player character, such as boxes that can be pushed or broken.

Following this train of logic, some game entities react only if the causal chain of events goes in one direction—from the player to the entity. Interaction would take place then only if the causal chain of events zigzags back and forth in at least two directions. "Interaction" is, in this sense, a term that proves useful to speak of agents that influence each other's behavior. In the end, the physical world (including ourselves) could be reduced to a sum of reactions between atoms. Behavior is the result of vastly complex chains of reactions, but it does not make intuitive sense to think of agents in those terms. Instead, we use a shorthand like "behavior" to describe the actions of agents and "interaction" for the mutual influence between two or more agents.

To sum up: If one focuses on the relation between a player and a computer, all video games are interactive. If the focus is on the relation between a player and an in-game entity (disregarding the computer), then there can be interaction or just reaction. In the pages of this monograph, I will mostly refer to video games as "interactive" in the computer-science sense (as opposed to batch processing). The terms of reaction and interaction as one-way or two-way influence will become relevant in different sections, especially in 1.2, Structuring Gametime, and 1.3, Cause, Effect, and Player-Centric Time.

This study concentrates primarily on artifacts that are widely regarded as video games. It is not a search for those video games that handle time in unusual or salient ways, but an effort to analyze the most common aspects of the temporality of the medium. Borderline cases will be taken into consideration, but they can only be identified once a center is defined.

A NOTE ON INTERDISCIPLINARITY

Over a century ago, in his LECTURES ON INTERNAL TIME-CONSCIOUSNESS OF THE YEAR 1905, philosopher Edmund Husserl dismissed psychology for considering it an irrelevant discipline to the phenomenological enterprise (my emphasis):

"Just as a real thing or the real world is not a phenomenological datum, so also world-time, real time, the time of nature in the sense of natural science *including psychology as the natural science of the physical*, is not such a datum" (Husserl 1964, p. 23).

Half a century after Husserl's remark, British scientist and writer C.P. Snow warned of the balkanization of the humanities (back then represented mostly by literary scholars) and the natural sciences (exemplified by physicists) in his lecture THE TWO CULTURES:

> "Literary intellectuals at one pole—at the other scientists […] Between the two a gulf of mutual incomprehension—sometimes (particularly among the young) hostility and dislike, but most of all lack of understanding" (Snow 1961, p. 4).

Nowadays, with disciplines like experimental psychology, neuroscience, and evolutionary biology (and the cognitive sciences in general) providing deep insights into the understanding of the human condition, the humanities cannot afford to look away. The experimental study of the psychology of time—including cognition, neurophysiology, and the mental phenomenon of time[12]—has made so many valuable advances in the past few decades that this thesis will focus predominantly on them as a source of information when it comes to theories of time perception. Some of these advances have even provided evidence for some of Husserl's theories (see for example Lloyd 2012; Wittmann 2011, p. 1). By combining formal analysis of video games with the cognitive science of time perception, the present work attempts to further the consilience of the humanities and the natural sciences.

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12 It is important to distinguish between "phenomenology" and a "phenomenon" ("phenomena" in plural). The former refers to the philosophical method of examining human experience started by Edmund Husserl; the latter is a qualitative aspect of subjective experience, such as color, sound, emotion, or duration. It is what things feel and seem like to an observer. Phenomena are studied by phenomenology, but also other disciplines, such as psychology. A phrase like "the phenomenon of time" would then mean how time feels and seems like from a subjective perspective. Phenomena are different to the neurophysiology of time perception, which is concerned with which parts of the brain process information related to time. Even though these two layers are studied by separate disciplines, they are both constituents of time perception, given that phenomena emerge from neurophysiological features. Therefore, both fields should (and do) inform each other. The same applies to any studied aspect of time. We may divide scholarship into disciplines, but the world we study is unitary. The philosophical field of phenomenology is not included in this dissertation, not for being considered irrelevant, but because of scope and time limitations that did not allow me to make an incursion into that literature. For a phenomenological take on the temporality of video games see Grabbe and Rupert-Kruse (2017).

Efforts to bring cognitive sciences into the humanities within the game studies field are already underway, exemplified by the work of Torben Grodal (2003), Andreas Gregersen (2008, 2016) and the anthology edited by game scholars Bernard Perron and Felix Schröter (2016). The present study attempts to contribute to this ongoing effort. Other humanities fields have also served as inspiration for my research: Darwinian literary studies, especially the work by Jonathan Gottschall (2012); cognitive film studies, with scholars like David Bordwell (1989) and the aforementioned Torben Grodal (2009); evolutionary aesthetics, with the work of Dennis Dutton (2009); and philosophy, in particular the work of Daniel Dennett (1991) and Andy Clark (2013, 2015). Additionally, the work of psychologists who have explored topics incumbent to the humanities has also been of great importance. Here the efforts of Steven Pinker (1997, 2003, 2007) and Paul Bloom (2010) stand out as significant influences. Finally, THE GAMER'S BRAIN by Celia Hodent (2018) constitutes a valuable resource that merges psychology and video games from the perspective of user experience design.

An important bridge between the humanities and cognitive science is evolutionary psychology. This discipline studies human psychology through the lens of Darwinian evolutionary theory and has had a profound impact on the work of many of the scholars mentioned above. Applying the principles of natural and sexual selection to the study of human behavior can help explain cultural phenomena in ways that were unthinkable before. The work of Leda Cosmides and John Tooby (1992), the founders of the discipline, is of paramount importance to the epistemological framework of this thesis.

Furthermore, consilience should not only manifest itself in the content of academic research but also in the style and language with which it is presented. This text is written in a reader-friendly way, in clear prose and eschewing unnecessary jargon. In this way, humanist scholars should not have issues with the terms borrowed from cognitive science. In the event that this work might provide insights to psychologists or game designers, I have toned down the humanities' jargon as well. In the cases where specialized terminology is considered helpful or unavoidable, the introduced concepts are duly explained.

STRUCTURE AND CONTENTS OF THE STUDY

The present work is structured in three chapters, which contain three sections each.

The first chapter is entitled Brain Time in Virtual Space. Section 1.1, The State Machine and the Present Moment, discusses the perception of movement and introduces central notions about time perception with a focus on how we experience the passage of time, that is, the "now." The concept of "state machine" is an analogy borrowed from Jesper Juul—who, in turn, took the notion from computer science. It implies that video games are systems that can be arranged in different states at different points in time. This section argues that we construct the temporality of a game by recognizing these states and assigning them temporal labels. Section 1.2, Structuring Gametime, introduces a typology of temporal structures. The goal of this section is to dissect video games into the formal elements and principles that structure their temporality. These will serve as tools for analysis of the temporality of video games and as a language that I will use throughout the remainder of the text. The final section, 1.3, examines our causal intuitions. Games require us to act in ways that yield the results we desire. In order to understand how gameworlds work, we need to engage our sense of causation, which allows us to learn how different entities can affect each other. The perception of causation is rooted in our temporal intuitions, given that it relies on the succession of events, where each event results from a previous one.

The second chapter, Iteration in Virtual Space, is concerned with the role of repetition in gaming. Section 2.1, Predictive Thinking in Virtual Worlds, describes how we become proficient at games through repetition. To explain this, I introduce the notion of the Bayesian brain, which states that the brain estimates the likelihood of an event by combining two sets of data: knowledge stored in memory and the information acquired through the senses during the present moment. The more knowledge we gain by repeating tasks (say, jumping in a platformer[13]), the better we are at predicting the outcomes of events that involve those tasks. Being proficient at predicting states of the environment is crucial for mastering skills. Section 2.2 describes the Groundhog Day Effect, which results from the capacity to reset time in gameworlds by loading previously saved states—a phenomenon that is prevalent in video games. The Groundhog Day Ef-

13 The *platformer* is a game genre where the main mechanic involves jumping from platform to platform. One of the most prominent examples in this genre is SUPER MARIO BROS.

fect is the result of the player traveling back in gametime with knowledge about the future. Since the character is reset with the gameworld, it cannot possess this knowledge. This knowledge gap between the player and the player character can generate issues while telling stories with the medium. The Hybrid Narrator, section 2.3, focuses on how the interactive nature of video games, combined with the iteration that causes the Groundhog Day Effect, complicates the implementation of a narrator. From the combination of retrospective and real-time narration, a hybrid figure arises that seeks to reconcile storytelling with interactivity and constant repetition.

The third and final chapter, Through the Temporal Landscape, examines how the experience of time is not a uniform and constant flow. Temporal perception is akin to traveling through a landscape. We can move faster and slower through it, and it has a perspective that allows us to see forward and backward. The Speed of Time, section 3.1, describes how time passes at different speeds depending on factors like attention and arousal. This section analyzes how video games can modulate our experience of the passage of time. On one extreme, time can appear to pass in slow motion, which is typical of dangerous situations. Games are not hazardous activities, but they implement mechanics that emulate the experience of the slowing down of time. On the other extreme, time can seem to be fast-forwarded. This phenomenon is most discernible in the state of flow that arises when we are deeply focused on an activity—such as playing a video game. Section 3.2, Marshmallows and Bullets, is concerned with the relation between time perception and self-control, a crucial skill to efficiently administer resources. The section analyzes psychological concepts associated with self-control (delay of gratification, temporal discounting, and time perspective) and how they relate to video games in which resource administration is central—paying particular attention to the survival horror genre. Section 3.3, Chekhov's BFG, scrutinizes how games can create expectations through their narrative and mechanics. An analysis of Chekhov's Gun and the difference between "surprise" and "suspense" start this section. Subsequently, these notions are analyzed with regard to game mechanics and accordingly expanded into the medium of the video game.

The entirety of the study is aimed at laying the groundwork for a wide-ranging temporal aesthetics of video games. The first chapter focuses on the perception of the present. The second chapter analyzes the connection between past and future. The third chapter describes how the experience of time (past, present, and future) can be modulated and altered by the relationship between one's goals and the conditions of the environment. These elements, coupled with the work of game scholars and the direct formal analysis of video games, reveal a two-way relation between the medium and time perception: On the one hand, video games are directly shaped by our temporal cognitive architecture. On the other hand, they can modulate our experience and even introduce novel aspects to it—such as resetting time to replay a section of a game.

THE LIMITS OF THE STUDY

Finally, I should point out some constraints of the present study. The main limitation is, ironically enough, time. During the span of a research project such as this one (maybe even a lifetime) there is simply not enough of it to scrutinize the entirety of the literature on time perception. Thus, a selection process was necessary. The extent of our current knowledge of time perception, while still incomplete, vastly exceeds the scope of one single manuscript and would likely span several volumes. As stated above, the theories discussed in these pages have been selected for their capacity to shed light on different aspects of video games. This selection was naturally subject to my own judgment and is not representative of the entirety of the psychology of time perception. Additionally, each of the theories analyzed is highly complex. One research project per theory would likely not suffice to acquire the full extent of the highly specialized knowledge that each of them has to offer. Therefore, this study presents the theories in a succinct way, based on the original studies that support them, but also relying on already summarized accounts—such as review papers and books aimed at non-specialized audiences.

One central preoccupation of this study is to present theories that have an epistemological standing on empirical evidence, and which connect the dots in plausible ways in the context of a naturalist framework. The theories presented here will likely evolve in the future, maybe to the point of becoming different theories entirely, but the empirical evidence they are based on provides solid ground to continue exploring. Some of the approaches discussed in this study are one of many competing frameworks within an area of time perception. Baddeley's working memory model, presented in section 1.1, while accepted by a significant portion of the scientific community, is not the only one available (see Baddeley 2012, pp. 19-22). The pacemaker model described in section 3.1 serves as a heuristic to account for the phenomenon of time dilation, but competing explanations have been put forward (see Wittmann 2009, pp. 1956-1958).

Another characteristic of the theories presented is that they complement each other. The aim was to paint a coherent picture of time perception, which is why I remained within one epistemological framework and did not include theories of, for example, phenomenology—a discipline that has also provided insights into the perception of time, but which can sometimes collide with the models presented above (see Dainton 2017).

Concerning causation, I have chosen to focus on Talmy's theory, since it matches empirical evidence in psychology. Causality as we see it is not "out there," but it relies on assumptions that we make intuitively. Other theories have tried to explain causation as well. The most prominent two were postulated by David Hume (2007) in section VII of AN ENQUIRY CONCERNING HUMAN UNDERSTANDING. The first one states that we learn about causation by observing repeated instances of an event, known as *constant conjunction*. However, the studies conducted by psychologist Albert Michotte (as well as others) showed that we can see causation in single instances. The first time the participants took part in the experiment, they instantly saw a causal relation. The second is the *counterfactual theory* of causation, first formulated by Hume but largely developed by philosopher David Lewis (1973). This theory asserts that the statement "A causes B" is true if the statement "B would not have happened if A had not happened" is true as well. There are several problems with this theory. For instance, events have more than one single cause. If someone lights a match, one could say that the striking of the match caused it to catch fire. But that would overlook other necessary conditions, such as the presence of oxygen, or the absence of wind (Pinker 2007, p. 213). Counterfactual causation requires singling out one cause when in reality every event is the result of a complex contingency. Another problem is known as *overdetermination*, which leads to absurd scenarios such as this one:

> "Consider a firing squad that dispatches the condemned man with perfectly synchronized shots. If the first shooter had not fired, the prisoner would still be dead, so under counterfactual theory his shot didn't cause the death. But the same is true of the second shooter, the third, and so on, with the result that none of them can be said to have caused the prisoner's death" (ibid., pp. 214-215).

There are more issues with the counterfactual theory of causation, but it is still a sophisticated and interesting framework to use in video game analysis, given the capacity of the medium to reset time. Players can change their actions with every iteration to test the different outcomes that can be produced by altering specific variables. In this way, they can engage in counterfactual reasoning. Video games do not solve the problems of the counterfactual theory of causation, but an analysis of the medium through the lens of this theory could still offer valuable insights. To my knowledge, there is still no study that observes video games in this light. I have omitted counterfactual theory from my study in light of said problems and because I chose to focus on human intuition. In that regard, Talmy's model is the most pertinent.

Concerning the analysis of video games, the limitations are twofold. First, just like with the literature on time perception, there is not enough time to observe every game out there.[14] Second, the video game medium evolves at an intense speed, and it proves challenging to keep up with the development of franchises and genres. Nowadays, thousands of video games are released within the span of a research project, with both their technology and design moving forward within this period of time. This study analyzes a wide range of games and game genres, focusing on landmark games (for example SPACE INVADERS, SUPER MARIO BROS., DOOM (id Software 1993), RESIDENT EVIL (Capcom 1996), and HALF-LIFE (Valve Corporation 1998)) and selecting artifacts that can be uncontroversially categorized as video games. At the same time, it keeps an eye on borderline cases that expand the limits of what video games usually do (such as allow the player to rewind time or feature retrospective narrators that react to the player's actions). There is unfortunately still no clear methodology to select a sample of video games in the game studies field, and this dissertation does not constitute an improvement in that regard.

Still, this study sheds light into significant aspects of video games through formal analysis and the presented theories of time perception. All of the formal features of video games discussed here are directly observable in a multiplicity of games, as the examples will show. No feature mentioned in this work is hypothetical or representative of an ideal that video games should strive for. This study is solely based on the description of observable characteristics of video games, and anyone who plays them should be able to see them, too. An additional objective of this analysis is to offer useful insights to game designers, providing them with tools to reflect on how they treat time in their games.

Finally, each aspect analyzed in the following pages could be subject to future examinations that could further expand both the understanding of formal characteristics of video games and of the pertinent theory (or theories) of time perception. It is certainly not the aim of this study to exhaust the possibilities of analysis, but rather to provide a foundation upon which a temporal aesthetics of video games can be built. The cited efforts of game scholars in this regard are of crucial importance, and the account presented here would not exist without them.

14 According to the website Steamspy (2017), 6,912 games were released on Steam in 2017 alone. This number still does not include games that were released for consoles, mobile devices, and those for the PC that are not available on Steam.